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INVESTIGATIONS ON THE RELEASE OF ELECTRICAL CHARGES UNDER MODERATE PRESSURE FROM PHOTOGRAPHIC PLATES AND OTHER MATERIALS.*

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AND

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ABSTRACT.—An attempt has been made to study whether any electric charges are developed when moderate pressure is applied on a photographic plate or film, *i.e.*, to see how far the ejection of electrons can serve as a physical basis for the pressure effect found. From the measurements recorded in the paper, it cannot be decisively asserted that there is an ejection of electrons when photographic plates or films are pressed moderately. Suggestions for future line of experiments to test more adequately the hypothesis have been made and it is hoped to undertake these measurements as soon as opportunity permits.

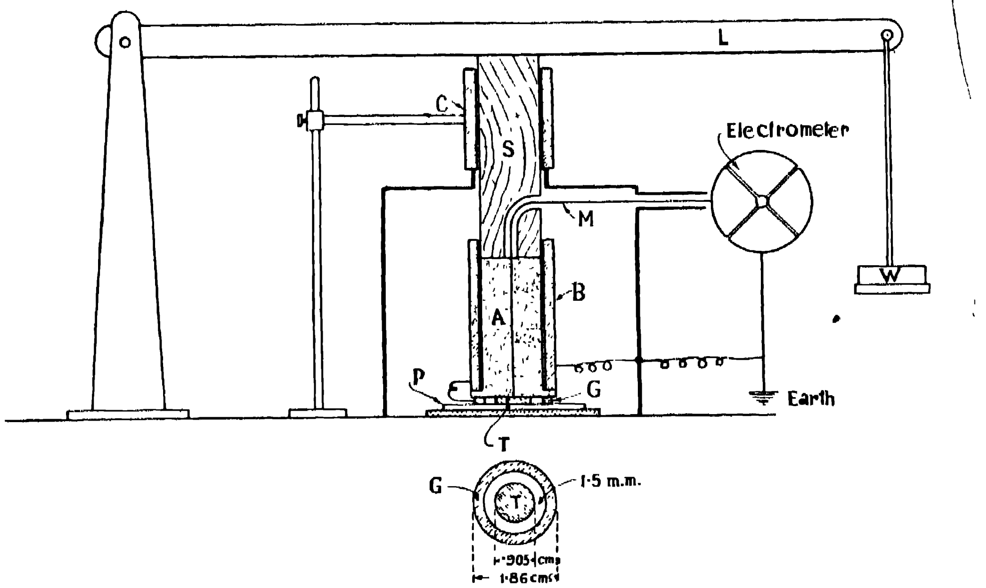
INTRODUCTORY

It is well known that agents other than radiation may leave their imprint on a photographic plate. Mechanical scratches as lines drawn by round point style are developable. M. Volmer[1] has described some experiments wherein an impression was made upon a photographic plate by drawing fine lines with rounded end of a glass rod. He referred to this as a pressure effect. Warnercke[2] seems to have been the first to note the effect of writing on a photographic film with a rounded glass rod using gentle pressure so as not to scratch the film; these marks developed out black. If, however, the plate was fogged with daylight before developing then the marks came out white on a dark back ground. This is the well known phenomenon of Photographic Reversal and an interesting account of it may be found elsewhere.[3, 4] The object of the present investigation was to study whether any electric charges are developed when moderate pressure is applied on a photographic plate, *i. e.*, to see how far the ejection of electrons can serve as a physical basis for the pressure effect found, as was suggested by one of us in a recent paper.[4]

* Communicated by the Indian Physical Society.

PROCEDURE AND APPARATUS

As the photographic plate had to be protected from light, it was put inside a black paper envelope, the paper being previously well soaked in clean molten paraffin wax to make it insulator ; so during experiment, the composite system consisting of paraffined black paper, photoactive material spread over the thin glass plate and the glass itself was under pressure. To determine the effect of pressure on the photoactive material alone, we also tested the effect of pressure on the same glass plate, devoid of photoactive layer and put inside the paraffined black paper envelope. Alternatively, we also cut out two pieces from a photographic film, one of these was developed out without exposing to light and the remaining was left fresh. The two were placed side by side inside a paraffined black paper envelope. The pressure was first applied on one piece and then on the other. The difference, if any, in the electrical effects produced under pressure in the two pieces was attributable to AgBr alone.



Details of test disc and guard ring.

FIGURE 1.

In figure 1, P is a photographic plate or film inside the envelope under test. The envelope lies on a stout brass plate at the bottom of an earthed metal box; the column standing vertically on P and being pressed by the lever L consists of (*i*) an amber rod A which is surrounded tightly by a hollow earthed brass cylinder B and (*ii*) a hard wooden rod S fitting closely into a groove at the top of the cylinder B, the lower end of S resting on A. C is a properly and rigidly clamped stout hollow brass cylinder acting as a guide to prevent lateral play of the pressing column. To the lower end of the amber pillar are fixed a circular brass disc T, 0·64 sq. cm. in area and an earthed concentric guard-ring G flush with T. The clearance between the ring and the disc is about 1·5 mm. A thin copper wire M connects the test disc T through a narrow bore in the amber rod and comes out of the pressing column sideways through a sufficiently wide ⌈-shaped boring in the wooden rod S, such that the wire does not touch any part of the wooden rod. The other end of this wire is connected to the insulated pair of the quadrants in a Dolezalek electrometer. Thus any charge received by the disc T fixed at the lower end of the pressing column and placed in contact with the envelope containing the photographic plate, will be indicated by the electrometer. A Wulf's single fibre electrometer was also employed as an alternative detecting instrument. If there be an ejection of electrons due to the pressure applied by the lever arrangement on the photographic plate or film, the surface of the plate will develop a negative charge at the localities pressed ; this will act inductively on the test disc accross the paraffined paper dielectric and the electrometer will indicate an acquisition of a negative charge. As the film is covered by an intervening layer of paraffined paper any charge released by pressure on the later will also simultaneously contribute to the indication of the electrometer. As we are considering either (*i*) the difference of electrical effect of pressure on a fresh film and that on a film developed without exposing to light—each under the same paraffined paper envelope or (*ii*) the difference of electrical effect of pressure on a fresh photographic glass-plate and that on the glass-plate from which the active layer has been removed—each, as before, enclosed within the envelope, so the charge released, if any, by pressing the envelope alone does not come into consideration.

