REPORT

OF THE

COMMITTEE ON POST-GRADUATE ENGINEERING EDUCATION AND RESEARCH

MINISTRY OF SCIENTIFIC RESEARCH & CULTURAL AFFAIRS

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CHAPTER I

Appointment of the Committee—Plan of Work

1. On the recommendations of the All India Council for Technical Education, the Government of India appointed *vide* Resolution No. 4-4/59-T.5, dated 18th November, 1959, a Committee to make a comprehensive study of the present state of Post-Graduate Engineering Education and Research in the country and to recommend the lines along which further development in the field should be undertaken. The composition of the Committee and its terms of reference are as given below:

Chairman

1. Prof. M. S. Thacker, Secretary to the Government of India, Ministry of Scientific Research & Cultural Affairs, New Delhi.

Members

2. Dr. S. Bhagavantam, Director, Indian Institute of Science, Bangalore.
3. Shri G. K. Chandiramani, Joint Educational Adviser, Ministry of Scientific Research & Cultural Affairs, New Delhi.
4. Shri N. S. Gupchup, Chief Engineer, Hindustan Construction Company Ltd., Bombay.
5. Dr. D. S. Kothari, Chairman, University Grants Commission, New Delhi.
6. Dr. K. S. Krishnan,* Director, National Physical Laboratory, New Delhi.
7. Shri P. R. Ramakrishnan, M.P., Principal, Coimbatore Institute of Technology, Coimbatore.
8. Dr. H. L. Roy, Professor Emeritus, College of Engineering & Technology, Jadavpur University, Calcutta.
9. Prof. B. Sen Gupto, Director, Indian Institute of Technology, Madras.

Member-Secretary

10. Shri P. K. Kelkar, Director, Indian Institute of Technology, Kanpur.

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*Dr. K. S. Krishnan passed away on 14th June, 1961.

Shri K. N. Sundaram, Assistant Educational Adviser, Ministry of Scientific Research & Cultural Affairs, acted as the Joint Secretary of the Committee.

Terms of Reference

(a) To visit the various centres of Post-Graduate Studies and Research.

(b) To evaluate the progress made so far in the development of Post-Graduate Courses and Research in Engineering and Technology.

(c) To examine the difficulties experienced and to suggest modifications and improvements in the existing facilities.

(d) To examine the advisability of concentrating Post-Graduate courses in selected institutions for better progress.

(e) To consider the manner of achieving close co-ordination of Post-Graduate Training and Research with the major developmental and engineering schemes of the country.

(f) To report on all other aspects of improvement and development of Post-Graduate courses.

2. The Committee held its first meeting on the 17th January, 1960 in New Delhi, when its plan of work was discussed. In order to facilitate the discussions, the Chairman circulated before the meeting a note (Appendix I) explaining the background against which the entire question of Post-Graduate Training and Research in Engineering and Technology should be considered. The Committee also discussed the guiding principles for its programme of work, including visits to institutions and discussions with professors and other experts.

3. At the outset the Committee considered it necessary to visit a fairly large number of institutions to make an on-the-spot study of the present state of technical institutions and the manner in which post-graduate courses and research had been organised. Such visits also enabled the Committee to discuss with the heads of the institutions and their staff various aspects of post-graduate education and research.

4. The visit to the institutions consisted of two parts. The first was a discussion with the heads of the institutions and professors on the general aspects of post-graduate education and research and problems or difficulties faced by each institution individually. The second part was an inspection of the departments and laboratories in order to make a factual study of the position in each institution and discussion with individual professors or teachers on specific

points. Over 40 institutions were visited by the Committee in the course of its 18-month work.

5. In order to facilitate the work of the Committee, both during its visit to the institutions and its subsequent discussions, a comprehensive questionnaire was issued to the institutions to obtain factual information regarding the present state of post-graduate education and research in various fields and the scope for further development. The information collected was analysed and made available to the Committee.

6. On the 24th October, 1960, the Committee took advantage of the presence in Delhi of Vice-Chancellors, Directors of Technical Education in the States and Principals of technical institutions in connection with the introduction of the Metric System, to have a free exchange of views regarding the entire set-up of post-graduate courses and research and the problems of further development in the field. The important aspects discussed included the nature and scope of post-graduate engineering education; development of engineering research in universities and other institutions; provision of scholarships, fellowships etc. for post-graduate students and research scholars; advanced training of members of staff; integration of basic sciences in engineering studies.

7. In the presentation of the Report, the Committee has given due consideration to the views expressed by the Vice-Chancellors, Directors of Technical Education and Principals of technical institutions as also by individual professors. The views expressed by them as also the suggestions received from various sources have been of great value to the Committee in its deliberations.

8. The Committee was gratified to note that in all the institutions visited keen interest and enthusiasm were evinced in post-graduate engineering education and research and the Committee had an opportunity to elicit a complete cross-section of opinion and information at the actual working level.

9. A list of institutions visited by the Committee is given at Appendix II. The Committee would have liked to visit all the institutions in the country but could not do so owing to the limited time available.

10. The Committee wishes to express its sincere thanks to the institutions, educationists, State Governments, Universities, experts etc. for their valuable suggestions and information. The Committee is also thankful to the institutions for the excellent arrangements made for its visits.

CHAPTER II

General Considerations—Impact of technology on society—Education as the foundation for progress

11. The dominant feature of our times is the vast changes in the social and economic order that are being brought about by the technological revolution started in Europe over a hundred years ago. Centuries of traditions have been or are in the process of being swept away. Ideas, beliefs and values are changing and human society everywhere is not only being transformed but is moving at a fresh pace and there is no country that is not being affected by the technological revolution.

12. Change in the social order is only one aspect. The other and equally important is the change in the economic order. Countries that were, till recently, under-developed are moving fast towards economic development. The means to a better life in the form of food, clothing, housing, health etc. are being brought nearer to the people all over the world. Irrespective of the particular system of economic and social order in every country, science and technology are playing a dominant role in the everyday life of man.

