TATA INSTITUTE OF FUNDAMENTAL RESEARCH

REPORT

1945-1970

GENESIS OF THE INSTITUTE

The Tata Institute of Fundamental Research was founded in June 1945 by the Trustees of the Sir Dorabji Tata Trust in co-operation with the then Government of Bombay. The initiative to set up such an Institute was taken by Homi Bhabha in 1943. In this Report, which is concerned with the activities of the Institute during the first quarter of a century of its existence, it would be appropriate to recall, and to place on record, the various steps and factors that led to the establishment and subsequent growth of the Institute.

Letter from Homi Bhabha to J.R.D. Tata (19th August, 1943)

In a letter dated 19th August, 1943 to Mr. J.R.D. Tata, Homi Bhabha pointed out that:

> "the lack of proper conditions and intelligent financial support hampers the development of science in India at the pace which the talent in the country would warrant".

In particular, he was concerned that the lack of support operated adversely in several ways: firstly, it did not provide men who have chosen a scientific career, with the necessary equipment, facilities and environment for doing research; secondly, by throwing too great an administrative burden and teaching load on their shoulders, it did not leave them enough time and energy for advanced study and research; and thirdly the poor conditions of work and the poor financial prospects of a scientific career induced many of the most able university men to take up an administrative or commercial career. In the same letter to Mr. J.R.D. Tata, Homi Bhabha pointed out that if Indian science was to progress, far greater financial support was needed for "pure" or "fundamental" research, which was not likely to give any immediate economic return. He emphasised that even in the Soviet Union, where the stress was on gearing scientific research and development to economic and social problems, nevertheless, fundamental research was also strongly supported, for, in the official Soviet view:

> "there is no genuine knowledge of the universe that is not potentially useful for man, not merely in the sense that action may one day be taken on it but also in the fact that every new knowledge necessarily affects the way in which we hold all the rest of our stock".

Homi Bhabha: his background and aspirations

To appreciate this initiative on the part of Homi Bhabha, it would be useful to recall briefly his career and aspirations. Homi Bhabha spent 13 of the most impressionable years of his youth in the west, from the age of 17 to 29; he had worked in Cambridge, England in the heady atmosphere of the physics of the 1930s, a decisive and most fruitful period in the history of theoretical physics, nuclear physics and cosmic ray physics, and had associated himself with some of the greatest names in physics of this century: Blackett, Chadwick, Dirac, Heitler, Kapitza, Rutherford and others in England, and elsewhere in Europe with Bohr, Fermi, Kramers and Pauli. During this period, he had established himself as a theoretical physicist in the front rank, with work of great originality which was internationally known; and had also established a broad and high level base of cultural interest, notably in music, painting and architecture. Homi Bhabha was on a holiday in India in 1939, when owing to the outbreak of the Second World War and the consequent changes which occurred in England he could not return to Cambridge to continue the work that he was doing. Therefore, in 1940, he accepted a position at the Indian Institute of Science in Bangalore as Reader (and later Professor) in charge of a special cosmic ray research unit, which was set up for him by the Sir Dorabji Tata Trust.

In the rapidly developing frontier areas in which he had worked for almost a decade in Europe, Homi Bhabha was all by himself in Bangalore; and he knew that these areas of nuclear physics, elementary particle high energy physics, cosmic rays and associated theoretical physics, had just opened up; and would flower with the great possibilities for conceptual and fundamental breakthroughs as well as in terms of their applications. He further realised that it would be necessary to provide a fair amount of financial support in order to train and to provide opportunities for work for a sufficient number of scientists in these modern areas; and that it was only from such a base that one could hope to make real progress.

Homi Bhabha was an extrovert and a dynamic personality with a great deal of drive and energy. And he believed that he could, provided the right type of support and encouragement were forthcoming, develop new sophisticated areas of science and technology in the country, and equally important, harness these developments to achieve economic prosperity and social change. He had established an identity between himself and his country, and wanted to remain in it and play his role in its development. In order to do this, he felt it was essential to set up a new institution, concerned with scientific development in the topical, sophisticated and frontier areas of science and technology, with modern concepts of administration and research management, which had an atmosphere and environment conducive to the growth of a scientific community and of self confidence, and which would act as a pace-setter and be the base from which major ventures could be undertaken. Many of these thoughts are contained in scattered correspondence and writings of Homi Bhabha; and one comes across phrases such as:

> "would have an electrifying effect on the development of science in India"; "build up in time an intellectual atmosphere approaching what we knew in Cambridge and Paris"; "it is the duty of people like us to stay in our own country and build up outstanding schools of research such as some other countries are fortunate to possess"; etc.

Lastly, even at that time, (1943-44), Homi Bhabha thought of nuclear physics not just as an area of esoteric research, but one that would lead to the controlled uses of nuclear energy, with prospects for abundant and cheap electric power for national development. It was in the light of this background that Homi Bhabha took the initiative to write to Mr. J.R.D. Tata, on 19th August, 1943.

<u>Letter dated 12th March, 1944, from Homi Bhabha to Sir Sorab Saklatvala, Chairman of the Sir Dorabji Tata Trust</u>

In his reply dated 2nd September 1943, Mr. J.R.D. Tata wrote: "From what you say in your letter, it is evident that there is scope for rendering valuable service to the country and to the cause of scientific research in India. If you and/or some of your colleagues in the scientific world will put up concrete proposals backed by a sound case, I think there is a very good chance that the Sir Dorabji Tata Trust and perhaps also the Sir Ratan Tata Trust, will respond. After all, the advancement of science is one of the fundamental objects with which most of the Tata Trusts were founded, and they have already rendered useful service in that field. If they are shown that they can give still more valuable help in a new way, I am quite sure that they will give it their most serious consideration". Thus encouraged by Mr. J.R.D. Tata, Homi Bhabha wrote a letter dated 12th March 1944, to Sir Sorab D. Saklatvala, Chairman of the Sir Dorabji Tata Trust, in which he outlined his proposal for the setting up of an Institute of Fundamental Research in Bombay.

The letter is a remarkably prophetic letter and contains many of the basic guidelines which defined the way in which Homi Bhabha and the Tata Institute of Fundamental Research functioned later. For example, the letter contained the sentence:

> "Moreover, when nuclear energy has been successfully applied for power production, in say a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand".

This was written 18 months before the first atom bomb was dropped on Hiroshima in August 1945, by one sitting in Bangalore, with only the knowledge that nuclear fission had been discovered. It also emphasised Homi Bhabha's philosophy that, by planning and foresight, the country could train its own experts for the tasks of development, to have them ready to undertake these tasks as and when they did arise; and it was important for the nation to find strength within itself rather than develop an attitude of weak-kneed dependence on others.

Location of the Institute in Bombay

One of the reasons for locating the Institute in Bombay was the circumstances that the Director of Public Instruction of the Government of Bombay had approached Homi Bhabha to accept a chair of physics at the Royal Institute of Science, Bombay. Since the Sir Dorabji Tata Trust had already accepted Homi Bhabha's proposal for the establishment of a new Institute, he suggested to the Government of Bombay that the money which they proposed to spend on the creation of a chair for him and on equipment, would more effectively be used if they co-operated with the Sir Dorabji Tata Trust in a joint venture.

Founding of the Institute: June 1945

Thus it came about that the Institute was founded jointly by the Sir Dorabji Tata Trust and the Government of Bombay in 1945; the provisional Council of Management consisting of representatives from the two bodies held its first meeting on 18th May, 1945, when the budget proposals for the year 1945-46 were passed, involving a total expenditure of Rs 80,000/- At this point it would be appropriate to place on record the important role played by Professor Rustom D. Choksi, on the one hand in advising Homi Bhabha and on the other in dealing with various aspects relating to the setting up of the Institute on behalf of the Sir Dorabji Tata Trust. Professor Choksi has been a Member of the Council of Management since 1949 and has throughout been a wise counsellor and advisor to the Institute.

EARLY HISTORY SINCE ITS FOUNDATION

Kenilworth

The Institute may be considered to have commenced its work on 1st June, 1945, at the Indian Institute of Science, Bangalore, in the accommodation then belonging to the Cosmic Ray Research Unit which was set up for Homi Bhabha. Its work continued there till it was gradually shifted to its temporary premises at Kenilworth, 53 Pedder Road, Bombay, in the course of the following year. These premises consisted of about 6000 sq. ft. of space in one half of a bungalow; it was in this bungalow that Homi Bhabha was born on 30th October, 1909. The temporary premises of the Institute at Pedder Road, Bombay, were formally declared open at an inaugural function on 19th December 1945 by Sir John Colville, Governor of Bombay. The equipment of the Cosmic Ray Research Unit at the Indian Institute of Science, Bangalore, was brought over with a special grant given by the Sir Dorabji Tata Trust.

Role of the Government of India in the early stages:

Role of Council of Scientific and Industrial Research and Ministry of National Resources and Scientific Research

In the first year, 1945-46, the Council of Scientific and Industrial Research (CSIR) sanctioned a grant of Rs 10,000/-; this was for "Measurements on Cosmic Rays and ground experiments on Mesons". For the next year, CSIR under the presidentship of Sir Ardeshir Dalal, and with the enthusiastic support of Dr. S. S. Bhatnagar provided a block grant of Rs 75,000/-, subject to the condition that adequate representation was given to CSIR on the Council of Management of the Institute; and thus in April 1947, Dr. S. S. Bhatnagar, FRS, took his seat on the Council of the Institute as the representative of CSIR. In 1946, CSIR appointed an Atomic Research Committee for promoting research in atomic energy. As the Institute was the place in India at which the largest amount of theoretical and experimental work in nuclear physics was being carried out at that time, CSIR, on the recommendation of the Atomic Research Committee, gave a special grant to the Institute in 1947-48 for training a team of scientists in the general techniques of nuclear physics, with special reference to high energy accelerators. In 1948, the Government of India in the Ministry of Natural Resources and Scientific Research entered the picture with a block grant of Rs 1 lakh for 1948-1949; and over the period 1948-51, support by the Government of India to the Institute through this block grant was gradually increased.

Role of the Atomic Energy Commission

The Atomic Energy Commission of the Government of India was established in 1948. One of its immediate problems was the shortage of trained scientific personnel in its field. During the three years preceding the establishment of the Commission, the Institute had already collected and built up a small group of scientists trained in some of the special techniques of nuclear physics with the assistance of CSIR. It was therefore natural that the Commission should turn to the Institute for carrying out its own projects and for training further personnel for it. The Institute thus carried out a number of projects for the Atomic Energy Commission with joint teams of personnel belonging to the Institute and the Physics Division of the Atomic Energy Commission. The senior members of most of these teams belonged to the Institute and were drawn from the original group built up at the Institute. This co-operation has steadily grown and forms the basis on which the Institute is supported today by the Government of India through the Department of Atomic Energy. The close link established between the activities of the Institute and the Atomic Energy Commission, and the satisfactory manner in which these services were rendered by the Institute moved the Atomic Energy Commission, on the initiative of Dr. S. S. Bhatnagar, at its 27th meeting on the 22nd and 23rd April, 1953, to record the following: "The Commission noted that it had recognised the Tata Institute of Fundamental Research as the only laboratory of the Commission for fundamental research in atomic science. In view of this decision, the Commission would not set up another laboratory of its own for fundamental research in atomic physics".