RESULTS AND DISCUSSIONS

Maximum pressure applied was of the order of $3{\cdot}3 \times 10^{6}$ dynes per sq. cm. In general, a release of considerable amount of negative charge was shown by the

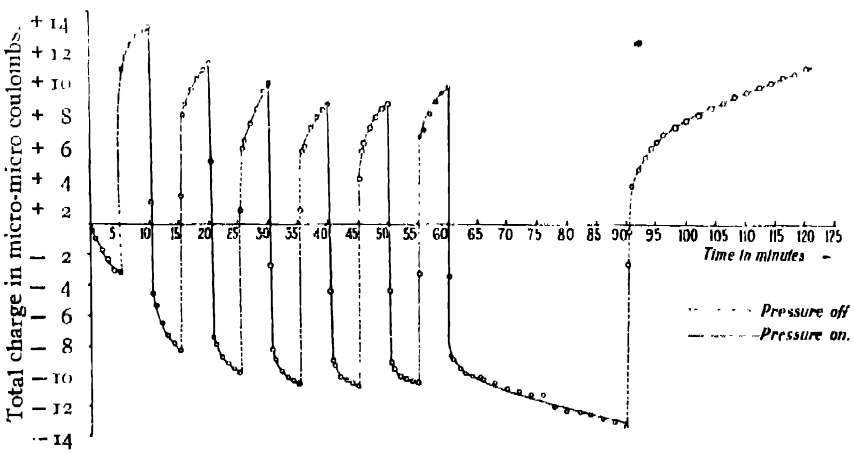


FIGURE 2.

electrometer when the system was pressed and a substantial decrease of this negative charge and sometimes a definite appearance of positive charge were observed when the pressure was removed. Observations clearly illustrating the development of positive charges whenever the pressure was released from a glass plate under paraffined envelope are plotted in figure 2: but as the mechanism of this is not very clear, discussion on the point is postponed for the present. Magnitudes of these charges were different for different pressures and no regular relationship was found to exist between them. In a series of observations with a particular pressure, the observed charges differed appreciably and sometimes considerably from one another as will be seen from the figures in table 1. A sudden substantial decrease of negative potential indicated by the electrometer when the pressure is removed cannot be accounted for by the assumption that there is a change in the capacity of the system when pressed; because with a set of film and envelope the capacity of the system with the test disc T loosely placed on the envelope and that with the disc pressing were also measured ; the difference was found to be too small to account for the observed changes in charge, as is evident from the actually measured values given below :—

Total capacity of the whole system including the quadrant electrometer and the connecting wires.

Test plate loosely placed.	With a pressure of 2·12 × 10^6 dynes on the test plate.
61·56 e. s. u.	61·63 e. s. u.

TABLE 1.

No. of observations.	Negative charge indicated by the electro-meter in micro-micro-coulombs per sq. cm. of the surface pressed.		
	in case of fresh film under envelope.	in case of developed film under envelope.	in case of paraffined paper envelope alone.
1	13·68	9·58	9·58
2	6·84	4·10	10·94
3	5·47	13·68	5·47
4	12·31	8·21	8·21
5	6·84	6·84	5·47
6	10·94	5·47	12·31
7	6·84	10·94	8·21
8	5·47	6·84	10·94
9	13·68	13·68	8·21
10	9·58	10·94	9·58
Average	9·16	9·03	8·89

Thus the average negative charge released, when a fresh photographic film under envelope was pressed, was practically the same as that when a photographic film developed without exposing to light and placed inside the envelope was pressed. Also the average negative charge indicated by the electrometer when the pressure is applied on a photographic plate inside the envelope was found roughly the same as in the case of a glass plate alone put within the envelope, the photosensitive material being removed. From these measurements, therefore, it cannot be affirmatively and decisively asserted that there is an ejection of electrons when photographic films or plates are pressed moderately. But as pointed out later, further modifications in the experimental technique seem desirable before deciding the point.

In course of these experiments an interesting phenomenon was observed which is worthy of a detailed description. It was decided at first to ascertain what fraction of the total charge observed in the above-mentioned experiments was contributed by the compressed paraffined paper ; the investigation was repeated with a piece of paraffined paper alone and later on with a thin plate of paraffin wax. It was found that a considerable amount of negative charge, as indicated by the electrometer, was given out when these are pressed. These charges are solely due to the application of pressure. It is unlikely that any appreciable portion of the charge is due to friction. In the arrangement adopted every precaution was taken to eliminate sliding contact of the surfaces. The lateral play of the test disc T, if any, was exceedingly small and could not account for the magnitude of the charge actually developed. It was observed that when pressure is applied, the negative charge at first arises very suddenly and in large quantity and then slowly increases as the time goes on ; and the total negative