13. The most important force behind the present rapid transformation in all industrially advanced countries is a climate in which the pursuit of science and technology is promoted on the widest scale possible. Conditions exist in those countries in which disciplined and organised scientific and engineering activity is sustained on a national level. An industrial revolution derives its energy from a psychological revolution, and the basis of all psychological revolutions is organised educational effort at all levels. The broader the base of educational development and the more intensive the national effort towards it, the faster is the rate of progress of the country in science and technology.

14. The most significant aspect of our present-day problems is education in the fullest sense of the term. Education to be effective in terms of a national effort must be dynamic and capable of meeting the challenges of new situations. Inasmuch as these will mainly be the result of scientific and technological advance, education should seek to develop in the students. the scientific temper. Scientific education should be integrated in an organic manner with Secondary

Education. All further education either in science or in technology or in the humanities and social sciences have their tap roots in Secondary Education. The more purposeful Secondary Education is in relation to life, the more useful will advanced education be to the individual and to the society.

15. The Committee notes that Secondary Education in the country is in a process of reorganisation, and wishes to emphasize that in this effort the science content of courses in high schools and higher secondary schools should be increased, and progressively taken to higher levels.

16. As a sequel to the reorganisation of Secondary Education, the first degree courses in engineering and technology are also in a process of reorganisation. On the recommendations of the All India Council for Technical Education, a five-year Integrated Course for the first degree has been accepted generally as the new pattern of engineering education at the undergraduate level. The Committee is of the view that this Five-Year Integrated Course provides a very good opportunity to reorganise the existing degree courses in Engineering and Technology and to enhance their scientific content particularly in the fundamental sciences that form the basis of all advanced technical studies and research. The Committee recommends that this opportunity should be exploited to the fullest so that the prospective candidates for post-graduate studies and research possess a thorough scientific preparation in the physical and mathematical sciences.

17. This reorganisation of first degree courses in engineering and technology would require improvement of science facilities in technical institutions. Full-fledged departments of physics, chemistry and mathematics in the unitary type of technical institutions are necessary. In addition to increasing the science content of undergraduate curriculum these departments would facilitate bringing together of science and technology, a much needed combination for engineering research. In the universities that have technological departments, the times demand establishment of closer links between the science faculties and the technological faculties.

18. Although the establishment of full-fledged science departments in their own fields and for that purpose wherever conditions are purpose of improving the science content of technological courses the scope of work of the science departments should not be restricted. The departments should have full opportunities of advancement in their own fields and for that purpose wherever conditions are satisfactory, the institutions concerned should be permitted to enrol students for Master's Degree and Doctorate in their own fields. That

will enable the science departments to have broader objectives than would otherwise be possible from a purely functional point of view of the technological curriculum. At a few selected institutions the universities may also consider the question of permitting them to conduct Bachelor's Degree Course in Science on a limited scale.

19. In view of the fact that scientific studies at an advanced level are a very good preparation for engineering research, design and other types of original work, the Committee recommends that at a few selected institutions provision should be made for conducting special first degree courses in engineering of about three years' duration for those candidates who have graduated in physics, Chemistry or mathematics. The actual details of the special course and how and where that should be organised may be examined by the All India Council for Technical Education.

CHAPTER III

Present position and problems of Engineering Education

20. A historical perspective is necessary for a correct assessment of the present state of technical education in the country and the problems facing us in the field. Technology in the modern sense of the term made its first appearance in the country in the 19th century, when it was applied to communications, irrigation works and building construction that were of importance at that time. Before World War II, there were only about 11 engineering colleges in the country that offered degree courses in the three main branches of engineering viz. civil, mechanical and electrical. Facilities in other fields as for instance, chemical engineering, metallurgy, mining etc. were extremely limited and only a few institutions offered these subjects. Although some engineering colleges in the country are more than 100 years old, technical education remained almost static for a long time and this condition is reflected in a large measure in the general lack of scientific and technological progress of the country.

21. The organisational aspects of technical institutions also left much to be desired. Very little contact existed between technical institutions and science institutions and even where technological departments existed in universities, there was little contact between these departments and the science faculties. The universities to which the institutions were affiliated were concerned mainly with the curriculum and syllabus of studies and examinations for the award of degrees. The manner of conducting the courses, the type of instructional facilities required and other aspects were left entirely to the institutions concerned. The main emphasis was on the professional and vocational aspects of training. Fundamental sciences, the scientific method, laboratory techniques of measurements, analysis and experimentation were not given their rightful place in the curriculum excepting in a few subjects. In a majority of institutions library facilities were also of a very limited nature.

22. The staff structure also reflected the limited scope of work of the institutions. The number of Professorships was small, usually three or four relating to the main fields of engineering. There was no provision either for increasing the number of Professorships according to the developments in particular fields; nor for the flexibility that facilitated the advancement of younger teachers according to their abilities and achievements.

23. Advanced work and research had limited scope, and the staff had little contact with professional or industrial activity in the country. Occasionally engineers from the State Public Works Department were deputed to teach as Professors or Lecturers for certain periods in some institutions. That arrangement, however, did not make for much progress in the institutions. This state of affairs was responsible largely for the lack of initiative on the part of the staff as also lack of proper academic atmosphere in the institutions.

24. In so far as post-graduate courses, advanced studies and research are concerned, facilities were almost non-existent excepting perhaps at an institution or two. Even in those institutions, the provision was limited to a few branches like chemical engineering and chemical technology and electrical engineering.

25. After World War II and particularly in the last ten years there has been almost a phenomenal expansion of technical education in the country. As a result of concerted national efforts made, the number of institutions for first-degree courses increased to 100 with a total admission capacity of over 13,850 students by 1960-61. The number of institutions for diploma courses increased to 196 with an admission capacity of over 26,500 students. This represents more than four-fold expansion at the degree level and seven-fold expansion at the diploma level as compared to 1947.

26. A comprehensive survey of the state of technical institutions in the country was carried out and schemes were formulated for their improvement and development with financial assistance provided by the Central Government. Boards of Technical Studies were set up under the aegis of the All India Council for Technical Education to prepare courses of study in various fields of a suitable standard which could serve as a model for the institutions in the improvement of standards. Four Regional Committees, one for each region in the country, were set up to survey the needs on a regional basis, to formulate and implement development programmes in a co-ordinated manner and to help in the establishment of liaison between industry and technical institutions.