The temporary premises of the Institute in Kenilworth on Pedder Road, having a usable floor space of some 6000 sq. ft. were entirely inadequate for these expanded activities. Consequently, a floor space of some 35,000 sq. ft. was leased in the premises vacated by the Royal Bombay Yacht Club at Apollo Pier Road; and in September 1949, the Institute's activities were moved to these new temporary premises. The Commission also leased space for its work in the same building.

Permanent buildings of the Institute

For a period of approximately a decade, throughout the 1950s, the Institute continued with its activities at the Old Yacht Club building. Even within the first few years it became clear that shortage of space would be the main restricting factor in the growth of the Institute. Accordingly, the Council sought for a suitable site for putting up the permanent buildings of the Institute. A valuable plot in the new reclamation area of Bombay was generously offered by the Government of Bombay; this offer was not accepted since it was clear from the rapid expansion of the Institute that this area would be inadequate. Finally, a suitable plot of land was located in Block VIII of the Colaba Reclamation. This land was in the possession of the Ministry of Defence; and accordingly, a request was made to the Government of India to transfer this to the Institute. Whilst the Government of India was unable to spare the full area asked for, it generously gave the Institute 15 acres in Block VIII of a most suitable site adjoining the sea. This was a result of the great personal interest that Prime Minister Jawaharlal Nehru took in this matter, the tireless efforts of Sir S. S. Bhatnagar and the co-operation extended by Sardar Baldev Singh, Minister of Defence.

In planning the buildings of the Institute, the Council took the view that the latest and the best ideas in laboratory design should be incorporated; accordingly, a noted firm of architects in the USA, M/s Holabird and Root of Chicago were commissioned to design these buildings. This firm, and particularly the principal architect, Mr. Helmuth Bartsch, who took a deep personal interest in this project, did a truly magnificent piece of work; the overall architectural concepts, involving the balanced juxtaposition of the masses of the buildings and changing vistas, constantly arouses the admiration of those privileged to work in it, as well as those who have occasion to visit and to see these buildings. In order to minimise the dollar payments which would have to be made to a foreign firm, and in order to utilise the services of Indian architects to the maximum extent possible, M/s Master, Sathe and Bhuta, who had designed and built the National Physical and Chemical Laboratories of the CSIR, were appointed as executing architects; Shri Kanvinde, architect of CSIR, was also associated with the early stages of the building project. The foundation stone of the New Buildings was laid by Prime Minister Jawaharlal Nehru on January 1, 1954.

It may be interesting to recall that in putting up these buildings, several pioneering efforts were made which have been of permanent benefit to the country in the area of building construction; for example, aluminium companies in India were induced to extrude special large sections for windows and doors in a rustless alloy resistent to corrosion by the warm sea air; the welding and fabricating of these windows, the use of adjustable louvres for sun control and such other features were carried out for the first time in India; these are only examples in a whole list of such items that are now common in Indian buildings as a result of these efforts.

Special mention should be made of the principal contractors, M/s Shapoorji Pallonji and Co. Pvt. Ltd., who carried out a magnificent job of building construction, both in putting up the main laboratory and office areas and later the Homi Bhabha Auditorium and Museum complex. It is important to stress that the task of putting up these buildings was not just given out as a standard job; it was an effort in which senior members of the Institute on the academic and administrative side, as well as the members of the Architecture and Civil Engineering Division of the Bhabha Atomic Research Centre participated whole-heartedly; as a result the quality of the building, particularly as can be seen after a decade of use, is very much higher than normally the case at the same cost per square foot of construction. It should be particularly stressed that Homi Bhabha spent a great deal of his time and energy in the detailed planning and aesthetics; and the buildings and the landscaping, bear the impress of Homi Bhabha.

Research work in hutments for half a decade

When this particular site was taken over by the Institute in 1954, it had on it a large number of hutments and barracks, as also gun emplacements; it had been a military site and was a location for coastal gun batteries. The hutments were renovated and fitted up as laboratories; and active research was conducted in these for half a decade so as to ensure that the growth of the Institute was not restricted through lack of space. Homi Bhabha has remarked:

> "work has inevitably been built up first and the permanent buildings have come afterwords".

Even when the New Buildings were under construction, and only the basement was just ready in 1956, the balloon production group was moved into it; the long basement was ideal for placing the very long tables needed for the production of large volume polyethylene balloons. And as the buildings became ready, group after group moved in. The buildings were formally inaugurated by Prime Minister Jawaharlal Nehru on January 15, 1962; by then they were already fully occupied.

Tripartite Agreement

By 1955, it had become clear that the Government of India's interest in the work of the Institute was of a permanent nature. Considering it "to be in the interests of the country to maintain a high level academic institution where study, search for knowledge and scientific research shall be pursued for the purpose of increasing man's knowledge of nature without considerations of practical utility", the Government of India signed a new Tripartite Agreement with the Government of Bombay and the Sir Dorabji Tata Trust, as a result of which the Institute came to be recognised as the National Centre of the Government of India for advanced study and fundamental research in nuclear science and mathematics.

Prior to 1956, the administration and management of the Institute vested in a Council consisting of one representative of the Government of Bombay, two representatives of the Sir Dorabji Tata Trust, one representative of the Government of India and the Director of the Institute. The Tripartite Agreement envisaged extensive financial support from the Government of India and correspondingly a greater and more permanent representation for it on the Council of Management.

The Tripartite Agreement came into force with effect from April 1, 1956. Under the Agreement each of the parties covenanted to pay a minimum block grant-in-aid towards the maintenance of the Institute and also to pay a non-recurring specified grant-in-aid towards the cost of buildings and equipment of the Institute. These are the minimum grants provided under the Tripartite Agreement. The annual block grants-in-aid are fixed by mutual agreement between the parties in the light of the existing conditions. Since the Government of Bombay (now Maharashtra) and the Sir Dorabji Tata Trust were not in a position to enhance their financial contributions above the minimum laid down in the Tripartite Agreement, the Government of India has assumed the entire responsibility to provide the additional funds needed by the Institute. Today, 99% of the expenditure of the Institute is borne by the Government of India. The Institute comes under the administrative purview of the Department of Atomic Energy through which these grants are channelled.

Homi Bhabha strongly believed that:

"financial support from Government need not, however, entail government control".

In this he quoted Professor A. V. Hill, FRS, Senior Secretary of the Royal

Society, who in his lecture to the Indian Science Congress at Delhi had stated: "many of these independent scientific institutions in Great Britain now-a-days are receiving substantial state support; but nearly always, when this is done, a buffer of some kind is interposed to prevent Government support from becoming Government control". Accordingly, when the Tripartite Agreement was drawn up, importance was attached to the necessity of introducing financial procedures that are consistent with those followed in the Universities and high level scientific institutions abroad and which do not have the rigidity of government procedures. In particular, the Institute accounts are audited by a firm of commercial auditors, who answer a specific set of questions laid down by Government to ensure that the grants are utilised for the purposes for which they were given.

Council of Management

Under the Tripartite Agreement the Institute is run by a Council of Management consisting of three persons appointed by the Government of India, one person appointed by the Government of Maharashtra and two persons appointed by the Trustees of the Sir Dorabji Tata Trust; the Director of the Institute is an ex-officio member of the Council. A list of those who have served on the Council of Management of the Institute is given elsewhere in this Report. The Institute has been fortunate in the quality of the members it has thus far had on its Council. They have throughout displayed a sense of vision, imagination, and a keen sense of awareness of the needs of scientific research. Homi Bhabha remarked in January 1966, in the last speech he gave before his death:

> "the type of administration required for the growth of science and technology is quite different from the type of administration required for the operation of industrial enterprises, and both of these are again quite different from the type of administration required of such matters as the preservation of law and order, administration of justice, finance, and so on".

The Institute has been fortunate in having on its Council, Members who fully appreciated this and provided it with an administrative structure of the type needed for growing science.

The immoveable properties and funds of the Institute other than those vested in the Council of Management are vested in a Board of Trustees on which each of the 3 parties to the Tripartite Agreement are equally represented.

Rules and Byelaws: Management of the Institute

On the basis of the Tripartite Agreement, new Rules and Bye-laws were framed for the general administration and management of the Institute. These provided for large scale delegation of powers at all levels. It is gratifying that the Model Constitution which was prescribed by the Scientific Advisory Committee to the Cabinet for scientific institutions in the country in general was based on the Rules and Bye-laws of this Institute.

The Council of Management of the Institute deals with policy aspects which have long range implications or involve large financial outlays; in particular, it normally considers the annual budget, appointments at senior levels, new programmes involving a large initial/recurring financial outlay, matters relating to scales of pay, etc. Within the framework of policy laid down by the Council, the Director has full authority to run the Institute as he considers appropriate.

The Director is assisted by two Faculties, one for the School of Mathematics and the other for the School of Physics; staff of the rank of Associate Professor and above are members of either of the two Faculties as appropriate. Additionally, there are a large number of Committees to deal with various general facilities of the Institute, such as the Library, Engineering Services, (including the workshop, glass blowing section, technical maintenance, etc.), Stores and Purchase; as also Committees appointed by the two Faculties to deal with matters which come under their purview. There is a constant rotation of membership of these Committees, so that the administrative load on individual scientists is reduced; and at the same time, there is a greater sense of participation at various levels in the running of aspects of the Institute which directly concern the scientists and their programmes of work. Each Faculty Member is fully authorised to incur expenditure up to the limit of the budget sanctioned for his group, whether for capital or for stores, in the manner he considers appropriate, without reference to the Faculty, Director or Council. Even more important than the formal aspects just discussed are the continuing informal contacts and discussions characteristic of the existence of a genuine scientific community.

Relationships with the Atomic Energy Commission

When Homi Bhabha set up the Tata Institute of Fundamental Research, he already had in mind plans for growing the Indian atomic energy programme. The Atomic Energy Commission was set up in 1948 and the Department of Atomic Energy in 1954. Work on the thorium plant at Trombay was started in 1953 and on the first 1 MW Swimming Pool Reactor APSARA in 1955, and gradually the whole complex of the Bhabha Atomic Research Centre grew. Homi Bhabha headed . of these until his death in 1966. The relationships of the Institute and the Atomic Energy Commission are therefore best expressed in his own words as in the following paragraphs:

> "In the field of research an Atomic Energy Commission must promote two kinds of activity: (1) research of a semi-technical or technical nature aimed at solving the problems which arise in the construction and design of atomic reactors and in the processing of materials connected therewith; and (2) fundamental research in all aspects of atomic science without any reference to its immediate utility.
>
> (1) should be carried out mainly in establishments owned solely by the Commission though individual problems may be farmed

out to various laboratories .... An atomic reactor should only be set up, at least under present circumstances, in establishments owned solely by the Commission.