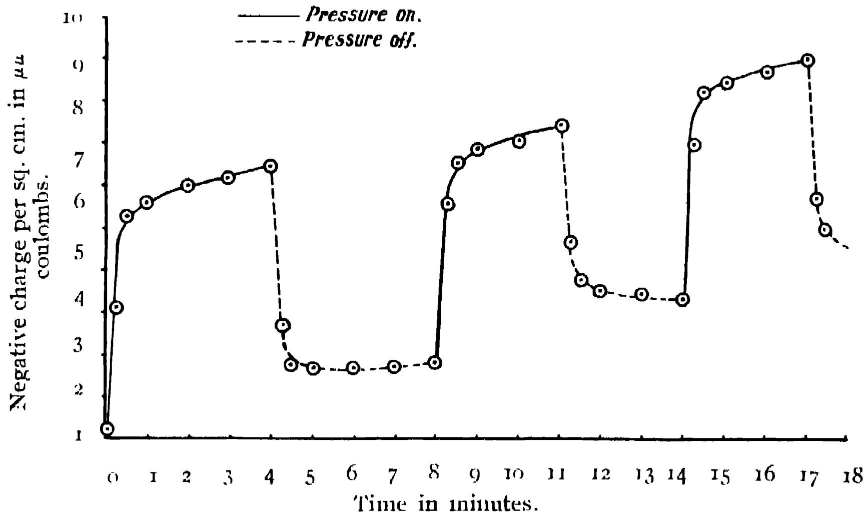


FIGURE 3.

charge released tends to approach a limiting value, as will be seen from the figure 3 which graphically represents how the quantity and the nature of the charge as indicated by the electrometer connected to the test disc T vary as the pressure is successively applied and removed after interval of 3 or 4 minutes. It is certain that this squeezing out of the electrons cannot continue indefinitely, as the removal of the electrons from the crystallites and groups of molecules of the body under pressure will leave them positively charged which will tend to stop further movement of electrons towards the surface ; also a paraffined paper or a thin plate of paraffin wax first rapidly and then slowly and gradually yields to the applied pressure ; these facts explain the observed phenomenon that some time is elapsed before the maximum negative charge appears on the surface and the electrometer indication reaches an approximate saturation value in about 5 minutes and then very slowly creeps on. As the pressure is released the squeezed out electrons in the plate gradually recombines with the residual positively charged crystallites and groups of molecules left in the body. These electrons now go back to the interior and there is a marked decrease in the negative charge. It is not easy to explain the definite appearance of positive electrical charge which was actually the case on several occasions when pressure was removed. This may be due to some peculiar changes which take place when the compressed paraffined paper or a paraffin wax plate is relieved of pressure and gradually tends to settle down to its normal condition and is, to a certain extent, analogous to the piezo-electric phenomena found with quartz and a few other crystals, or it may be that electrons under released pressure overshoot their former equilibrium positions.

These experiments serve to indicate that the negative charge released by pressing the paraffined paper envelope is so large (see Table 1. last column) that it may altogether mask the little charge which might have been released by the application of pressure on a photographic plate put inside the envolpe. It could not be decisively settled that electrons are ejected when a photographic film or plate is pressed. It would be interesting to repeat the experiment in complete darkness without the use of the paraffined envelope and we hope to take up this work as soon as opportunity permits.

In conclusion, we should like to record our thanks to Mr. S. N. Chatterji for help in drawing the figures.

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SUPPLEMENTARY

THE MISSION OF THE PHYSICIST IN NATIONAL LIFE.

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The Indian Physical Society is now passing through the third year of its existence and so far there has been no precedent compelling the president to deliver an address. When we consult the practice in similar societies in Europe and America, we find that there is no uniformity of practice. The German Physical Society with branches spread over all German-speaking countries does not compel its President to deliver any address ; neither do the French nor the American. In the Physical Society of London, the President, who holds office for two years, delivers one address during his tenure of office. I believe that in this respect, as in many others, it will be wise for us to follow the British practice.

The next point is choice of a subject. The President of the Physical Society of London generally delivers an address on some topic of current scientific interest. I think that the president of the Indian Physical Society should follow the same practice. But as you are probably aware, your President has been on tour throughout the major part of the past year, and he has not yet found time to sit down quietly and write out a purely scientific address. You will therefore excuse me if instead of delivering a purely scientific address, I entertain you to a kind of miscellany consisting of my experiences, as far as our subject is concerned, which I have gained in course of my travels, and of the future of our Profession in this country.

IN THE ROYAL INSTITUTION.

I will begin by recounting my experience which I obtained in course of a recent visit to the Royal Institution of Great Britain ; the present director, Sir William Bragg, President of the Royal Society, was kind enough to guide me personally through the scientific exhibits—reminiscent of the scientific works of his predecessors—Davy, Faraday, Tyndal and Dewar, and also of the earlier work of Count Rumford, the founder of the Royal Institution. Here I saw, not without a certain amount of thrill, some of the material used in the famous experiments which are now familiar wherever physics is read and practised : the famous ring of iron with copper wire which formed Faraday's first dynamo ; the heavy bent glass tube with a yellow

* Presidential address delivered at the Third Annual General Meeting of the Indian Physical Society, held at Hyderabad-Deccan, on the 6th January, 1937.

liquid in one arm ; which I recognised as the apparatus in which Faraday liquefied chlorine by the combined application of pressure and low temperature,—the little kerosene lamp (Davy's safety lamp) with the wire-gauze mantle about it which made mining safe, and a large number of others of which you may read a full account in the graphic description given by Sir William Bragg in his introduction to Julian Huxley's charming book 'On Social Needs and Scientific Research.' But what struck me most was the idea with which the Royal Institution was started. Probably very few of you will be prepared to believe that it started as a 'Society for improving the condition and adding to the comforts of the Poor' by Count Rumford and a few other kindred spirits. To understand the significance of the new idea, we should remember that up to this time, philanthropic work was the monopoly of religious institutions alone, who set to do their task by giving doles to the poor or opening relief work for them. But this was not the way which Rumford proposed to follow in his self-imposed mission. He foresaw that Science had made possible a new kind of philanthropy, and if the knowledge of science were utilized to the common needs of mankind, great economy could be effected, and the poor would get relief against hunger, disease and weather at a cost which would be within the reach of everybody. Let us see how he proceeded in his work. A single example will show.