27. The Central Government also undertook to establish four Higher Technological Institutes, one in each region, East, West, South and North. These institutes were to give training to the highest possible grades of technologists. They were to be national institutions provided with all the necessary resources and with full freedom to adapt themselves to the fast changing situations in science and technology. In addition to the training of technical personnel, the institutions should be fountain-heads of scientific and technical knowledge and contribute through research and other activities to the industrial advancement of the country.

28. The first Higher Technological Institute started functioning at Kharagpur in 1951. In the last 10 years, it has been developed for undergraduate and post-graduate courses and research in a wide range of subjects. An important feature of the Institute is the adoption of an integrated approach to the problem of engineering education in relation to socio-humanistic studies, fundamental sciences and the technologies. For all these three components full-fledged departments have been established in the Institute. The Institute has at present on the rolls about 1,600 students in the undergraduate courses and about 160 students in post-graduate courses and research work. The other three Higher Technological Institutes are in the process of establishment at Bombay, Madras and Kanpur and are being planned on the same comprehensive scale as the Kharagpur Institute. When completed, each will be a fully residential institution providing facilities for about 1,600 students in undergraduate courses and 400 students for post-graduate courses and research. While the nature and level of work of all the Institutes is the same, each will pay particular attention to certain special fields of technology that are of importance to the industrial development of the country.

29. The Indian Institute of Science, Bangalore, is another important centre of post-graduate studies in engineering that has been developed since 1946. The facilities offered by the Institute in such subjects as Power Engineering, Aeronautical Engineering, Metallurgy, Internal Combustion Engineering and Electrical Communication Engineering are important. Provision exists at the Institute for the training of over 400 post-graduate students and research scholars in various fields, including fundamental sciences.

30. The experience of the last 10-15 years has demonstrated that given the necessary funds and a central agency that could take a long range view of the country's needs and promote a co-ordinated development, it is not difficult to expand facilities for technical education at all levels. Experience has also shown that a rapid expansion is accompanied by several difficulties particularly in respect of the staff required for the institutions.

31. The problem of shortage of teachers is a complex one. The shortage at present is of the order of 40-50 per cent of the sanctioned strength in the institutions. It is also becoming increasingly difficult to attract persons of high calibre to the teaching profession. These difficulties will be felt even to a greater extent as further expansion of technical education is undertaken in the Third Five-Year Plan. The Committee wishes to emphasize that unless the problem of staff is adequately solved, it will be futile and even

dangerous to expand technical education any further. The foundation for post-graduate studies and research is laid in the first degree courses. If the standard of undergraduate courses falls due to inadequate teachers in the institutions, the foundation becomes weak and progress at the post-graduate level suffers.

32. Equally important is the question of equipping the laboratories and workshops of engineering colleges. A good proportion of the equipment has to be imported but serious difficulties are being experienced by the institutions due to the meagre foreign exchange allotted by the Government for the purpose. The Committee would urge that since the maintenance of correct standards of technical education is of the greatest importance, the Government should assure institutions of the foreign exchange required by them for importing equipment. In order to overcome the present difficulties in some measure, the institutions should produce as many items as possible in their own workshops. The position will ease further if the Model List prepared by the All India Council for Technical Education were made flexible enough to permit the institutions to obtain alternative items of equipment to serve the same purpose.

33. In 1953, the All India Council for Technical Education appointed a standing committee known as the "Post-Graduate Development Committee" to formulate schemes for the development of post-graduate courses and research in our technical institutions. The appointment of this Committee gave an impetus to developments in this field in various institutions. At the outset the Committee defined its objectives as given below:—

(a) Development of facilities for advanced training to produce professionally well-qualified personnel for employment as specialists in certain selected fields.

(b) Development of research facilities to promote engineering research.

34. The Committee suggested that post-graduate courses leading to the Master's Degree should be at least of one year's duration. In addition, practical training for a period of six months should be an integral part of the course. The Committee selected certain institutions for post-graduate development, as also particular fields of study to be assigned to each institution.

35. As regards research, the Committee recommended that this activity should be limited, in the first instance, to encouraging qualified individuals in the institutions to carry out research rather than to establishing research schools. The guiding principle was that the development of research should take place in definite stages over a

period of years by a gradual integration of research units set up especially for the investigation of specific research problems. As the units progressed, their fields of work will enlarge and ultimately they will grow into well-established research departments. The primary consideration for the establishment of a research unit should be the availability of expert staff to guide research and provision of facilities in the form of equipment and accommodation.

36. The All India Council for Technical Education and the Central Government accepted the recommendations made by the Post-Graduate Development Committee from time to time and sanctioned financial assistance to the institutions concerned for post-graduate courses and research. In the last eight years, a number of institutions have been included under the scheme. There are at present about 29 institutions conducting between themselves more than 70 post-graduate courses. Some institutions have only one or two such courses while the number in others range from 10 to 37. The duration of the courses also varies from one to two years. In the same institution the duration differs from course to course. A list of institutions conducting post-graduate courses, the duration of the courses and other details are given in Appendix III.

37. On the basis of the data collected from the institutions as also on the basis of the on-the-spot study of the institutions carried out, the Committee would analyse the present problems of post-graduate studies as given below:—

(a) In a majority of cases the main objectives of the post-graduate courses are not clearly defined. Confusion exists on the question of whether the courses are intended to train specialist technical personnel in particular fields of immediate practical value to industry, departments of government and other organisations or they are intended to give the students a broad-based academic training in the basic scientific principles underlying engineering, practice in rigorous theoretical and practical analysis, ability to think independently and an understanding of the inter-relationships of different branches of science and engineering.

(b) As a result of the confusion in the aims and objects of post-graduate courses, the contents of the courses, the methodology, standards etc., vary widely from institution to institution. Co-ordination between training in the formal sense and research is lacking. Further, the fields of study chosen are neither directly related to the training of specialists of an immediate value to industry nor to the broader objective of training technologists with a thorough scientific preparation who could undertake independent research and contribute to the advancement of knowledge.