On the other hand, fundamental research should be sponsored by the Commission mainly in institutions other than its own, as for example in the universities and research institutes, where a free intellectual and academic atmosphere prevails. Certain projects of this type, however, are too big to be conveniently carried out in the normal laboratory of a university ....

The Tata Institute of Fundamental Research fulfils precisely this role of being an Institute at which the Commission can carry out its large scale projects of fundamental research. Fundamental research thrives best in an atmosphere that is free, permitting an unrestricted exchange of ideas. An Institution for fundamental research should be open to all scientists of eminence, whatever the country to which they belong, and should be unfettered by the secrecy regulations required in commercial or strategic establishments. Had the Institute not existed, the Indian Atomic Energy Commission would have been compelled in time to create such an institution where fundamental research in atomic science could be carried out in a free academic atmosphere on a scale larger than is convenient in a university laboratory." (Homi Bhabha - 1954).

"The Atomic Energy Commission of the Government of India was first established in 1948, and one of its immediate problems was the shortage of trained scientific personnel in its field. It was therefore natural that the Commission should turn to the Institute for training personnel for its work, and for carrying out some of its own major projects. These early projects were carried out by joint teams belonging to the Institute and to the Physics Division of the Atomic Energy Commission, which was then housed in the Institute's premises and looked after administratively by the Institute. The Commission, on its part, gave substantial help to the Institute by providing funds for increasing its activities and for specialised equipment for nuclear research.

One of the first activities undertaken by the Institute for the Commission was the setting up of a small electronics group to design and build the electronic instruments without which atomic energy work is impossible. This group was the nucleus from which grew the present Electronics Division of the Atomic Energy Establishment at Trombay with a staff of over 560 people, and which is now producing not only most of the electronics instrumentation used at Trombay, including the control system of reactors, but also that which will be used all over the country in agricultural, biological, industrial, and medical work with radioactive materials.

The Institute has given some 46 members of its scientific staff to man various divisions of the Atomic Energy Establishment at Trombay, to mention only two, Shri A. S. Rao, Head of the Electronics and Health Physics Group, and Dr. R. Ramanna, Head of the Physics Group. There was a time when no less than 175 members of the staff of the Trombay Establishment were looked after by the Institute. It is also appropriate to recall on this occasion that the control system of APSARA, the first reactor in Asia, was built under the auspices of this Institute in a war time hutment on this very site, and many parts of the reactor in the Institute's workshop. It is not an exaggeration to say that this Institute was the cradle of our atomic energy programme, and if the Atomic Energy Establishment at Trombay has been able to develop so fast, it is due to the assisted take-off which was given to it by the Institute in the early stages of its development. It is equally true to say that the Institute could not have developed to its present size and importance but for the support it has received from the Government of India." (Homi Bhabha - 15 Jan. 1962).

In addition to the above organic relationships outlined by Homi Bhabha, it would be useful to record some of the individual activities characteristic of the strong bonds that exist between the Institute and the Atomic Energy Commission:

(i) The Electronics and Technical Physics Division of the Bhabha

Atomic Research Centre had their origins in work initiated at the Institute.

(ii) The 1 MeV cascade generator of the Institute was used extensively as a source of pulsed neutrons for studying the slowing down of neutrons in various assemblies.

(iii) The mass production of Boron trifluoride neutron counters and of plastic scintillators by groups from BARC was carried out at the Institute.

(iv) Considerable time on the CDC-3600-160A computer system at the Institute is availed of by institutions under the administrative purview of the Department of Atomic Energy: Bhabha Atomic Research Centre, Power Project Engineering Division, individual power projects, and groups concerned with space science and technology.

(v) The Computer group of the Institute and the Electronics Corporation of India at Hyderabad are working together on the design and manufacture of a family of versatile real time computers, to meet through indigenous production the demands for small and medium range computation and for on-line applications.

(vi) Staff from the Institute have carried a considerable part of the teaching load of the Training School operated by the Bhabha Atomic Research Centre since 1957.

(vii) Liquid helium from the Institute plant is regularly supplied for experimental work at Trombay.

(viii) The Institute uses appreciably the facilities at the APSARA and CIRUS reactors and the Van-de-Graaff accelerator at Trombay.

(ix) The Institute has undertaken a major project connected with the design and fabrication of radars required for the space programme.

(x) There are regular administrative arrangements for the transfer of staff between the various institutions that come under the purview of the Department of Atomic Energy, including the Tata Institute of Fundamental Research.

These and many other such aspects are indicative of the interactive relationships that exist between the Institute and the atomic energy and space programmes of the country.

SUBJECTS OF RESEARCH AND STUDY

The work of the Institute has, up to now, been carried on in two Schools: a School of Mathematics and a School of Physics. In the paragraphs below, a brief account is given of the work currently in progress in the Institute.

SCHOOL OF MATHEMATICS

The School of Mathematics was organised with a view to building up a body of competent scientists, who could carry out mathematical research at the highest level in fields of current interest. For this purpose, a few talented young persons are selected each year and prepared for mathematical work, by means of a carefully planned programme of intensive training, meant to bridge the gap between college mathematics and creative work. The activities of the School centre round lectures and seminars conducted by members of the School, supplemented by lectures given by eminent visiting mathematicians from all over the world. The group is engaged in active research in almost every major branch of pure mathematics - classical and functional analysis, differential equations, function theory, differential geometry, algebraic geometry, Lie groups and Lie algebras, commutative and homological algebra, differential and algebraic topology, analvtic and algebraic number theory, etc.; substantial contributions have been made to these subjects by members of the School. The School has organized international symposia from time to time, four up to now, under the co-sponsorship of the International Mathematical Union: on Zeta-functions (1956); Function theory (1960); Differential Analysis (1964); and Algebraic Geometry (1968). The proceedings of these symposia have been published.

SCHOOL OF PHYSICS

Work in the School of Physics covers both theoretical and experimental investigations. In addition to what might be termed as pure physics, work in progress includes aspects of biology, chemistry, geophysics, astrophysics, computer sciences, solid state electronics and microwave engineering. These are detailed in the sections below:

Theoretical Physics:

High Energy Physics and Particle Physics

The strong, electromagnetic and weak interactions of elementary particles and their symmetry properties are being studied, using the methods of field-theory and group theory and the S-matrix approach. Phenomenological approaches to high energy physics are also being pursued.

Nuclear Physics

Problems of nuclear structure are being studied, both on the basis of various nuclear models, as well as in terms of basic nucleon-nucleon interactions using the techniques of many-body theory. Work is also being carried out on the statistical properties of nuclear levels, and on nuclear reactions.

Solid State Physics

The interest has mainly been in the theoretical aspects of non-linear optics, Raman scattering, positron annihilation, phase transitions, magnetism, band structure, superconductivity and liquid helium.

EXPERIMENTAL PROGRAMMES

Experimental work is being carried out in the following areas: (i) Cosmic Ray Physics; (ii) High Energy Physics; (iii) Geophysics; (iv) Radio Astronomy and Astrophysics; (v) Nuclear Physics; (vi) Chemical Physics; (vii) Solid State Physics; (viii) Computer Sciences and Technology; (ix) Instrumentation I - Solid State Electronics; (x) Instrumentation II - Microwave Engineering; (xi) Molecular Biology; and (xii) Basic Dental Research.

Cosmic Ray Physics

Studies at Balloon Altitudes: There is a continuing programme of cosmic ray studies at high altitudes based on the balloon facility developed by the Institute, which is described in a later section. These studies are being carried out with specially designed nuclear emulsion assemblies as also electronic counter assemblies, that are kept floating on balloons, for extended periods of time, close to the top of the atmosphere. The current emphasis is on: the spectrum of high energy electrons; background X-rays and gamma rays; X-rays and gamma rays from discrete sources such as pulsars, supernova remnants, galactic nucleus etc; neutrons and gamma rays from the sun; and the chemical and isotopic composition of the primary radiation. Examples of the equipment carried up on these flights are: large-aperture magnetic spectrograph incorporating wide gap spark chambers, scintillation counters and nuclear emulsions, for the accurate measurement of the momenta of charged particles in the primary cosmic ray beam up to energies of 10^{11} eV; X-ray telescopes mounted on orientation platforms which enable long exposure to specific X-ray sources etc. Time variations in the intensity and spectra of some of the X-ray sources are being investigated; and in the case of certain individual sources simultaneous observations are being made in the X-ray, radio and optical regions of the electromagnetic spectrum.

Extensive Air Showers: Extensive Air Showers of the cosmic radiation are being studied at two locations, viz. Ootacamund (altitude 2.2 km) and at Kolar; at Kolar, underground levels in the gold mines up to a maximum depth of 10,000 feet below ground are available. In the Ooty array the shower size and core position is obtained from large number of scintillators spread out within a circle of radius 40 m; various other detectors have been used at appropriate locations from time to time to suit the observational needs; they have included: shielded GM counter trays, Total Absorption Spectrometer, neutro counter assemblies, large multiplate cloud chamber etc. The detailed structural properties of air showers and the inter-relations between the various components have been under investigation. At Kolar a surface air-shower array is operated in conjunction with large-area particle-detectors, like scintillation and Cerenkov counters, at various depths underground where only the ultra high energy muons can reach. These experiments have a bearing on the characteristics of ultra high energy interactions, and on the chemical composition and spectrum of cosmic radiation at energies beyond 10^{14} eV.

Underground Experiments on Muons and Neutrinos: Systematic investigations on the variation of muon intensity with depth and on the angular distribution of muons at various depths are being carried out in the Kolar Gold Fields using detector systems of large area consisting of scintillators, neon flash tube arrays as visual detectors and absorber layers of iron or lead. The observations made have a bearing on the electromagnetic and nuclear interaction characteristics of muons at very high energies, on the manner of production of high energy muons, and on the nature of the primary spectrum in the energy range above 10^{12} eV. These experiments are being carried out in collaboration with the Osaka City University, Japan.

Several specially designed large area telescopes, incorporating neon flash tubes and scintillators, were operated at a depth of 7600 ft.

below the earth's surface for several years for the detection of muons produced in the interactions of natural neutrinos. These experiments, involving neutrinos of much higher energy than are available at the accelerators, have a bearing on the character of weak interactions, and on such aspects as the production of intermediate bosons etc. This experiment was carried out in collaboration with the Osaka City University, Japan and the University of Durham, U. K.

Theoretical and Interpretative Studies: Theoretical and interpretative studies are being carried out in various areas of what could be termed cosmic ray astrophysics: on aspects relating to the origin and propagation of cosmic rays, in relating information obtained through studies of high energy electrons with radio astronomical observations, models of pulsars etc.