From his scientific studies, Rumford found that fire-places, boilers and cooking appliances in those days were very badly designed, and consumed a very large amount of coal. He designed new types of fire-places, boilers and cooking pots in which the consumption of coal was very substantially reduced so that poor people might cook their food at much reduced expense, would have not to inhale unhealthy fumes, and could get sufficient warmth and comfort. Through some of his friends who were connected with big hospitals, he tried to introduce these new appliances amongst the public. But did he succeed ?

Sir William Bragg has a pathetic story to tell us. When these improved kitchens, and heating arrangements, the principles of which are now incorporated in all modern housing establishments, were introduced in some hospitals, they could not be made to work owing to the hostility of the cook who had the perquisite of the dripping and her husband who had the perquisite of the cinders. What a lesson for all times!

Now to come to my point,—the basic idea with which Rumford started was that all human needs can be met and human distress relieved by systematic and judicious use of scientific knowledge. This is more true in these days than in former times on account of the wonderful progress science has made in all directions. If in any country medieval conditions still prevail, you can always presume that there is always some stupid orthodoxy, or entrenched Greed to oppose these humane schemes. This is nowhere more true than in this unfortunate land of ours !

We cannot claim that application of the knowledge which a study of our subject has given to the world has always been attended with humane motives. Most frequently, the impulse has come from the motive of greater profits to the inventor. But nobody can deny that the application of such knowledge has entirely transformed the modes of living in the world during the last hundred and thirty years and has incidentally brought greater comfort to the poor and the needy. Whether the changes have been humane or not, there is no doubt that they have transformed all arts and crafts, and the modes of human life in Europe, America and Japan. Says Prof. K. T. Compton :—

" Historically we note that the Science of Physics has given birth nearly to all those ideas, processes and agencies which have brought man to an understanding of the Material Universe, and to the use of its forces, Civil Engineering, a large part of Chemical Engineering, Metallurgy, Electrical Communication, Refrigeration, Testing, Ventilating, Automotive, and Aeronautical and the countless products of those arts which have revolutionised modern life, not only in its material aspects, but also in intellectual, economic and social relationships. Physics has not only originated these things, but continues to develop them."

As a matter of fact a science which is playing such a great part in the evolution of human civilisation has certainly a great claim on Society and Governments. The material prosperity, and political safety of countries are intimately connected with the active cultivation of our Science.

It is therefore natural that in Europe, America, and Japan, increasing attention should be paid to the teaching of our subject in elementary and advanced schools, in professional schools, in the universities and technical high schools, in special research institutions maintained by the Government, private benefactions, or by the great industries which have sprung up as a result of the discoveries made in physics. Large amounts are willingly spent on research by Governments and Research Foundations. In England, the country which we follow, the change in the official attitude and the attitude of industrialists towards research since the Great War has been remarkable. Sir J. J. Thomson records in his personal recollections that in his days he had great difficulty in getting money for a little extension to the overcrowded Cavendish Laboratory and he had to do it by accumulating little savings for a number of years from the reccurring laboratory grant. But largely as a result of the lessons learnt during the Great War, the attitude has been completely changed. Not only are the University laboratories far better equipped, but the number of research fellowships have increased enormously. You have all heard of the magnificent gift of Sir H. Austin to the Cavendish Laboratory, and of Lord Nuffield to the Oxford University, part of which will be spent on the improvement of the Clarendon Laboratory. Further, the department of Industrial and Scientific research spends about 1·30 million pounds in giving small doles to research workers, and a large number of them are workers in physics. The Royal Society of London has been getting endowments for founding research professorships, and only a week ago, they were recipients of a magnificent sum of two million pounds. It is calculated by J. Huxley that the Industries in England spend about 5 to 6 million pounds in scientific research, and in the United States of America about 300 million dollars are annually spent in scientific research by Industries alone. A large part of this sum naturally goes to researches in pure physics or to researches in associated subjects. As a result of these endowments I found very few students of physics unemployed ; for the intellectually-minded it is quite easy to get research fellowships which enable them to keep the wolf out of doors while they are struggling with a fundamental problem. For those who have a mechanical and commercial bent of mind, there are hundreds of industrial concerns willing to profit by modern discoveries. What a sad contrast to the medieval conditions prevailing in this country !

UNEMPLOYMENT AMONGST PHYSICISTS IN INDIA.

The conditions prevailing in Europe, America and Japan with respect to the cultivation of the physical sciences and the place of the physicist in national life may be contrasted with those prevailing in this country. It is not many years that Physics found a place in the curricula of University and elementary education which is compatible with its importance. In fact, serious study of physics in the Indian Universities was first taken up only after the University reforms of 1904. Since this time, however, physical laboratories have been added almost to every university and college, and the schools are also gradually taking up the subject. A few of the University laboratories have grown into active research centres, and Indian Physicists have within a short time made original contributions to their subject the value of which is recognised in the world of international science. In spite of such auspicious beginning, it is feared that cultivation of the subject has not taken root in the soil of the country, which alone can ensure its vigorous growth in future. Every senior teacher in Physics knows how difficult it is for their meritorious students to get a footing in life ! It is a common experience that many young physicists who have proved their worth by making lasting contributions to the subject, have to wait for years before they can get a position in life, and many have not succeeded in getting any post at all ! It is the duty of the Indian Physical Society to analyse the causes of unemployment amongst the younger physicists, and devise methods for its cure, otherwise our science has no future in this country.