(c) The number of students trained varies widely from institution to institution and bears no relationship to the physical and other facilities created for the purpose. On an overall basis, the existing facilities made available after spending considerable amounts of money are not being utilised in full. The response from the students for the post-graduate courses has also varied widely from course to course and again from institution to institution. For certain courses there is no response either from the students or from the employing authorities.

(d) Post-graduate activity has tended to develop in isolation from the general working of the concerned departments in an institution. Often, funds sanctioned for post-graduate work have been diverted to make good deficiencies in the undergraduate courses. Emphasis seems to have been laid in a number of cases on the acquisition of expensive items of equipment not directly related to particular post-graduate courses. In general, there is not much evidence of a sustained organised effort to bring together individuals representing different disciplines and specialities to work as a team towards the development of post-graduate activity.

(e) A serious deficiency in respect of staff. Instead of making a careful choice of fields for post-graduate courses in relation to well-qualified and experienced staff available, the tendency of many institutions has been to get a post-graduate course sanctioned, construct buildings, acquire equipment and then lastly look for the necessary staff. This lopsided approach has resulted in the courses not being started in some institutions due to lack of staff though funds have been spent on equipment and buildings.

(f) Lack of response from students to take full advantage of the facilities available for post-graduate studies is much in evidence in a number of institutions.

38. The Committee considers that further development of post-graduate engineering education in the country can proceed along correct lines only when these deficiencies and defects are removed.

The aims and objects of post-graduate courses must be clearly defined. The contents and standards of the courses, the methodology of work etc., should be reorganised in relation to the defined aims and objects. The organisational aspects should be dealt with in a more realistic manner in order to exercise a more effective control over post-graduate activity.

40 S.R.C.A.

CHAPTER IV

Essentials of Post-Graduate Courses—Diploma and Master's Degree Course—Research and Doctorate Degree

39. Opinion seems to be divided in different countries on the question of whether formal post-graduate courses in engineering and technology are necessary—what should be the aims and objects of such courses, how they should be organised and conducted etc. The existing practice also varies widely from country to country. The graduate courses at Master's degree level are organised on a large scale in the U.S.A. In the U.K., the general opinion till recently was critical of formal courses at post-graduate level but the trend now is to conduct Master's degree and Post-graduate Diploma Courses at a number of technological institutions and universities. In Germany, post-graduate courses are practically non-existent and all work after the first degree in engineering is mainly research for Doctorate Degree. Nevertheless, post-graduate education and research is a subject of much discussion all over the world, both in academic and in professional circles.

40. Wherever formal post-graduate courses have been organised, greater support has been received in those fields which have a strong scientific basis, as for instance, Chemical Engineering, Electrical Engineering, Electronics, Aeronautical Engineering, Physical Metallurgy etc.

41. Mere engineering practice, as for instance, construction methods and techniques, production, operation and maintenance of engineering systems have not lent themselves much to post-graduate studies. The pattern of post-graduate courses is largely governed by the science content of different fields. Future developments also will be governed chiefly by the impact of scientific advances of technology.

42. The Committee considers it necessary to define the aims and objects of post-graduate courses not in terms of the subject matter of the courses but in terms of competences which a student should acquire in his chosen field. These competences may be grouped broadly under two heads. In the first,

(a) mathematical studies should be brought up to a level where it becomes possible to envolve a mathematical model representative of a physical situation. Application of mathematices to engineering studies should reveal the common scientific basis of apparently diverse phenomena.

(b) a knowledge of materials technology should be imparted to students in order to give them the modern concepts of how the physical properties of materials arise.

(c) training in instrumentation to develop an appreciation of precision measurements with the help of electronics and other fields.

(d) A rigorous theoretical and experimental analysis of the chosen field mainly from the point of view of understanding the scientific basis of engineering.

43. The second would consist of Research and Design in the broadest sense of the terms. Research means essentially concentration of efforts based on the scientific method for acquiring new knowledge of nature—matter, phenomena and energy. The most important contribution of research is in the cultivation of a scientific attitude of mind and in the use of scientific method in the solution of problems. All advanced engineering studies are based on the scientific method. It is this competence in the scientific method that a post-graduate student should seek to acquire in his advanced studies in an institution.

44. In the development of technology, the contribution of the designer is as important as that of the scientist. The highest form of expression for an engineer is a successful design. The scientific approach is based on analysis and abstraction whereas the designer works towards a synthesis consistent with basic scientific principles and properties of materials with which he has to deal. A successful synthesis involves scientific principles, physical properties of materials, manufacturing techniques and economics in varying degree depending upon the complexity of the final product. There is, therefore, a methodology of design just as there is a methodology of research and both research and design are equally important for technological studies at an advanced level.

45. In order to achieve these goals, an organised training programme which includes project work as an important element, is necessary for all post-graduate studies. The project work may be research-oriented: this will initiate the students into the methodology of research and also help them to cultivate the scientific attitude; or design-oriented which develop an understanding of design; procedures, engineering synthesis and advanced calculations. Whether

it should be one or another would depend upon whether a particular institution has an active school of research or it is able to establish close association with industry for design work.

46. The emphasis on one or more of these competences will vary depending upon whether the post-graduate course is designed to serve an immediate or a long range purpose and also on the time available to complete the course. The immediate purpose would be to train an engineer-specialist in a particular field who could readily apply his advanced training to industrial operations, design, construction, manufacturing processes etc., in a scientific way and also develop the results coming out of research laboratories in their application to industry. The long-range purpose would be to train engineers with a deeper understanding of the scientific principles underlying engineering who could undertake research and make fundamental contributions to the advancement of technology.

47. On the basis of these general considerations, the Committee would recommend two distinct types of post-graduate courses in engineering and technology, the first to be designated as Post-Graduate Diploma Course of one year's duration and another designated as Master's Degree Course of two years' duration.