High Energy Physics

Current work in high energy physics is based on the analysis of photographs taken with bubble chambers at the high energy particle accelerators. A new facility capable of processing 100,000 events per year has been set up; this programme depends heavily on the excellent computing facilities available at the Institute. Three measuring machines, in addition to the scanning machines, have been built at the Institute. A computer OLDAP, designed and built at the Institute is also being used as an on-line facility. With this set up it has become feasible for the Institute to participate actively, at a moderate cost, in elementary particle physics based on the use of high energy accelerators. Two exposures have already been obtained. These are of a hydrogen-neon bubble chamber exposed to 3.5 GeV/c positive pi-mesons at Argonne National Laboratory (USA) and the other a hydrogen bubble chamber exposed to 0.72 GeV/c antiprotons at CERN, Geneva.

Geophysics

GEOPHYSICS

The natural distribution of a host of cosmic ray produced and naturally occurring radionuclides has been under study in diverse terrestrial materials with the help of specific micro-radiochemical and ultra low level counting techniques; many of these isotopes were discovered for the first time in these geophysical environments at the Institute. The observed distributions have been used to unfold the intricate nature of diverse geophysical processes: exchange of air across the tropopause; north-south mixing in the stratosphere and in the troposphere; rate of washout of aerosols from the troposphere; circulation of water within and between the principal oceans; rates of accumulation of biogenic silica-rich sediments; growth of manganese nodules, etc. A simple technique for the in-situ extraction of trace elements from large amounts of sea water, (100-10000 tons), has been developed for the study of concentrations of radionuclides and stable trace elements present in sea water. A novel method has been developed and successfully employed to delineate the course of the south-west monsoon using natural radon (half-life = 3.8 days) as a tracer.

Cosmogenic alterations i.e. isotopic changes and alterations in crystal structure (solid state damage) have been studied in extra-terrestrial materials, (meteorites and lunar samples), due to the passage of charged particles. Important technical developments for the revealing of fossil tracks in silicate materials have been carried out. Results that are significant from the viewpoint of understanding the history of cosmic radiation as well as the history of formation and irradiation of solid objects in the solar system are as follows: prehistoric intensity of cosmic ray protons has been found to have remained constant during the last about 5 m.y. within a factor of two; the long term average fluxes of both low energy solar cosmic ray particles and galactic iron group and heavier nuclei have been determined; there appears to be good evidence (from fossil track records) for the existence of transuranic Pu^{244} and elements of charge, about 115 and mass about 300.

The remanant magnetisation of rocks collected from several geological horizons in India has been studied using sensitive magnetometers; the stability of the magnetic records has been examined. Interesting results have been obtained that bear on the drift of continents and reversals of the magnetic field through geological times. More recently, studies have been started on the basic properties of rocks as magnetic substances;

several interesting results have been obtained in this area.

Radioastronomy and Astrophysics .

A high resolution radio interferometer, working at 600 Mcs, for studies of the quiet as well as the active sun, has been in operation since 1965 at Kalyan near Bombay. It consists of 32 dishes, each 1.8 m in diameter, of which 24 are placed in a 2100 foot each-west array, and 8 in a 900 foot long north-south array. Observations with this array indicate that the solar corona has a temperature of 1.5×10^6 °K.

The main interest of the group now is in studies with the cylindrical radio telescope of large gathering power, (described in a later section), that has been set up at Ootacamund in South India. This radio telescope was designed primarily for lunar occultation studies of very distant radio galaxies lying at the edge of the Universe. Information on the detailed structure in these cases, with a resolution of a few seconds of arc, (which at present is avilable only for a few strong sources), is likely to be highly significant from the viewpoint of cosmology and for studying the origin and evolution of radio galaxies. The radio telescope is also currently being used for studies of pulsars. Other programmes for this instrument include: long base line interferometry, study of flare stars, radio emission from planets (particularly Jupiter), interplanetary scintillation, survey of weak radio sources in the southern hemisphere, determination of deuteron to hydrogen ratio, etc.

Work in Theoretical Astrophysics has covered: the equation of state valid for neutron stars, and the maximum mass of such a star; origin and variation of polarization of radio radiation from pulsars; properties of interstellar grains to explain the polarization of starlight; reformulation of the Wheeler-Feynman absorber theory of radiation; study of cool stars, etc.

Nuclear Physics

This group is mainly concerned with problems relating to the structure of nuclei. The experimental approach is through spectroscopic studies of beta and gamma-radiations emitted by radioactive isotopes and by analysing nuclear reactions induced in stable nuclei by high speed particles from accelerating machines.

Nuclear energy levels and their properties, (namely, spins and parities, life-times and magnetic moments, internal conversion of gamma-rays), are being studied using magnetic beta-ray spectrometers, scintillation gamma-ray spectrometers and solid state detectors. The 5.5 MeV Van de Graaff machine and the reactors at BARC are being used for nuclear reaction studies and for isotope production. Investigations are being carried out using the ion implantation technique and channelling of charged particles in single crystals. The circular polarization of gamma-rays and polarization correlations are also being studied.

The one million volt cascade generator of the Institute has been in use to study nuclear reactions with fast neutrons with a maximum energy of 16.75 MeV. Mono-energetic gamma-rays of energy up to 17.6 MeV are employed for photo-nuclear reaction studies. This accelerator is also used for studies of the slowing down of fast neutrons in various media and assemblies of materials - aspects that are of interest for the construction of reactors.

Chemical Physics

The Chemical Physics Group is basically interested in elucidating the electronic structure of molecules using modern theoretical and experimental techniques.

Work is being carried out on high resolution Nuclear Magnetic Resonance of organic compounds and transition metal complexes, and on the bulk magnetic susceptibility measurements of transition metal complexes and rare earth compounds. Mössbauer effect of Fe^{57} in several iron complexes at various temperatures is being studied. Electron Spin Resonance and Electronic Spin Lattice Relaxation in organic free radicals, inorganic complexes and doped single crystals are under investigation. Work is in progress on: electrochemiluminescence; microwave spectroscopy of gases; valence bond and molecular orbital calculations of spin density distribution in free radicals. The conformational shape of biopolymers and its relation to biological activity is being investigated, both theoretically and experimentally.

Solid State Physics

Modern nuclear techniques, and radioactive nuclei as probes, are being used to investigate various aspects of solid state physics. Work is being carried out in the areas of the magnetic properties of solids, radiation effects in solids and defects in crystals.

Magnetic and electric interactions in metals, alloys and non-metals including Kondo systems are being investigated with wideline nuclear magnetic resonance spectrometers and resistivity techniques. Studies in Mössbauer spectrometry, positron annihilation, ultrasonic absorption and nuclear orientation at very low (liquid helium) temperatures are in progress to analyse various aspects of solid state physics. The facilities used for these investigations include a crystal growing capability, electron microscope and X-ray unit for structural studies, and the 3.5 MeV electron linear accelerator and a 3000-curie Co^{60} source for radiation damage studies.

Computer Sciences and Technology

Work in the area of computer sciences and technology is broadly divided into three parts: (i) Design, development and fabrication of computers and computer sub-systems; (ii) Software development; and (iii) Research in computation theory, logic, operations research, machine intelligence and perception. The Institute has been operating a CDC 3600-

160A computer system as a national facility since 1964. OLDAP, an on-line data processor designed and fabricated by the Computer Group, is being used as a data acquisition facility for physicists in the Institute, particularly for the bubble chamber film analysis work.

The current areas of interest in hardware systems technology relate to on-line computers, on-line graphic consoles, thin film memory devices, and the fabrication of computer modules using multilayer printed circuit packaging techniques. In software development, a project to design and implement a small time-sharing system has been completed; and further work is envisaged in the study of languages for system programming and system design. Apart from this, program development is being undertaken to enable the use of a locally built cathode ray display console for computer-aided design of circuits and their layout.

Work is being carried out in mathematical logic, switching theory, theory of programming languages, and computation theory. Studies are being made in the field of system sciences and the application of operations research techniques for planning and management problems. In addition, there are active research projects in the following areas: question-answering systems, speech recognition and speech synthesis by machine, visual pattern recognition, simulation of human verbal behaviour and problem-solving by machine.

Instrumentation I - Solid State Electronics

The Solid State Electronics Group is primarily engaged in the study of the physics and technology of semiconductors and of thin films. Experimental facilities, (such as diffusion and alloying furnaces, epitaxial reactors, clean room, capacity discharge type welders, die bonding equipment, vacuum evaporation units, semi-automatic probing and mask alignment equipment), have been set up indigenously. Solid state devices like planar transistors and silicon-controlled rectifiers have been successfully fabricated and the properties of these devices investigated. The fabrication and study of integrated circuits, thin-film passive networks and solid state microwave devices viz. Schottky barrier diodes, Gunn diodes and Avalanche diodes, are in progress. Instruments are available for measuring diffusion depths, resistivity, and electron and hole mobility. The study of amorphous semiconductors has been taken up, particularly as low cost memory elements. Work on microwave ICs is in progress and for this thick film technology is being developed.

Instrumentation II - Microwave Engineering

The Microwave Engineering group has been engaged in the design and production of microwave test equipment in the S- and X-band frequency ranges; signal generators, slotted lines, standing-wave ratiometers and frequency meters have been built and supplied to other users in the country.

Noise sources, I. F. amplifiers and mixers for radar receiver testing have also been designed and built. Work on the fabrication of high power microwave tubes and on passive components such as transmit-receive cells is being carried out. Projects relating to the fabrication of several major systems needed for radars for the Indian space programmes have been taken up.

Molecular Biology

The Molecular Biology Group is concerned with the study and interpretation of basic biological processes at the molecular level, i. e. in terms of the structure and properties of molecules. Research is being carried out in the following areas: the process of genetic exchange during replication, recombination and transformation in bacteria; the synthesis and regulation of macromolecules such as RNA and proteins, with special emphasis on enzymes; mechanism of enzyme action and control of flux in multi-enzyme systems. Work has recently been undertaken also on differentiation and hormonal regulation in plant and animal cells.

The Molecular Biology Laboratory is specially equipped to study biological macromolecules. The available facilities include equipment for analytical and preparative ultracentrifugation, high voltage ionophoresis, amino acid analysis, isotopic methods, fluorometric and other photometric systems.

Basic Dental Research Unit

A large scale epidemiological study of oral cancer and precancerous conditions in the population of rural India in the states of Andhra Pradesh, Bihar, Gujarat, Kerala and Maharashtra has been carried out. About 10,000 cases were studied in each area; whenever lesions were encountered, a full clinical, histological and cytological examination was performed at the Institute's laboratory. A full record has been maintained using polaroid pictures. The CDC 3600 system at the Institute has been used for the final evaluation and correlation of oral cancer and precancer amongst the selected individuals in the above states; of interest is the correlation with existing habits and practices. Follow-up studies in the same areas are currently in progress.

INSTITUTE ACTIVITIES THAT CONSTITUTE NATIONAL FACILITIES

As a result of research that has been carried out, the Institute has developed competence of a unique character in several fields. Because of this it has become possible for the Institute to set up and to provide in these areas facilities which can be made use of by other scientists and institutions in the country. These national facilities are described in the sections below.