The causes of unemployment are not far to seek. The number of posts available for a trained physicist in India is very small compared to those available for chemists. It is largely because industries which absorb a large number of trained physicists have not developed in this country. Let us see how prospects in these directions can be improved.

Physicists in the Teaching Professions.

The largest number of physicists is to be found in the educational lines as professors of various grades in Universities, Colleges, Engineering Institutions, and as teachers in schools. Unfortunately, the number of University teachers in Physics is generally very insufficient, and has not kept pace with the rapid growth of the subject. In every European and American University, the number has almost doubled within the last ten years. One particular feature is the creation of posts of "Theoretical Physicists" in every University, as it has been felt that very few physicists can now handle competently both the theoretical and experimental sides of our subject. This practice should be followed in India by the creation of posts of theoretical physicists in every University, Intermediate Colleges, and Engineering Colleges.

Need of Refresher Course for Science Masters.

Under the new conditions which have been in vogue since 1923, between teachers of physics in intermediate and Engineering Colleges and those in the Universities, almost a Chinese wall of separation has been created. It is almost impossible for one who has distinguished himself in research work to get an employment in any intermediate College, for the authorities with whom decision rests have developed an obsession that those who have made a name in research work are unfit for teaching work in the schools and colleges. In England, on the contrary, I found the opposite opinion to prevail. Nobody is considered competent to teach even in a school or in a junior college unless he has some research training. In Scandinavian countries, I found that University teachers and science masters in what we call Intermediate Colleges are all State employees ; and by a very useful arrangement, science masters are enabled to take leave after three years, for a period not exceeding one year, which time they utilize in taking a full course in research, and qualifying for the doctorate degree in one, two or more turns. Science masters who have thus qualified themselves are allowed to compete for university posts, and I found that many prominent Scandinavian men in Science have risen from the ranks of Science masters. I think that some such practice may be followed in our country, so that science masters in schools and teachers in Intermediate Colleges may be enabled to come to the University to do some research work under competent professors. When some of them have shown aptitude in such work they should be allowed to qualify for their doctor's degree. Encouragement should be given in the way of better prospects and promotions to enterprising science masters, who have shown aptitude in research.

The effect of such an arrangement would be a much greater efficiency in the standard attained by science teachers in the Schools and Intermediate Colleges who under the present conditions find it very difficult to keep in touch with the rapid progress made in our subjects, and it is our experience that after a number of years they lose all interest in their subject

As an example of the evil effects of the present system I may cite the example of a Professor of Physics in a junior college in this country whom I met in 1911. He had never heard of the electron, because it had not been discovered when he took his M. A. degree in 1891. Even amongst my own students who have become professors in junior colleges after a good career, I have found, after such people have remained in the country for a number of years, they reveal appalling ignorance of all modern developments. I need hardly add that it is unsafe to place young boys in such hands, and the only remedy is to arrange for refresher courses in the way suggested above.

EMPLOYMENT OF PHYSICISTS IN HOSPITALS AND MEDICAL INSTITUTIONS.

It is usual for medical colleges to employ a teacher in Physics for giving junior medical students elementary lessons in physics. But there is now greater need for employment of Physicists trained in research in medical institutions and hospitals. Most hospitals are now provided with X-ray sets, and with Radium. In this country, it is the practice for medical authorities to train a medical man in the use of these apparatus according to the rule of thumb method. Whenever any difficulty occurs in the management of the apparatus. they usually call an expert engineer from outside to help them.

It is superfluous to add that such a practice is not only harmful but inefficient and expensive in the long run. In European countries the government maintain a number of trained physicists for the service of hospitals. Their duty is to keep the X-ray plants in order, assist the medical men with expert advice about the handling of apparatus and carry out researches on the standardisation of the doses to be applied. They sometimes conduct researches bearing on medical subjects in collaboration with medical men. Many hospitals in our country have now large quantities of Radium which are kept in small quantities distributed in a number of tubes As Prof. D. M. Bose pointed out sometime ago, this practice limits the utility of radium and is sometimes very ineffective. Radium should be kept under the charge of a trained physicist in a safe place in the hospital and the emanation evolved should be collected and stored in small tubes and given to medical men, official as well as non-official, on payment of small charges. Needless to say that this is the practice in all foreign countries.

There are indications that in future the latest advancements in physics will be more and more used for the investigation of fundamental medical and biological problems. During the Harvard tercentenary, I listened to a very interesting lecture by Prof. A. Krogh of the University of Copenhagen who in collaboration with Profs. Niels Bohr and Von Hevesy, is developing a fine technique based on the use of heavy hydrogen and radioactive isotopes of light elements for the study of fundamental physiological problems. As you are aware, it is possible now to obtain radioactive varieties of light elements like Na, Mg, which occur in our foodstuff and can be administered internally. In contradistinction to the ordinary varieties of these elements which, when taken as food or medicine undergo such chemical transformation within the human system as to render their identification impossible, the radioactive varieties each carry a special label, in the form of their ability to emit electrons or positrons with a certain life period, which render the course of diffusion of these elements through the system extremely easy of detection. Krogh, Madam Curie-Joliot and others have pointed out the extreme utility of this new technique for biological investigations and in course of my travel, I found that many great centres of research are equipping themselves with the latest appliances for producing artificial radioactivity in common elements. Thus physics which has so long been accused of dealing only with lifeless matter is placing at the disposal of medical science a fine technique for investigation of biological problems. I see a time when medical hospitals will be provided with cyclotrons for the production of light radioactive elements, and their administration to the human system. These arrangements will require the services of trained research workers in nuclear physics.

ALL-INDIA RADIO SERVICE.