48. The scope of the Post-Graduate Diploma Course should be further study of a selected subject in a major field of engineering beyond the first degree stage. The study should include advanced knowledge and technical details of the chosen branch with emphasis on current practices. A certain amount of mathematical preparation and engineering sciences would be necessary together with a short course in instrumentation and materials. Experimental work would depend upon the subject chosen but the emphasis should be on testing and verification of fundamental principles and characteristics and performances of the engineering system. Project work should be so devised as to enable the student to collect, sift, analyse and present technical data in a systematic form and to carry out advanced engineering calculations. If the subjects of specialisation are chosen in a careful manner in relation to the requirements of industry for specialist personnel, the diploma course would serve a very useful purpose.

49. In the Master's Degree Course, the emphasis should be on the fundamentals of engineering and on the scientific method in the solution of engineering problems. The standard of the various subjects like mathematics etc., will be of a high order to give the student a deeper understanding of the manner in which physical properties of materials arise. Specialisation in a narrow field is not the aim, and the approach is to give a broad-base to a composite group of

related engineering and science subjects. The experimental work also would be of an advanced nature designed as a systematic preparation for a research project. In certain cases, the project may have a design bias and, therefore, the initial preparation will be different. The main purpose of the course is the development of a quality of mind which is capable of finding solutions of problems from the fundamentals.

50. All post-graduate courses whether for a Diploma or for a Master's Degree should consist essentially of four elements *viz.*

(a) Lectures
(b) Seminars
(c) Experimental work
(d) Project.

The scope of each of these elements would depend upon the main competences sought in the Diploma or Degree courses.

Lectures and Seminars should be integrated with study and independent reading carried out by the students themselves. In general the lecture courses should comprise—(i) Background courses; (ii) Orientation courses; (iii) Supplementary courses; (iv) Advanced courses; and (v) Optional courses.

Background courses deal with the appropriate topics or portions of Mathematics, Physics, Chemistry, Geology or any relevant fundamental science of importance to engineering.

Orientation courses deal with instrumentation, applied electronics, materials technology, exprimental procedures etc.

Supplementary courses are concerned with the subjects auxiliary to the main field of specialisation.

Advanced courses provide the main base for the formal training process at the post-graduate level. They enable the student to develop the power of abstraction, ability to analyse and gain mastery over details. They should invariably lead to an appreciation of advances at the fundamental level and/or in the practice of a particular technology. These courses may be classified into three broad categories. The first deals mainly with the fundamentals in relation to a particular field or branch of study. The second leads to specialisation at an advanced level in the chosen field. The third aims at giving comprehensive details of technology of processes, manufacturing techniques, design procedures and calculations together with constructional details.

Optional courses are in the nature of an experiment for the teachers who wish to introduce post-graduate students to fields of their specialisation and in which advances are constantly taking place. These courses are an indication of the development of an institution in various fields and of the freedom enjoyed by the teachers in their academic work.

Facilities for advanced experimental work have to be organised for post-graduate studies in the institutions. These facilities would relate to construction of measuring devices and engineering analysis and synthesis based on experimental analogies. Provision has also been made to enable the students to become familiar with certain experimental techniques as a preliminary to project work or research problems. In other cases, systematic laboratory training facilities also become necessary.

51. The Committee has given in Appendix IV a suggestive list of fields or subjects in which Post-Graduate Diploma courses and Master's Degree courses may be organised. Institutions may add to this list but the main consideration in the choice of a particular subject for the Master's Degree should be whether it is broad-based enough from the point of view of scientific content, and for the Diploma course, whether it is of sufficient and immediate practical value to industry in respect of specialist personnel required.

52. On the basis of these general principles, the existing post-graduate courses in our institutions should be completely re-organised. The fields or subjects of study now offered should be re-classified depending upon whether they are suited to Diploma courses or to Master's degree courses. The Committee wishes to point out that a majority of the existing subjects or fields could only fit into Post-Graduate Diploma Course.

53. Quality and standard rather than numbers should be the watchword of post-graduate courses. These can be assured only when the number of students to be dealt with in each course is limited and the teachers give personal guidance to the students. In the considered opinion of the Committee, the Master's Degree course in any particular branch should not have more than 15 students. For the diploma course the number may be somewhat larger but in any case not more than 20—25. The students should be selected on the basis of their mental ability, maturity, aptitude for advanced work and capacity for concentrated effort. Post-graduate studies are a highly selective process and, therefore, the number of students admitted and their calibre are of the highest importance.

54. Advanced research as a preparation for the Ph.D. Degree is a logical sequel to post-graduate courses. At the Ph.D. degree level,

students should demonstrate their competence to carry out research of an original nature. The effort of the individual and the kind of environment that supports it are the two important factors on which the final result depends. The selection of the correct type of students, therefore, is more important for research and the institutions should have active schools of research.

55. As a general rule, enrolment for Ph.D. Degree should be permitted only after a candidate has obtained Master's Degree. A minimum of two years' research work at an institution should be prescribed as an essential requirement for supplication for the degree. In exceptional cases, however, a candidate of high ability may be permitted to enrol directly for Doctorate after the first degree but in those cases a minimum of three years should be insisted upon.

56. Elsewhere in this report, the Committee has explained the importance in general of fundamental sciences including mathematics to advanced studies and research in engineering. There are, however, certain fields of technology, as for instance advanced electronics, metallurgy, etc., in which a high degree of competence in the fundamental sciences is of particular value. If a candidate possessing this competence is available for post-graduate studies in these fields, even though he might not have taken the first degree in engineering or technology, he should be given every encouragement. The Committee would recommend that in certain selected fields, admission to post-graduate courses should be open to M.Scs. in the appropriate branches.

CHAPTER V

Organisation of Post-Graduate Courses—concentration of Efforts—Opportunities of development for all institutions—co-operation with industry.

57. Whatever be the pattern of post-graduate courses, and however carefully they may be formulated, the success of all efforts in the field will depend ultimately on the institutions. It is, therefore, necessary to make a careful selection of institutions where post-graduate courses might be developed and to give them all assistance possible. As indicated earlier in the Report, a majority of the institutions now encouraged in post-graduate courses are of very recent origin and the older institutions have shown little evidence of post-graduate activity during their long history. There are, therefore, no strong traditions to influence the future development in this field and our efforts are to be guided solely by the new concepts now formulated.