National Computation Centre

The National Computation Centre at the Institute is equipped with a Control Data Corporation 3600-160A computer system with a 48000 word fast access core memory. The high speed peripheral equipment include: two punched card readers (which can read 1200 cards per minute); two fast line printers (which can print 1200 lines per minute); 12 magnetic tape units; a 16 million word disc-file; and a drum-type and a flat-bed Calcomp graph plotters. An on-line visual console with a light pen has been designed and built locally for use with this system.

The computer centre is completely maintained and operated by specially trained Institute staff members. Programming staff attached to this installation conduct periodic courses to instruct users in the utilization of the system. In addition, a considerable amount of system programming work has been done to improve the efficiency of the system. A limited time-sharing facility has been implemented with 4 on-line remote consoles.

The national Computation Centre has been in operation since June 1964. Currently the system is being operated for about 135 hrs. a week on a job-shop basis. Over 180 different organizations throughout the country regularly make use of the computational facility. These include the Bhabha Atomic Research Centre, other units under the administrative purview of the Department of Atomic Energy, all the major Universities and Institutes of Technology, public and private sector industries, quasi-government organizations and national laboratories.

Balloon Facility at Hyderabad

Polyethylene balloons of volume up to 3 million cu. ft. are fabricated by the Institute; these are made both with imported polyethylene film as well as with film extruded in India under quality-controlled conditions, under supervision of Institute staff; the film is about 1 mil in thickness; a large balloon is about 250 ft. in length. Ceiling altitudes up to 120,000 ft. have been obtained; gross lifts of about 900 kgms. have been handled. The balloons are filled with hydrogen. Tracking is done both optically as well as by radio; radio-command is used for in-flight operations and for cut-down of equipment on termination of the flight. Regular flight programmes are conducted from Hyderabad, which is close to the geomagnetic equator, and has thus many unique advantages for work at balloon altitudes in the fields of cosmic-ray astrophysics and atmospheric research. Balloon flights over Hyderabad are also carried out by the Institute on behalf of other institutions in India. In addition, two major programmes were carried out from Hyderabad in 1961 and 1965 involving international collaboration. A regular national balloon facility has been set up at Hyderabad consisting of: a launch area, (from which balloons up to 10 million cubic feet in volume can be launched); laboratory for pre-flight work on equipment; hostel accommodation for those engaged on flight operations; hydrogen cylinder storage shed; and area for regular balloon production.

Radioastronomy Centre at Ootacamund

A large cylindrical radio telescope, 500 m long and 30 m wide, with its axis in the north-south direction, has been operational since February 1970 at Ootacamund. The telescope is placed on a slope with the northern end higher than the southern such that the latitude of the location, (Ootacamund), is exactly compensated for; thereby the axis of rotation of the telescope coincides with that of the earth. The instrument thus utilizes fully the location of India close to the geographic equator and provides very large gathering power, about 4 times that of the 250 foot dish at Jodrell Bank in England, at relatively low cost. The telescope can be mechanically rotated along its long axis in the east-west direction for 9½ hours per day. The beam of the telescope can be moved in the north-south direction by electrical phasing. The telescope operates in a fixed radio band of 324-329 MHz. It is proposed to add another frequency at about 100 MHz to it. The telescope which was designed and fabricated entirely indigenously is located in a 100 acre site in the picturesque Nilgiri Hills in South India. There is a hostel at the site for visiting scientists.

Radiocarbon Laboratory for Archaeology

The Radiocarbon Laboratory of the Institute was set up in 1961 as a national facility for archaeological work. To-date several hundred samples, deriving chiefly from sites in India, and representing the Chalcolithic, Harappan, Neolithic and the Gangetic cultures, have been dated; this represents the only large-scale, precise dating of archaeological samples in India; these dates have been of great help in establishing the chronology of these cultures in India. The errors in the estimation of a date are as low as ± 100 years.

Laboratory for Hydrology

A Laboratory for Hydrology has been set up at the Institute as a national facility. Radioactive tritium, an isotope of hydrogen of mass 3, is used as a tracer for studying the characteristics of water reservoirs below the earth's surface. Other isotopes used for these studies are Si^{32} and C^{14}. The rates of recharge, the sizes of the underground reservoirs, and sources of water in the waterlogged areas are some examples of problems which are being studied in this laboratory. Collection of surface and subsurface water samples from several areas in India where such hydrological information is of vital importance was begun in early 1961. Important results already obtained relate to the rather old character of most of the ground water reservoirs investigated thus far in Rajasthan, Gujarat and even in the Gangetic plain.

SUPPORTING FACILITIES IN THE INSTITUTE

To support the research activities of the Institute the following general facilities are available: (i) Library; (ii) Workshop; (iii) Glass Shop and Precision Instruments Section; (iv) Cryogenic Facility; (v) Electron Microscope and X-ray Units; (vi) Irradiation Facility; (vii) Laboratory for Chemistry involving radioactive materials and (viii) Lecture and Conference Facilities.

Library

The Institute has a well equipped library which functions on an "open access" system. The Library is open for 15½ hours on working days and for 8 hours on closed Saturdays, Sundays and holidays. The Library has about 25,000 books and 17,000 volumes of periodicals. 825 periodicals are received by subscription and as gifts or by exchange.

Workshop

The Institute has a well equipped workshop for the design, fabrication, and where necessary the manufacture, of all mechanical equipment needed for its research activities, as well as for maintenance of the buildings and services (air conditioning, electricity, water supply, vehicles, etc.). The workshop works in two shifts; it also executes work orders from BARC for the development of special items of equipment, particularly those relating to the Technical Physics Division. The workshop has conducted an apprentice training school under which a large number of apprentices were given an intensive two-year course in worksho technology.

Glass Shop

The Institute has a glass shop and precision instruments section in which highly skilled work is carried out in areas involving a combination of materials and needs: glass, metals, plastics, mechanical, electrical and electronic systems. In addition to meeting the routine requirements relating to glass and quartz apparatus, it has specialised in the fabrication of high vacuum stopcocks, ground-glass joints, glass-metal seals, dewar flasks, liquid helium cryostats of glass and quartz, etc. saving considerable imports. The shop carries out work for other scientific institutions in the country whenever necessary.

Cryogenic Facility

An Arthur D. Little Collins Helium Liquefier, (8 litres per hour), and a four-stage Phillips Nitrogen Plat, (30 litres per hour), are available for cryogenic work. The group working at the plants also undertakes service and development work in cryogenics.

Electron Microscope and X-ray Units

An electron microscope, (Phillips Type E-M200), capable of a resolution of 8 Å and magnification of 200,000 x, and a Siemens Crytalloflex-4 X-ray unit with back reflection camera and Debye-Scherrer powder camera are available for crystal structure studies, and for investigating biological and metallurgical specimens.

Irradiation Facility

For studies involving irradiation with electrons and gamma rays, the facilities available are a 3.5 MeV electron linear accelerator, designed and fabricated at the Institute, which has been in operation for several years, and a 3000-curie Co^{60} radiation source which was recently installed.

Hot Laboratory

The hot laboratory is used for the storage of highly radioactive materials, for enforcing health physics procedures, and for the preparation and purification of different radioactive isotopes and sources; the latter work involves methods such as ion exchange, solvent extraction precipitation and electrodeposition. By confining all storage and chemistry involving highly radioactive materials to the hot laboratory, it is feasible to reduce the chance of radioactive contamination in the main laboratory areas, and to carry out work in fields such as in isotope geophysics involving extremely low levels of activity.

Lecture and Conference Facilities

The Institute has 4 lecture halls and several seminar rooms in regular use. These have been used in the past for international and national conferences and symposia, held under the auspices of the International Council of Scientific Unions, International Mathematical Union and International Atomic Energy Agency on the one hand and the Department of Atomic Energy, Bhabha Atomic Research Centre and the Institute on the other.

EDUCATIONAL PROGRAMMES

The Institute is "a constituent recognised institution" of the University of Bombay. In the letter dated 12th March, 1944 that Dr. Bhabha had written to Sir Sorab Saklatvala, Chairman of the Sir Dorabji Tata Trust, he had explicitly stated:

"The Institute would be affiliated to the Bombay University".

A member of the academic staff can register himself at the University of Bombay, (as also at many other Universities in India), for a post-graduate degree by research, and work under the guidance of a scientist in the Institute who has been recognised by that University as a teacher for that degree. The Institute is recognized by the University of Bombay for post-graduate research in mathematics, physics, (experimental and theoretical), and molecular biology; subjects to be added shortly for this purpose are: chemical physics and computer sciences.

Regular courses of lectures are conducted at the Institute, both in mathematics and physics, at pre-doctoral and post-doctoral levels; younger scientists at the Institute, particularly those registered for post-graduate degrees by research, have to take these courses. Most Indian Universities do not have any course requirements for the Ph. D. degree. The Institute has taken the viewpoint that even if this is so, it would like to ensure that those who obtain degrees through work carried out at the Institute have a broad high-level training which is so essential for scientific research today.

The main energies of the Institute have no doubt been directed towards creative research in the Schools of Mathematics and Physics, and in providing the necessary background for its staff engaged in this research, through colloquia, seminars, programmes of lectures given by staff of the Institute as well as by eminent scientists from abroad who are invited to spend extended periods of time at the Institute. In addition, the Institute is keenly alive to its responsibilities as a constituent institution of the Bombay University and the need to participate in the teaching programme of the University for its students. The School of Mathematics actively collaborates with the University of Bombay in the latter's Centre for Advanced Training and Research in Mathematics; senior staff members of the School of Mathematics are deputed to the University for this purpose. The School of Physics participates in the teaching programme for the physics students of the Bombay University at the M. Sc. level. Members of the Institute serve on the Bombay University's Academic Council and

and Boards of Studies in Physics and Mathematics.

106 students have so far got their Ph. D. degrees and 27 their M. Sc. degrees, (in Mathematics and Physics), by working at the Institute. Currently 72 students are registered for the Ph. D. degree and 16 for the M. Sc. degree. 48 staff members are recognised guides for guiding students for the Ph. D. degree and 8 for the M. Sc. degree.

The School of Mathematics has conducted several Summer Schools intended mainly for University teachers. It organised Conferences on Mathematical Education in South-East Asia in 1956 and in 1960.

Members of the School of Physics have been delivering courses of lectures and acting as tutors at the post-graduate Training School, (for physicists; chemists; mechanical, electrical, chemical and tele-communication engineers, and metallurgists), run by the Bhabha Atomic Research Centre in Bombay.

The School of Mathematics and Physics conduct each year several Summer Schools, in Bombay and outside Bombay, on different topics of current research interest. These Summer Schools are well attended by scientists from institutions from all over India.

Programme Relating to Science Education in Schools

Entirely on a voluntary basis, Institute scientists have been working on programmes for the improvement of science teaching at the school level. A start was made by organizing lectures and lecture demonstrations for students at a few local schools; this was arranged in co-operation with concerned teachers. Again, in association with the Bombay Municipal Corporation, Institute scientists have been participating in a teacher training workshop, as well as in organizing an annual Inter-School Science Exhibition; 2 of the latter have been held so far, in February 1970 and February 1971, each involving about 50 schools. It is fully realised that improvements in the teaching of science at the school level have to be effected by the teachers themselves, and that research scientists, who are not experts in these areas, can only provide administrative support and scientific expertise; accordingly, monthly seminars have been arranged for school teachers to discuss teaching aids and teaching methodology with Institute scientists; as also monthly lecture demonstrations at the Institute for students; the latter have been very popular, and ways and means of using the Homi Bhabha Auditorium for this purpose are being explored in order to cater to much larger numbers. A regular teaching workshop on an annual basis for Municipal School Teachers has also been organized since 1970.