The avenues of employment for the trained physicist have enormously increased in Western countries as a result of the opening of broadcasting services and television. Quite a large number of trained physicists are also absorbed as ordinary officials in charge of broadcasting stations, in factories manufacturing wireless goods and also in the research sections of factories and broadcasting services. A large number of men with very ordinary knowledge of physics are absorbed as wireless operators in ships, in the army and the navy. The system of recruitment for these services in this country are such that they practically favour only one community. It is almost impossible for Indian students to get employment in these services.

In recent years, a Broadcasting Service has been opened in India under the name "All-India Radio," with headquarters at Delhi. In this connection the following comparative figures may be of some interest : The United Kingdom with a population of 50 millions, has issued seven millions receiving licenses, *i.e.*, one man in seven in the United Kingdom has a receiving set. In India the total number of receivers is only 38,000, *i.e.*, one man in 10,000 has a receiver. The objection may justly be raised that in the above comparison we have not taken into account the comparative poverty of India. This may be arrived at from the fact that the consumption of electricity per capita is only 6 units in India, while in England it is 420 units, *i.e.*, the average Englishman is 70 times richer than the Indian. On this basis one man in 500 in India ought to possess a receiver. The figures are twenty times lower. This shows that the management of the All-India Radio leaves much to be desired.

I have gone carefully into the cause of this inefficiency, and have elsewhere pointed how matters can be improved. All broadcasting organisations must have three well-organised sections—the technical section, the programme section, and the research section. The duty of the technical section is to construct transmitting stations, look after their running and maintenance. The work of this section can be carried on only by a competent technical staff who should have a thorough grasp of the fundamentals of the science, and should have opportunities of receiving practical training. It is well known that the Government has taken no steps to train a technical staff in India nor have utilized the available human material (which exists in plenty) in the country for this purpose. They depend entirely upon the foreign companies for helping them in this matter, and I am told that calls are frequently made upon foreign experts for setting apparatus right.

I do not wish to talk about the programme section which has received sufficient attention in the public press. The research section in a Broadcasting Organisation is as important as the two other sections, as a good deal of painstaking work is needed before the proper site for a transmitting station can be found ; also for finding out the right conditions for short and long distance transmission, the causes of fade-outs, and signal strength measurements. Such research cannot be conducted by the technical staff of a government department but can only be carried out by a Radio Research Board consisting of University Professors, representatives of Post and Telegraph, and of manufacturing concerns and other parties interested in the development of Radio. This is the practice followed in all European countries, in America and in Japan.

Early last year the Government invited Mr. Kirke, the head of the research department of the British Broadcasting Corporation, to report on the steps to be taken for the development of radio in India. Though it is now over eight months that Mr. Kirke submitted his report, it has not yet seen the light of the day. I understand on reliable authority that many of the useful suggestions put forward by Mr. Kirke are being shelved by the Government of India.

Though some of the Indian Universities have done fundamental research work in the propagation of radio waves, the Government has never asked for their co-operation, and has never encouraged them either by giving grants for research or by absorbing their students who have received special training.

The authorities in India are apparently of opinion that all the necessary research on radio problem in India could be very well undertaken by the newly formed research section of the All-India Radio : its organ, *Indian Listener*, in an editorial, gave expression to the same view. In a letter to the Editor (*Indian Listener*, Aug. 7, 1936), I pointed out several reasons why the research of the A. I. R. cannot perform the functions of a national radio research board.

"In the first place, the research section will be more concerned with immediate engineering problems of a commercial nature, and will not be able to undertake investigation of problems of a fundamental character, which is one of the main items in the programme of work of the Radio Research Boards. This is because the academic atmosphere which is necessary for the study of such problems is entirely wanting in the research section of a broadcasting organization.

Secondly, it has been our sad experience in the past that when a Government Department takes upon itself the task of carrying on fundamental research work, the duties of the officer engaged for the purpose very often begin and end in going through an interminable series of official files and the officer is hardly allowed any time for quiet thinking and sustained work ; the desire of the Government to carry out such investigations ultimately reduces to mere pious hope.

Thirdly, it has not been found possible for the research sections of other and much bigger broadcasting concerns to take upon themselves the performance of functions of Radio Research Boards, and it will no more be so for the newly formed similar section of the A.I.R.

(It may not generally be known that the British Broadcasting Corporation has a research section of which Mr. Kirke is the head. It deals with problems arising out of the technical development of the engineering of broadcasting and it has neither been within its scope, nor has it ever been its aim, nor indeed is it possible for it to perform the functions of the Radio Research Board.)"

OTHER AVENUES OF EMPLOYMENT FOR THE TRAINED PHYSICISTS.

Besides these departments, services of physicists are largely required for the Meteorological Survey of India. It is a rapidly expanding department and on account of its importance not only with respect to civil life, but also for the increasing demands of aerial transport, it should employ more physicists in future. The Geodetic Survey of India employs a few physicists, but the number may be considerably increased when a department of geophysics, including seismology and terrestrial magnetism, were added to it. The recent earthquakes in different parts of India have aroused the people to the importance of the fact that the subject of earthquakes should be scientifically studied. It is understood that some time ago the Government of India appointed a Committee consisting of different heads of scientific services to go into this question. They gave a very detailed plan of installing seismographs in about 40 centres distributed all over India and in representative regions. Every one of these stations was to be managed by physicists whose duty would be to keep the instruments going, collect seismographs and try to find out the causes of earthquakes. In addition, there was to be a central seismological laboratory where researches on the possibility of prediction of earthquakes on the safety of buildings and other related phenomenon were to be investigated. We understand however that this very useful and sensible proposal has been turned down by the Government on the inevitable financial grounds.

RIVER PHYSICS LABORATORIES.