58. Post-graduate activity is a logical sequel to a well-developed system of undergraduate courses in an institution. It also has an impact on the standards of the undergraduate courses. Therefore, on a long range basis, all institutions should receive encouragement and support to enter the post-graduate field, depending upon their ability and interest. We should, however, bear in mind that there are at present serious limitations to a widespread extension of this activity over a large number of institutions. There is an acute shortage of well qualified and experienced teachers to guide post-graduate courses and research in the institutions. A strong cadre of such teachers has yet to be built up. That necessarily takes time. The financial resources are limited to the funds allotted for this purpose in the Five-Year Plans. In addition, suitable employment opportunities for those who have done post-graduate courses or research have yet to develop. The Committee, therefore, is of the view that the national effort towards the development of post-graduate education in engineering and technology should be concentrated during the next ten years in certain selected institutions. As and when the resources, especially staff and funds improve, the activity may be extended to other institutions.

59. The concentration of national effort should not exclude other institutions that are in a position to do so, from undertaking post-graduate work in a limited way, particularly Post-graduate Diploma

Courses. An institution that is able to establish close relationships with established industrial concerns in its area in order to conduct Post-graduate Diploma Courses in certain selected fields of immediate value to the concerns should receive support.

60. In organising post-graduate courses and research on a national basis, a co-ordinated plan should be evolved whereby Post-graduate Diploma Courses, Master's Degree Courses and Research at the Doctorate level in as many fields as possible, are concentrated in a limited number of institutions specially selected for the purpose. The Plan should also provide for other institutions, depending upon their resources and abilities, to conduct Diploma courses of immediate practical value to industry within their respective areas. As a first step towards the implementation of this co-ordinated programme, the Committee would select the four Higher Technological Institutes that are being established as part of a plan for advanced engineering education, the Indian Institute of Science, Bangalore that has been engaged in advanced studies for a long time and a few other institutions like the Roorkee University where post-graduate courses in a wide range of subjects have already been started. In these institutions, however, the existing courses should be conducted in the light of the recommendations made by the Committee in Chapter IV. At other institutions where post-graduate work has already been initiated on a limited scale, the question of whether or not they should conduct Master's Degree and Post-graduate Diploma Courses should be examined.

61. A number of institutions would fall outside the above groups but all the same, should be assisted in various ways to enter the Post-graduate field eventually. Research projects in selected fields may be sponsored in those institutions in order to create an atmosphere of higher academic work and to enthuse the staff. Facilities for undergraduate courses should be improved and individual members of the staff should be assisted to do research in their respective fields that may be enlarged, depending upon their specialities and active research schools developed in the institutions.

62. A similar approach is also necessary in respect of research. The pattern of research in engineering and technology is fast changing. Modern engineering research is based essentially on an inter-disciplinary approach that brings together persons belonging to different disciplines of the fundamental sciences, mathematics and technology to work as a team in the solution of specific problems. This approach involves a large staff equipped with the necessary skills and competences. Equipment and apparatus, library facilities, and technical services are other requirements for organising research

schools in technology. When we are short of these essential requirements and particularly in respect of staff, our main effort should be selective in respect of institutions to be developed. The Committee would, therefore, recommend that the bulk of engineering research for Ph.D. or similar degrees should be located in those institutions where post-graduate courses at Master's Degree level are organised on an extensive scale.

63. No institution engaged in post-graduate courses or in research can fulfil its aims and objects unless it lays the greatest emphasis possible on staff—on the calibre of teachers recruited and the freedom given to them to develop this activity. A radical change in the present staff structure as also in the administrative procedures relating to the recruitment of staff etc. is necessary. A large number of professorships should be created in each major field to represent various branches of specialisation. Opportunities of advancement for teachers at lower levels viz. Assistant Professors and Lecturers should be available on the widest scale possible. Merit promotions based on the quality of work done by individuals should be an essential feature of the organisational set-up in institutions engaged in post-graduate work. The provision for merit promotions should be on as generous a scale as possible.

64. An important point to be kept in view is that advanced studies and research in engineering are essentially a team work; the team consisting of scientists, mathematicians and engineers with the same mental outlook, comparable ability and identity of interests. In all the institutions, therefore, special efforts should be made to establish departments of Physics, Chemistry and Mathematics with a strong bias towards engineering and to appoint well-qualified staff who could collaborate with the engineering departments in post-graduate work.

65. Adequate provision should be made for the supporting staff in all post-graduate institutions. The services of technicians and mechanics should be available especially for applied electronics, maintenance and repair of the instruments, optical work, glass blowing, metal fabrication, vacuum techniques, high and low temperature work etc. The work of a number of institutions is at present handicapped by the absence of these much-needed facilities. Therefore, when the question of further development of the institutions is considered, special attention should be paid to this aspect.

66. A well-equipped library generously provided with current and back numbers of journals and periodicals and other types of scientific and technical literature, translation and documentation services is necessary in all post-graduate institutions.

67. For a vigorous growth of technology, technical institutions and industry should come closer and establish co-operative relationships between themselves. The forms and dimensions of co-operative relationships are many and varied. From the point of view of post-graduate studies and research the Committee would stress the following:

(a) Industry should sponsor research projects to be carried out in institutions. Such research projects will not only make the work of the institutions purposeful but will help industry in the solution of its problems of design, development, manufacture etc.

(b) Institutions should make freely available to industry the results of research, both fundamental and applied, carried out in its laboratories. They should also seek problems of industrial importance, initiate research and extend the results to industry.

(c) Industry should provide to institutions technical data and other information required by post-graduate students in their project work.

(d) Industry should secure the services of the staff of institutions in a consultative capacity to advise on various technical problems. This will be to mutual benefit. By coming into contact with actual industrial situations the mental horizons of the teachers will widen and this will be reflected in the quality of their teaching to post-graduate classes. Industry will have the benefit of advice tendered on the basis of advanced scientific and technical knowledge gained by the teachers. Similarly, industry should assist the institutions by sparing freely the services of its own experts in the conduct of post-graduate courses.