PUBLICATIONS

The Institute publishes, on a regular basis, books, pamphlets, lecture notes and proceedings of conferences, symposia and summer schools. These publications can be classified as follows:

(1) Lecture notes in Mathematics and in Physics (87 volumes have

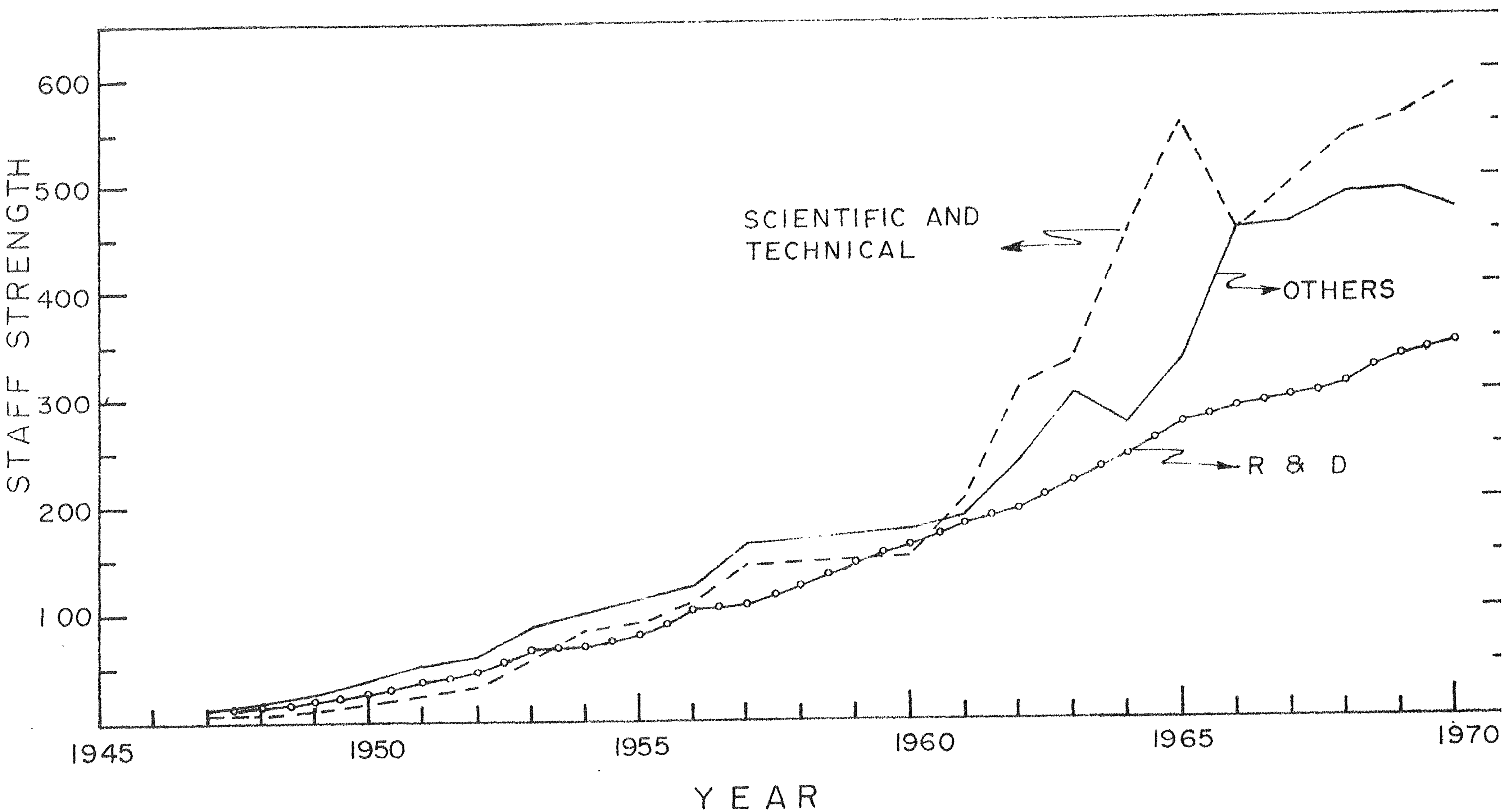
been issued); (2) Monographs in Mathematics and Physics (2 volumes have been issued); (3) Studies in Mathematics and Physics (7 volumes have been issued); (4) Mathematical pamphlets (4 pamphlets have been issued); (5) Books in the series 'Frontiers in Physics' published by W.A. Benjamin Inc., New York (1 volume has been issued); (6) The 1962 Inauguration Lecture Series (4 volumes have been issued); (7) Proceedings of Conferences and Symposia (6 conference proceedings and 1 symposium proceedings have been issued).

The School of Mathematics was responsible for bringing out a facsimile edition in two volumes of the published notebooks of Srinivasa Ramanujan. In addition to the Lecture Notes, Studies in Mathematics and Monographs, the School of Mathematics has also brought out the lectures given at summer schools (intended mainly for university teachers and research scholars), thus meeting the need for low priced text books in the country on these subjects. So far the following four titles have been published as pamphlets: Riemann Surfaces (1963), Algebraic Topology (1964), Galois Theory (1965) and Algebraic Number Theory (1966).

Over 1800 research papers have been published so far by Institute staff members in various scientific journals of repute.

STAFF

The Institute has a total staff of 1406, of whom 350 are qualified


STAFF STRENGTH
600
500
400
300
200
100
1945
1950
1955
1960
1965
1970
YEAR
SCIENTIFIC AND TECHNICAL
OTHERS
R & D

scientists and engineers concerned with research and development. The growth of staff in various categories, (research and development personnel, supporting scientific and technical staff, and other staff), over the history of the Institute is shown in the accompanying figure. Significant changes that have occurred through the 1960s, as can be seen in the figure, are related to the setting up of the National Computation Centre, the setting up of the large Ooty Radio Telescope, and the taking on of several projects of national importance on the basis of contracts awarded to the Institute. For all of these tasks, there has been need for an appreciable number of staff in the supporting categories.

A staff member is normally appointed on probation for one year, after which he or she may be given continuing appointment up to the age of 58; extensions beyond this age are individually considered by the Council. All members of the academic staff engaged in research and development are, however, appointed on a contract, which is normally for a period of 5 years. There is at present no member of the academic staff who is on a regular continuing appointment.

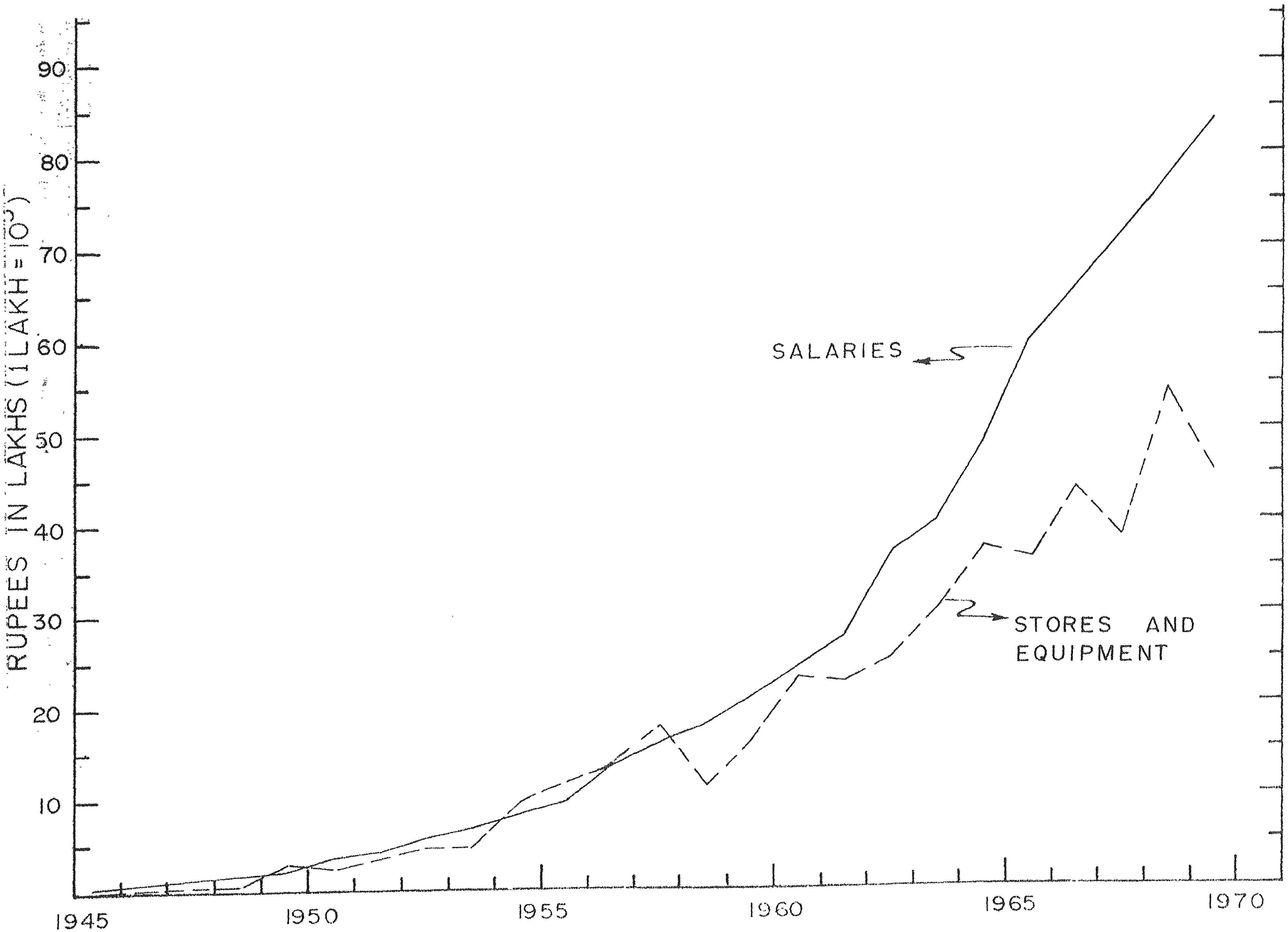
No institution can expand on a continuing basis; and a major problem that every institution faces is that of saturation, and as a result, not being able to provide opportunities for fresh and vital inputs; there is also the problem of the biological aging of the institution. As a partial solution to this problem, the Institute has reduced the in-take of staff who would continue on a semi'permanent basis even on a contract system, and instead has been providing a large number of visiting appointments at various levels for a year at a time, which would normally be for 3 years and never more than 5 years. This results in a flow of scientists through the Institute; and out of these the Institute can always select a few outstanding persons for longer term appointments at the Institute.