It is also hoped that in future the Government would see the wisdom of having a number of river physics laboratories in different regions of India. The importance of such a laboratory for the building up of the country cannot be overestimated. India is a land of big rivers and from time immemorial, human life has concentrated in the valleys of the great rivers, the Indus, the Ganges and the Brahmaputra and the South Indian rivers, the Godavari, the Krishna and the Kaveri. All the great centres of civilisation during the last 5,000 years have flourished on the banks of these rivers. But the rivers are liable to change their course and if they are not properly trained, not only do they cause floods and erosions, but the topography may be changed to such an extent as to give rise to unhealthy swamps and to malaria. The fate of the old centres of civilisation like Pataliputra and Gaur which now lie buried under the soil illustrates the effect of rivers, and very much the same fate is overtaking Calcutta under our very nose. In order to prevent these, it is necessary that the physics of the rivers should be properly studied in suitably designed laboratories. Research in this direction should be classified under several heads:—(1) Fundamental Research—which will deal more or less with theoretical problems like the hydrodynamic laws regarding the flow of rivers, deposit of silt, problems of erosion and so forth. (2) Then will come the field survey—which will deal with the actual discharge of the different rivers in India, their liability to changes and the best ways in which these changes can be controlled and the rivers may be trained so that most efficient measures for sanitation, navigation and for the purposes of irrigation may be devised. Unfortunately, though in the past engineering enterprises on a stupendous scale have been undertaken in India, interfering with the discharge and course of rivers, *e.g.*, by the throwing of bridges over the rivers, cutting of canals, these works have been done more or less haphazardly on insufficient knowledge and their bad effects have been felt only years after their construction. It is high time that this department should be reorganised on a proper basis. If a number of river physics laboratories were opened as advocated here, they would give employment to a large number of physicists.

PHYSICS IN THE SERVICE OF INDUSTRY.

It is not realised what a large field exists for the application of physics to the problems of resuscitation of industrial life in the country. India is still an agricultural country and nearly 85 per cent. of her population live by agriculture. This disproportionate relation between agriculture and industry is not a healthy sign. The industries must be revived and put on a proper basis otherwise the standard of life in this country cannot be improved. The backwardness of India in industrial matters can be gauged from the following fact. For improvement of industries, the supply of power is an essential condition. In the most advanced industrial countries of the world, the supply of power is measured in the number of units of electricity consumed per head of the population in the year. In countries like Canada and Norway the consumption of electricity per capita amounts to about 2,000 units. In countries like Germany and England, a large amount of power is provided by steam, but even then the electrical power amounts to about 600 to 700 units per head. In India, the corresponding figure is only 6 per head. This shows how backward India is in matters of power supply.

It might be argued that this backwardness is the result of non-existence of power resources in this country. This is not a fact. Sir M. Visheshwaraya, ex-Dewan of Mysore, has estimated that the total power resources from hydro-electric sources alone amount to about 12 million kilowatts and of this barely 3 per cent. has been developed. If about 80 per cent. of the total power resources were developed the consumption of electricity per head in India would come to about 240 units. This would give India the same standard of living as in Japan and would provide her with a proportionate amount of power for the development of her industries. But there is neither the will nor a settled programme on the part of the Government of this country to undertake this electrification scheme.

Some people argue that industrial work like electrification should be left to private enterprises. Nothing can be farther from actual facts. In all European countries, in America and in Japan, the organisation of power resources of the country has been nationalised. It is never left to any private concern. Unfortunately in India, the electrical supply companies are all private bodies and as I have shown elsewhere they are all concerns for private profit. The result is that the price of power in this country is about 5 to 6 times higher than in other countries. On account of this high rate for power, industries cannot be developed to the same extent as in Europe and America. Unless this problem is seriously tackled, we shall always be at a disadvantage. Sooner or later the Government will have to take up the problem of supplying the country with cheap electrical power. In a scheme like this the services of the physicists would be required not only for designing the power plant but also for running power stations, and for solving such problems as that of surge, leakage, proper insulation and distribution.

DEPARTMENT OF INDUSTRIAL AND SCIENTIFIC RESEARCH.

Mr. V. Gordon Childe in his book " Man makes himself " has given a very thoughtful review of the modern currents in human civilisation. According to him the present-day scientific inventions are ushering a new phase of human civilisation which he calls the Third Great Revolution. The first revolution was brought about by the invention of agriculture which enabled men to live in settled cities and develop a sedentary civilisation. The second revolution was brought about by the invention of handicrafts which gave rise to different classes of artisans, cottage industries and the development of metallic industries. The third great revolution began with the Industrial Revolution of the last century. This has given rise to the factory system, employment of men in highly organised groups and control of the whole natural resources of the country by the totalitarian state. It began with the application of the results of scientific discoveries to problems of supply of human demands and needs by private parties, but gradually as a result of competition between different countries and due to new discoveries in science, it has been found that private individuals or parties are unable to cope with all the economic, social, and scientific problems which this great process of industrialisation or technocracy has given rise to. In every country the Government has to take upon itself the need for co-ordinating the industrial activities of the different members of the society. A new system is gradually emerging in every country the full effect of which we see in Russia. Before the War, Russia was a purely agricultural country like India ; 90 per cent. of her population lived in villages and depended entirely upon agriculture. As far as industries were concerned, they were mostly in the hands of foreign capitalists. The Russian people had practically very little knowledge of technics of modern industries and arts. As a result of the revolution of 1918, a new programme of industrialisation was undertaken. The development of power and the industrial system, and of the mines have all been taken over by the Government in the so-called Five Year Plan. The result of this planned action is seen in the tremendous strides which Russia has made in Technology and Industry within the last ten years. Before the War, the total production of electricity in Russia was only 5 or 6 billion units. Within the last 5 years it has become nearly 25 billion units and it is higher than that of any other country in Europe except Germany. It has already outstripped the production of electricity in England and I think in a few years to come, it will reach the figures of America. All this is the result of Lenin's pet idea that Russia should be electrified.