(e) Industry should extend the facilities of its research laboratories and design offices to post-graduate students in their project work.

(f) Since some of the post-graduate courses have to be designed and conducted to train specialist engineers of immediate practical value to industry, industry should take a positive and direct interest in such courses, advise institutions on fields of specialisation, standard and content of the courses and project work and offer suitable employment to candidates trained in the post-graduate courses.

(g) Industry should endow chairs or special professorships in the institutions. It should also institute scholarships and fellowships for post-graduate students. These scholarships and fellowships would be a long-term investment since some of the scholars after their studies will join industry.

68. The identity of interests between institutions and industry may also express itself in the form of 'Co-operative Courses', conducted jointly by them in certain fields. In the U.K., the U.S.A. and other advanced countries, post-graduate courses have derived much strength from research, design and developmental work carried out in industry, research laboratories and other organisations. The resources of these organisations in respect of expert staff, laboratory facilities, and advanced technological experience are co-ordinated with those of the institutions and on the basis of these pooled facilities, special courses at post-graduate level are conducted as a joint enterprise of industry and institutions. Such courses have been particularly useful in the training of specialist personnel who are capable of readily undertaking research, design and developmental responsibilities in accordance with the requirements of industry. The Committee would commend this system and suggest that the institutions should give special consideration to the question of developing 'Co-operative Courses' in association with industry and other organisations.

CHAPTER VI

Selection of students for post-graduate courses and research—Inducements and incentives for attracting better students—Training of teachers for technical institutions—Part-time courses—Central agency for co-ordination and direction

Financial estimates

69. The Committee has analysed in Chapter III the present state of post-graduate courses in various institutions and also explained some of the important factors responsible for the lack of progress. At this stage, the Committee wishes to draw special attention to the question of selection of students for post-graduate courses and research and inducements and incentives to be offered in order to attract better students. This is a matter of great importance since unless a sufficient number of students of high calibre join post-graduate courses and research, any expansion of facilities involving large sums of money will be wasteful.

70. Every student has a two-fold purpose in joining a post-graduate course. The first is to acquire a higher qualification for professional advancement. The second is to be able to join the upper echelons in industry and other organisations. These two are so closely interlinked that unless employment opportunities commensurate with the aims and objects of training at post-graduate level are available, rarely does a student spend further time, money and effort on post-graduate courses. Better employment opportunities should, therefore, be developed simultaneously with an expansion of post-graduate engineering education. To this end, industry, technical departments of government and other organisations should give their full support to post-graduate courses.

71. Industry should realise that its future will depend ultimately upon its technical personnel—their quality, standard of performance, originality and inventiveness. The better equipped the technical personnel is in these respects, the quicker will be the pace of industrial progress. On a long range basis, it is to the advantage of industry to increase its investment in terms of better qualified engineers and to provide them every opportunity to make their contribution to industrial development. The Committee would recommend that in the recruitment of technical personnel, industrial concerns, government departments and other organisations should give special consideration to candidates possessing post-graduate

qualifications in engineering and technology. For positions of higher responsibility relating to research, design and developmental work, post-graduate qualifications should be an essential requirement.

72. Industry and other organisations should also give every encouragement to serving personnel to undergo post-graduate training and improve their knowledge and competence in their respective fields. For this purpose, they should send their employees on deputation or study leave or other suitable terms to institutions for post-graduate studies. By drawing experienced candidates from the professional field to post-graduate courses, institutions will not only enhance the importance of the courses conducted but also raise their standards.

73. In the sphere of academic activity, the importance of post-graduate courses and research cannot be over-emphasised. The teachers of engineering institutions engaged in under-graduate work can only improve their performance and also raise the standards of under-graduate courses by themselves having advanced knowledge of their own fields. All engineering colleges and other institutions engaged in first degree courses should generally insist that their future teachers particularly at the senior level should possess post-graduate qualifications at least a Master's degree, in order to be eligible for appointment on the staff. They should also send their present teachers who do not possess post-graduate qualifications to recognised centres of post-graduate studies to qualify for Master's degree. For this purpose, they should sanction on a liberal scale deputation, study leave and other terms.

74. At this stage the question of numbers becomes important. What should be the scale on which facilities for post-graduate studies should be developed? How many centres should be started and what should be the range of subjects at each centre? How should the quantitative aspects of post-graduate development be related to the needs of the country? These and related problems need to be considered in formulating a national plan for post-graduate engineering education.

75. The number of centres for Post-graduate Diploma Courses, the subjects or fields of study, the number of candidates to be admitted etc. will depend upon the actual needs of industry from time to time. As and when an institution in a particular area or region has established close relationships with industrial organisations, government departments etc. and has prepared itself to meet their needs in respect of specialist personnel, the institution should be encouraged to start Diploma courses in selected fields. An objective evaluation of the needs of industry should be the main criterion in the choice of a particular centre as also of the fields of specialisation. In

organising the courses, the institutions may also keep in view the long range needs of developing industry and organise courses to fulfil those needs. The Committee estimates that about 500 diploma seats might have to be provided for in the course of next five years.

76. As regards Master's Degree courses, the extent of expansion has to be related to activities in academic and research fields. The primary requirement is in respect of teachers for technical institutions. Both for the existing institutions and for new ones to be established during the current plan period, we need at least about 1,000 teachers with post-graduate qualifications. Next is the requirement for research engineers for research laboratories, industry etc. In order to meet all these requirements, provision has to be made for about 1,250 seats in Master's Degree courses. The corresponding provision at Ph.D. level would be about 100 places.

77. In order to attract candidates of high merit for post-graduate courses, institutions should offer scholarships and fellowships on the widest scale possible. Till recently, the institution awarded scholarships of the value of Rs. 150 p.m. only to 50 per cent of the students joining the courses. That, however, tended to keep out a large number of candidates who were otherwise qualified and desirous of doing post-graduate studies. On the recommendations of the All India Council for Technical Education it has now been decided to award scholarships of the value of Rs. 250 p.m. for all students joining post-graduate courses. The Committee considers this decision as an important measure for the promotion of post-graduate engineering education. For research scholars working for Ph. D. degree, the value of the scholarships should be Rs. 400 p.m. provided they have taken their Master's degree before enrolling for Ph. D. For those exceptional candidates who are enrolled for Ph. D. immediately after the Bachelor's degree, the value of the scholarships should be Rs. 250 p.m. in the first two years and Rs. 400 p.m. in the subsequent years.