FINANCIAL ASPECTS

The accompanying figure shows the actual expenditure each year between 1945 and 1970 under the two major heads of the Institute's budget: salaries, and stores and equipment. These two heads constitute more than three quarters of the annual budget of the Institute, excluding non-recurring large individual items of expenditure e. g. construction of buildings, purchase of major pieces of equipment such as computer systems etc. ; in this figure expenditure on the purchase of the CDC 3600-160A computer system in 1964, and on considerably enlarging the system in 1969, as well as the expenditure on the cylindrical radio telescope project at Ootacamund, (1966-1970), have been excluded.

There has been rather strict control in the Institute on the growth of staff, particularly in the lower supporting and auxiliary categories. The basic philosophy has been that as much as possible of the budget should be available for actual research and development activities, and for the training of scientists.

A characteristic feature in the development of the Institute over the


RUPEES IN LAKHS (1 LAKH = 10^5)
90
80
70
60
50
40
30
20
10
1945
1950
1955
1960
1965
1970
SALARIES
STORES AND EQUIPMENT

past few years has been the acceptance of contracts from several government agencies; these are additional to the funds received on an annual basis from the Government of India through the Department of Atomic Energy. These contracts have been of different types: in some cases they provide only for purchase of the stores and equipment needed for the Institute scientists to develop know-how concerning a piece of equipment or process; in other cases, the contracts also provide for the recruitment of project staff to execute the tasks assigned. Funds received on the basis of such contracts are now getting to be of a magnitude comparable to the annual budget of the Institute. Contracts accepted so far cover applied areas in computer sciences and technology, instrumentation, cancer survey, etc.

ADMINISTRATION

The administration of the Institute is carried out through sections concerned with specialised areas of activity: accounts, purchase, stores, establishment, public relations, filing, general administration, transport, security, cosmetic maintenance, canteen, parks and gardens; the technical maintenance services (which deal with electrical, air conditioning, civil engineering aspects), come under a technical Engineering Services Committee. In addition to these sections which are concerned with the general administrative aspects of the Institute as a whole, there are administrative offices attached to each of the Schools of Mathematics and

Physics; and further secretarial staff is attached to each of the active groups. All of this is in the normal pattern of administration. What is particularly relevant is the clear emphasis and understanding that the administrative structure is to be regarded as a supporting aspect, to enable scientific research to be carried out with the greatest efficiency; administration is not an end in itself in the Institute, nor is it a dominant element. It is the administrative sections which have to interface with the outside world of banks, suppliers, travel agents, customs, government departments and so on; and most of the delays that occur appear to be at this interface; in the purely internal administrative aspects of the Institute, efficiency is high, certainly compared to anything else that one normally encounters in the country: for example, great emphasis is laid on cleanliness of the buildings; the entire cleaning is carried out during the night to avoid inconvenience; the accounts of the Institute have always received very favourable comments from the auditors; whilst maintaining strictly all proprieties, appointments can in general be made in the Institute faster than in any governmental or government supported autonomous institute in the country. Dr. John Mathai, Professor R. Choksi and Shri E. C. Allardice gave Homi Bhabha all the necessary advice and support in the early days of the Institute to establish the foundations of this administrative structure.

BUILDING ACTIVITIES

An important phase in the construction of the permanent buildings of the Institute at Colaba was completed by the end of 1961; and it was to mark this stage in the history of the Institute that a formal function was arranged on January 15, 1962, when Prime Minister Jawaharlal Nehru inaugurated these buildings before a large and distinguished gathering. It is worth emphasising that the building activities of the Institute did not stop at that stage; and have been proceeding on a steady basis even since then. In particular, under the auspices of the Institute, more building construction has been carried out, in terms of money spent, since 1961 than during the entire period before. The construction carried out includes: (i) the 1036-seating Homi Bhabha Auditorium and Museum Complex; (ii) two floors on 'B' Block, one to accommodate the Molecular Biology Group, and the other for the Cosmic Ray Group for its high altitude programmes based on the use of nuclear emulsions and electronic detector systems; (iii) the preparation of the launch ground and the construction of the balloon production facility and laboratory-cum-hostel complex of the National Balloon Facility at Maula Ali in Hyderabad; (iv) landscaping of the $\sim 11^{\circ}$ north-south slope at the Fairlawns site for setting up of the Ooty Cylindrical Radio Telescope, and the construction of the laboratory and hostel buildings there, as well as all other site facilities such as approach roads, water, electricity, etc. Additionally, two buildings in the Colaba Housing Colony have been put up; a 10-storeyed 450 feet long B1 Block, with 99 flats, in which most of the senior staff members of the Institute live; and the E1 Block with 124 single rooms and 16 efficiency apartments, which will be ready for occupation during summer 1971. The Colaba Housing Colony is owned by the Department of Atomic Energy but the Institute has been assigned responsibility for all aspects relating to the layout of buildings, architectural and engineering design, award of contracts, and supervision of construction.

In order to handle these aspects, the Institute has a small cell consisting of an Institute Architect and a Building Project Officer with their staff. All the members of this cell have been very kindly placed on deputation with the Institute by the Architecture and Civil Engineering (A. and C. E.) Division of the Bhabha Atomic Research Centre; they work under the guidance of senior staff of the A. and C. E. Division at Trombay. This cell deals with all aspects of building construction work; conceptual design, architectural drawings, detailed structural engineering designs, services (electrical, airconditioning, public health, etc.), and implementation of construction. This group is currently engaged on a multistoreyed building with a total floor space of 100,000 sq. ft. within the Institute compound which is primarily needed for a major computer centre. By having such a building project cell in the Institute carrying out feasibility and design studies it has been shown that there have been significant economies compared to a situation where outside consultants have to be engaged; this is of course related to the existence of tasks on a continuing basis on which such a group can work.

ENVIRONMENT

The Institute, in many respects, reflects the personality that was Homi Bhabha. He was deeply interested in science and his greatest intellectual achievements were scientific; and the prime objective and characteristic of the Institute is scientific research. But Homi Bhabha was also interested in the many other facets which make up a complete life: music; architecture; painting and sculpture; landscapes, gardens, trees and flowers; good food; international friendship. His interest in each one of these was deep; he was also a practical person; and he gave practical shape to these interests. All of this can be seen reflected in the Institute.

Gardens

The gardens of the Institute were carefully planned out. What was originally a site for coastal batteries was converted into a large expanse of green lawn and a small casuarina forest, both right on the sea front; with trees carefully located - some in their original places and others transplanted; with herbaceous borders; and a large car park for the Auditorium and Museum complex in which the ugliness of metal and chromium, which is the main characteristic of a large assembly of modern cars, is hidden by high hedges.

Art Collection

Over the past two decades, the Institute has regularly bought paintings. Many of these have been bought from artists exhibiting for the first time and at a relatively small price; but with discriminating taste and good artistic judgement, it has been possible to identify artists who had potential for real creativity. And thus the Institute collection, (at present consiting of about 230 works of art), has grown to be one of the major collections of contemporary Indian art existing today. Indian art seen at the Institute is contemporaneous with its science; both cover the past quarter of a century of Indian creativity. There are a few exceptions; the head of Albert Einstein bought by Homi Bhabha from Sir Jacob Epstein; the Rajasthan temple pillar (9th century A. D.); several stone pieces of Chola period from South India (10th century A. D.), notably a large "Vishnu"; and wood carvings from Gujarat and South India. These works of art adorn the corridors, office rooms, museum area and the grounds of the Institute. And one does not feel the existence of any so-called "dichotomy of the two cultures".

With the commissioning of the Homi Bhabha Auditorium, music, dance, films and drama, have also become part of the environment of the Institute.

International links

From its early days the Institute has had a programme of inviting scientists from within the country and from abroad, to participate in the work of the Institute. Some of the very distinguished names in the world in mathematics and in physics figure in the list of visitors to the Institute. Many of them have stayed at the Institute to give courses of lectures, others to participate in summer schools which are organised on a regular basis, and yet others to work on collaborative experimental programmes. With regard to the latter, the Institute has had close relationships with several Institutions abroad. Some of these links are perhaps worth recording here: between the Geophysics Group and the Scripps Institute of Oceanography, La Jolla; between the Nuclear Physics Group and the Institute of Theoretical Physics, Copenhagen; between the Cosmic Ray Group and the University of Bristol, England, the University of Durham, England, the Danish Space Research Institute, Copenhagen, the Osaka City University, Japan, and Nagoya University, Japan, and the Smithsonian Astrophysical Observatory, USA; between the Basic Dental Research Unit and the National Institutes of Health, USA, and the Royal Dental Hospital, Copenhagen; and many others. The Institute has received great co-operation from a variety of high energy accelerator laboratories in the world, notably from CERN in Geneva, and from the Argonne National Laboratory, USA, in connection with nuclear emulsion and bubble chamber experiments. Two major international programmes of balloon flights were carried out from Hyderabad, one in 1961 and the other in 1965. The School of Mathematics has close links with many schools abroad, particularly in France, Germany, England and USA. The Institute has the privilege of having amongst its Honorary Fellows outstanding scientists from all over the world. The Institute has arranged many international conferences in different areas of interest to it; the earliest of these was the 1950 Conference on Elementary Particles, held at the Old Yacht Club building.

The primary aim of the Institute has been to carry out fundamental research; this activity is an international one. The work done here has to be judged on international standards. And the Institute has thus to be very much part of an international scientific community; the links between the Institute and institutions abroad, as well as between scientists here and those abroad are characteristic of this.

PHILOSOPHY OF GROWTH

Programmes built round men

No organisational chart of the future development of the Institute was submitted either when it was founded or later. The philosophy has always been to support ability whenever it has been found in the fields of work directly covered by the Institute or in related areas. In his letter to the Sir Dorabji Tata Trust, dated March 12, 1944, Homi Bhabha had pointed out that the philosophy underlying the Max Plank Institutes in Germany was: "The Kaiser Wilhelm Society shall not first build an Institute for research and then seek out the suitable man, but shall first pick up an outstanding man and then build an Institute for him".

The growth of the Institute has been based entirely on individuals who entered the Institute as students and developed through the programmes here into scientists of standing, or selected scientists working abroad who wanted to return to India to carry out scientific work here; two new areas, molecular biology and radio astronomy were recently developed on the basis of scientists trained and working abroad, who wanted suitable opportunities to work in India and who were willing to join the Institute.

In order to understand the significance of this philosophy, one has to compare the alternative normally practiced in India. In this alternative areas of work are designated and staff positions advertised, indicating the job specifications and qualifications for intending candidates. A selection committee then chooses from among those who apply. Unless the quality of those who apply is really poor, the normal tendency is to appoint the best among those available. Posts thus get filled, with the best available at an instant of time, rather than the best available over a period of time; the Institute has believed in choosing the latter category by a conscious search for in the case of scientists and engineers engaged in research and development. The normal method of recruitment is adopted for all other categories of staff.