Even in England where people believe more in private enterprise, the inevitable logic of circumstances has shown that no industry can survive in the face of competition unless there is a scheme of co-operation between the scientists, the government and the industrialists. The result is the establishment of the Department of Scientific and Industrial Research. This is a scheme of organised research in which industrialists are invited to co-operate with the departments of Government and professors in the Universities, in the engineering colleges and other places. A detailed scheme of research is planned and is distributed amongst the workers on the subject who are handsomely provided with funds for research. As a result of the researches carried out in this department, the British industry has made a great recovery and effected substantial progress within the last few years and is rapidly gaining the lost ground. It is to be noticed that this department, though brought into existence by the Government has a constitution which provides for an ample representation of non-officials as well as of the representatives of industrialists. The Government controls its activities but does not hamper it. The Board is presided over by the famous physicist, Lord Rutherford, and a review of its activities may be read in *Science and Culture*.

In this country also the Government has established a department of industrial and scientific research. But the organisation of this department leaves much to be desired. It is an entirely Government concern, presided over mostly by civil servants and co-operation by University workers and private bodies is not encouraged. Now civil servants may be excellent agents for maintaining law and order, or running the wheel of justice, but it is our experience that they have not the mental equipment to plan out and organise research work on any branch of human activity. The organisation of this department is a sad contrast to that of the Agricultural Research Council in which the Government departments, the various agricultural interests in the country, the professors in non-official universities are properly represented. In the I. A. C. a scheme of co-operative research has been planned, and grants are liberally given to such professors as can submit a suitable scheme and have shown aptitude for carrying on a particular line of research. It is beyond our powers of comprehension why such a sensible scheme of co-operation has not been devised for the department of industrial and scientific research, and why it has been left entirely to the care of civil servants who are too much engrossed in routine work. If this department be properly organised, it will certainly be able to employ a large number of physicists.

NEED FOR ENDOWMENTS FOR RESEARCH IN PHYSICS.

In the beginning, I have already told my audience that the lot of the meritorious physics students who are being trained as research workers is very gloomy at the present time. On account of the unsympathetic attitude of the Government towards scientific research, there are practically no avenues of employment in which the special knowledge of the trained scientist can be utilised. I would, therefore, plead that the rich men in this country should come forward with endowments in the different universities for fellowships, so that these promising students can devote a number of years in solving particular problems. It is no exaggeration to say that the few active centres of research in India are mostly due to private endowments. The University College of Science, which started scientific work on a new basis after the war, in Calcutta was established by the princely donations of Sir T. N. Palit, Sir Rashbehari Ghose, the Raja of Khaira and the Indian Association for the Cultivation of Science which developed into an active centre of research under Professor Sir C. V. Raman was established in 1876 by a private medical practitioner of Calcutta, Mahendralal Sircar. The Indian Institute of Sciences which now contains a department of research in physics owes its existence to the princely donation of the late Mr. J. N. Tata. The Physical Laboratory in the Andhra University is due to the munificence of the Maharaja of Jeypore in the Madras Presidency. The Physical Laboratories in the Muslim and the Hindu Universities are largely the results of private benefactions. The Government has, of course, after the educational reforms of 1922-23 taken steps in re-organising Government Colleges like those at Allahabad, Dacca and Lahore on a modern basis. But this spell of progressiveness lasted, at best, for a year or two and after that the Government officials and politicians, in order to hide their incapacity for dealing with the problems of unemployment, have been sedulously preaching the doctrine that higher education and research are harmful to the nation. At the present time, there is no central fund from which a promising scholar in physics can be helped with a research grant or with a fellowship. It is well-known that without such scholarships and fellowships and research grants no advancement can be made. We are all admiring now-a-days the great advances which have been made in the physical and other sciences in the United States of America. But people in this country do not realise how much these advances are due to the great endowments like those of Rockefeller and Carnegie. As a matter of fact, but for these great endowments for research, and if left to Government alone, the United States of America would not have attained a much higher level than those of the Latin American countries. The Indian physicists have shown a great promise and it is the duty of the people to support them so that they can not only make a substantial contribution to the stock of human knowledge, but can also devote their knowledge to the solution of industrial and economic problems peculiar to India.

INDUSTRIAL RESEARCH CAN ONLY BE MADE SUPPLEMENTARY TO FUNDAMENTAL RESEARCH.

A class of critics has arisen in this country who hold that the professors in the universities should devote their time in carrying out investigations on only industrial problems and should not waste their time on fundamental researches

This argument is entirely fallacious. No industrial research can be carried out unless the worker has a sound grasp of the fundamentals of science. It is the duty of every university teacher first and foremost to train his students in the fundamentals of the basic sciences and to acquaint him with the latest developments in his subject. He will, therefore, be failing in his duty if he neglects pure science. Any industrial research work which can be undertaken by him can only be supplementary to his main activities. An analysis of the present conditions in the country shows that there is at present a great surplus of trained physicists who can devote their time to industrial research provided small grants can be found for them in the form of fellowships and research grants. This policy was advocated by the Unemployment Committee presided over by the Rt. Hon'ble Sir Tej Bahadur Sapru. But the recommendations of the Committee did not find favour with the Government. It is the duty of the public to come forward with offers of help to the Universities.

DUTY OF THE INDIAN PHYSICAL SOCIETY.

The Indian Physical Society is only a child of three years. It has still to develop and to prove its worth to the country. It is therefore necessary that it should take steps for an organisation of the physicists on a proper basis and try to impress upon the public the importance of physical research for the future of national reconstruction. It should try to get endowments and establish research funds for the encouragement of the younger physicists and for providing them with a berth in life. I hope that in the years to come all this will happen and the Indian Physical Society will be as useful an institution as the much older societies in Germany, England and America.