In selecting new areas of work at the Institute, in addition to the philosophy of growing these round men of high quality, close attention is also paid to the manner in which they would integrate with the rest of the ongoing research at the Institute. This is to ensure that with the minimum additional investment one obtains the maximum return. Further it leads to the development of an interactive atmosphere which is conducive both to the growth of that which exists as well as that which is to be grown.

Philosophy of self-reliance

The Institute was founded with the objective of providing opportunities for scientists to work in the frontier fields of modern science. It was realised right at the beginning that this would involve the development and use of highly sophisticated techniques. Equipment for this type of work would clearly not be available in the country and, therefore, would either have to be imported or be made at the Institute. Whilst imports would be fully justified in the case of individual pieces of equipment that could be used for a wide range of programmes, in a variety of ways and for extended periods of time and, therefore, could be considered as basic or common facilities, this would not be the case for items required on a continuing basis in large quantities.

It was on this basis that the Institute bought the following major pieces of equipment as large scale facilities; the CDC 3600-160A Computer System; the 1 MeV Cockcroft-Walton High Voltage set; the Siegbahn-Slätis

Intermediate Image β-ray Spectrometer; the Liquid Nitrogen and Liquid Helium Plants; the Varian High Resolution NMR Spectrometer; large Multi-channel Analysers; the Phillips Electron Microscope, etc. Each of these has been used very heavily, considerably modified over its life-time and maintained and serviced by technical staff of the Institute.

On the other hand, for much of the work of the Institute, the Institute had to build the equipment it has needed and for this to create a large and highly competent base of technical personnel in the broad areas of electronics, high vacuum, radiation detectors, mechanical engineering, chemical techniques, etc.

This can be seen from the experience from its earliest days. For experimental programmes in the areas of nuclear physics and cosmic rays it was essential to have radiation detectors, particularly counters of various types. One of the earliest activities of the Institute was, therefore, work relating to the development and production of counters of various types. This straightaway meant the setting up of a glass blowing and vacuum facility. The use of these counters as radiation detectors involved electronic units of various types, (scalers, power suppliers, etc.); and these were then designed. None of this work started from scratch; the objective was to develop and have available these techniques as rapidly as possible, and full advantage was taken, of contemporary knowledge in this field elsewhere in the world, some of it obtained by sending Institute staff to the appropriate places for training. As soon as the Atomic Energy programmes started to grow, counter systems and associated electronics were required in fairly large quantity for surveys for atomic minerals, for health physics and for nuclear physics experimentation in general. The Institute, therefore, set up a "Development and Production Unit" for pilot plant production of various required units. When this became a fairly large activity, DPU was transferred to the Atomic Energy Establishment at Trombay that had just then been set up to be a part of its Electronics Division. At Trombay, the Electronics Division grew rapidly; and within a decade, when it was clear that, in scale and scope, further growth would be well beyond what would be appropriate at a research and development organization, the production activity was transferred to Hyderabad to become a public sector electronics factory called the Electronics Corporation of India Limited.

In similar fashion, the growth of the Technical Physics Division at Trombay started with initial work at the Institute on mass spectrometers, vacuum systems and radiation detectors such as scintillating plastics and crystals, etc. Today the Technical Physics Division is one of the very productive and competent groups of the Bhabha Atomic Research Centre.

In the more recent past one can cite many examples which relate to the philosophy of self-reliance and the building up of equipment and facilities here on indigenous basis. The National Balloon Facility is now a major capability for carrying out research close to the top of the earth's atmosphere; this was a programme entirely developed at the Institute.

The large cylindrical radio telescope at Ootacamund was conceived, designed and entirely fabricated indigenously. Various types of spectrometers (for wide-line magnetic resonance, electronic spin resonance, etc.) were constructed locally for programmes in solid state physics and chemical physics. Several major precision instruments have been constructed at the Institute for work in nuclear physics, such as a single-gap high resolution magnetic beta ray spectrometer; a six-gap spectrometer with 12% transmission, and lithium drifted germanium detectors for gamma spectrometry. A time sharing facility with the CDC-3600 computer, involving four remote terminals was designed and implemented, including the total software needed for this. These are a few examples from different areas of work at the Institute; this list is by no means comprehensive. Efforts in this direction permeate the activities of all the groups at the Institute.

Competence building in areas of national relevance

As a result of the research carried out in the Institute, a great deal of competence has been built in many areas of national relevance. It would be appropriate to cite a few examples to illustrate this. Work in the field of radio astronomy and the building of the very large cylindrical radio telescope at Ootacamund has created the base for further work relating to steerable antennas needed for communication system and radars as also relating to low noise receiver systems. Work in the field of geophysics based on the use of radioisotopes as tracers, has enabled the setting up of national facilities to tackle problems relating to archaeology, hydrology, meteorology, and oceanography; hydrological work is being carried out using three isotopes, tritium, silicon-32 and carbon-14; work on Indian archaeological horizons is being carried out using radio-carbon, neutron activation and metallurgical analysis; work in meteorology on the Indian monsoon is being carried out using a natural radionuclide radon. Competence in the area of computer sciences and technology was acquired through the design and fabrication of the first electronic digital computer in India (TIFRAC); this competence was immediately made use of for the maintenance and utilisation of the CDC-3600 computer system; this was followed by the design and building of an on-line computer OLDAP and several other hardware configurations. As a result of all this and the considerable, wide-based, competence that it has given rise to, the Computer Group of the Institute is associated with a major programme of computer manufacture (of systems that can be used as real time, on-line or general purpose systems) by the Electronic Corporation of India, Hyderabad. The major responsibility for the development of appropriate software is with the Institute. Further, in the Computer Group, methods of systems analysis, based on the availability of a large computer system, have been used for a variety of problems relating to the space programmes, transportation systems, electrical power networks including nuclear stations, etc. Core groups in areas of microwave engineering, solid state electronics, nuclear electronics etc. came into existence on account of research activities at the Institute, where all these techniques have a significant role to play. In view of the importance of these sophisticated technologies, these groups have been considerably enlarged and this process was rendered easy since a nucleus already existed. And it is these groups which are now working on the basis of contracts awarded by Government agencies for the development of active and passive microwave devices, test equipment, parts of radar systems and so on.

TRIBUTE BY THE INSTITUTE TO HOMI BHABHA

Homi Bhabha died on 24th January, 1966, in an airplane crash on Mont Blanc, while on his way from Bombay to Geneva en route to Vienna where he was to attend meetings of the International Atomic Energy Agency. His passing away, and the manner of it, was a blow of a major magnitude to the Institute.

The greatest tribute that the Institute can pay to its founder is no doubt by fulfilling the expectations that he had of it. But the Council felt that it would also be appropriate for the Institute to pay its tribute in several immediately tangible ways.

It was decided to name as the Homi Bhabha Road the main concrete approach road to the Institute. Homi Bhabha was personally responsible for the alignment of this road and for the avenue of trees, the gulmohurs, the barringtonas, the peltophorums, and son on, that line it.

It was also decided to name, after Homi Bhabha, the Auditorium and Museum Complex that was under construction. Homi Bhabha had conceived of this complex and its basic design; he had obtained the necessary financial and administrative sanctions for constructing it. At the time of his death, work on it was in full swing; the basement had been completed, as also a great deal of the structural work. The auditorium was formally inaugurated and named the Homi Bhabha Auditorium by Prime Minister Shrimati Indira Gandhi on November 9, 1968; the first lecture to be given in it was the Homi Bhabha Memorial Lecture by Professor C. F. Powell on "The Aims and Role of Science in our Time".

On the occasion of the Silver Jubilee Year 1970-71, Council also decided that the Institute should hereforth celebrate 30th October each year, the birthday of Homi Bhabha, as Founder's Day. On the occasion of the first Founder's Day on 30th October, 1970, the Institute, in honouring Homi Bhabha, decided to highlight a facet of his life, which was so important to him - his love for trees, flowers and gardens; and in doing this also to say "thank you" to the city of Bombay in which the Institute had grown so happily. The Institute presented to the City of Bombay several hundred trees for planting on Marine Drive (Netaji Subhas Chandra Bose Marg). These trees, called Barringtonia Speciosa grow well near the sea, and have the ability to withstand the salt air and high winds characteristic of the Indian monsoon; after Homi Bhabha's death, these trees were grown in the gardens of the Institute for four years, close to the sea, with this specific objective in mind, of presenting them to the City of Bombay in honour of his memory.

CONCLUDING REMARKS

The basic aim of the Institute has been to be a Centre of Excellence in the fields in which research activity is carried out at the Institute. The implementation of this aim is important in several different ways.

Firstly, it provides a place where potentially brilliant scientists of the country can find opportunities to participate in first rate research, to partake in the excitement of new discoveries at the frontiers of human knowledge, and to become deeply motivated in the process; whilst they are engaged in research they still remain emotionally and culturally part of the country and its aspirations; and such roots add greatly to stability, mental satisfaction and motivation. If there were no such places in the country, these scientists would look abroad for their opportunities; and having spent many years abroad, perhaps during the most impressionable periods of their lives, and with no satisfactory place to come back to, in order to continue such activity, these potential leaders would be permanently lost to the country.

Not only is the research of such men important; equally so is the role that they might play in the broader context of national development. Whilst it is true that some leaders in science confine themselves to their personal scientific interests, many more, particularly if they are deeply moved by the environment in which they live and work, find ways of exercising their intellectual abilities and their training in the scientific method, to provide badly needed leadership on a much wider front. Such centres of excellence would constitute islands of self confidence which can be so important in a country struggling to move forward rapidly.

A further important aspect of having such centres of excellence is that those who are trained abroad, especially the ones whom the country would particularly like to have back, can be expected to return only if they are provided opportunities here with work satisfaction.

Homi Bhabha believed, and this Institute shares that belief, that if it could be demonstrated that a country such as India could build institutions which would hold their own place in the world, institutions in which one could have a genuine pride for their quality of achievements and standards, a feeling would be generated that would be of tremendous practical and psychological importance to the country as a whole.

In its quarter of a century of existence, the Tata Institute of Fundamental Research has grown to be a large institution which is known internationally. During this period, it has played an important role in the early stages of the atomic energy programmes in India; and further, has developed viable and self-generating groups in many broad domains of scientific research; these groups provide support for one another and foster interdisciplinary work in areas at the forefront of scientific progress. To achieve this in the conditions which exist in India, it has also been necessary to develop in the Institute considerable competence in areas of applied science and technology.

Over the future the principal task of the Institute will be that for which is was founded, namely, the carrying out of fundamental research, and providing opportunities for young persons of the highest intellectual calibre in the country to train and work in areas at the forefront of human knowledge. At the same time, on account of its size, and the diversity of its interests and available technical know-how, it has started to play a meaningful role both in the field of education and in the field of applied research which has industrial applications. In this manner it is hoped that the continued development of fundamental research at this Institute will have a strong interaction with, and find deep roots in, practical and national problems.

RRD/tka. 30,3,71