78. From the point of view of students desirous of pursuing an academic career, it would be desirable to offer them opportunities of acquiring teaching experience as part-time teachers while studying for post-graduate degrees. In the U.S.A. more than 50 per cent of post-graduate students enrolled are teaching assistants.. The teaching assistantship enables a candidate to do a limited amount of instructional work to under-graduate students and acquire teaching experience. The rest of the time is devoted by him to post-graduate work. In India also this system of teaching assistantship should be adopted. In addition, post-graduate students should be encouraged to do part-time teaching work for which they should be paid separately.

79. The Committee notes that a large number of candidates are being sent to the U.S.A., the U.K. and other countries, under various Foreign Aid Programmes, for Master's degree or equivalent courses in engineering. Since facilities for such courses are available in the country and are proposed to be enlarged in the current Plan period, there is evidently no justification for sending abroad our scholars any more for Master's degree. Further, when the post-graduate courses in our institutions are reorganised on the lines indicated in this Report, the country's needs in respect of specialist engineering personnel could be met further. The Committee, therefore, recommends that the present practice of sending our scholars abroad for Master's degree courses in engineering should stop, excepting in certain special subjects in which facilities for advanced studies have yet to be developed. There should, however, be no bar to sending our best scholars who possess Master's degree for Doctorate till engineering research has made sufficient progress in the country.

80. The question of duration of Post-graduate Diploma and Master's Degree Courses has been dealt with in Chapter IV. The duration of one year for the Diploma course and of two years for Master's Degree course has been recommended by the Committee for those entrants who wish to study the courses on a full-time basis. Provision should, however, be made for teachers of technical institutions to do Master's Degree course on a part-time basis. The duration of the part-time course would, however, depend upon the amount of work a teacher can put in outside his normal hours of work, his initial equipment in mathematics and other subjects and the additional portions he has to study for the Master's Degree. These details should be decided by institutions conducting post-graduate courses. What is important is that the system of post-graduate courses should be flexible enough to permit of various arrangements being made to facilitate teachers and others engaged in academic activity to study on a part-time basis. For the Diploma courses that are intended to train specialists in particular narrow fields, institutions may consider the question of offering them on a part-time basis for persons working in industry and other organisations. The courses in Industrial Engineering, Industrial Administration and Business Management conducted by certain institutions on a part-time basis at present are a case in point.

81. For the formulation of a detailed plan for the development of post-graduate courses and research and for its implementation along the lines indicated in this report, a central body should be set up under the aegis of the All India Council for Technical Education. For this purpose, the Committee recommends that the present Standing Committee for Post-Graduate Studies of the All India

Council should be reconstituted as Board of Post-graduate Studies in Engineering and Technology. The Board may consist of about 20 members and should be representative of all interests concerned *viz.* universities and technical institutions engaged in post-graduate work, Boards of Technical Studies of the All India Council, industry and government departments, University Grants Commission, Council of Scientific and Industrial Research etc. It should also include experts in different fields who could advise on various aspects of post-graduate development.

82. The Board should be charged with the responsibility of selecting institutions for post-graduate courses and research, deciding the fields in which courses should be conducted, assessing the requirements of institutions and recommending grants to be given. The entire programme of development should be co-ordinated by the Board.

83. The facilities for post-graduate studies and research developed at an institution should not be restricted to candidates belonging to a particular state or region, but should be open to all. An All-India approach is necessary and institutions should assure that candidates from all over the country are admitted, subject to fulfilment of the prescribed academic requirements.

84. Detailed financial estimates should be worked out by the Board on the basis of schemes formulated for each institution. The Committee, however, has given in Appendix V a tentative estimate of the amounts required in the Third Five-Year Plan to reach the physical targets indicated in paras 75 and 76. According to this estimate, an amount of Rs. 10 crores has to be provided in the Plan for post-graduate engineering education and research.

CHAPTER VII

Summary of Recommendations

I. In view of the importance of Science and Technology to national progress, a deliberate effort should be made to promote the study of science from as early a stage of education as possible and the cultivation of a scientific temper. As a first step, the science content of secondary school curriculum should be increased.

II. The inroduction of the Five-Year Integrated Course provides a good opportunity to improve the science content of degree courses in engineering and technology. In order to assure that prospective candidates for post-graduate courses and research possess a thorough scientific preparation in the physical and mathematical sciences, this opportunity should be utilised to the fullest and full-fledged departments of physics, chemistry and mathematics should be established in all engineering colleges.

III. In order that the science departments of engineering colleges may have broader objectives beyond the purely functional requirements of technological curriculum, the departments should be permitted by universities to conduct Master's degree courses in Science and also to enrol research scholars for Ph.D. dergee. At a few selected institutions the question of conducting B.Sc. course in a limited scale may also be considered by the universities.

IV. In view of the fact that scientific studies at an advanced level are a very good preparation for engineering research and design, provision should be made at a few selected institutions for conducting special first degree courses in engineering of about three years' duration for those candidates who have graduated in physics, chemistry and mathematics with high credits.

V. Urgent measures should be taken to improve the staff position at all technical institutions, which is far from satisfactory at present. The Government should also allot adequate foreign exchange to the institutions for importing equipment that cannot be obtained from indigenous sources. Institutions should produce as many items as possible in their own workshops.

VI. At the post-graduate level, training should have two distinct objectives, immediate and long-range. The immediate objective is to train an engineer-specialist in a narrow field, who could readily apply his advanced knowledge of the field to industrial operations, relating to design, construction, manufacturing processes etc. in a scientific way and also to develop the results of research in their application to industry. The long-range objective is to train engineers with a deeper understanding of the scientific principles underlying engineering who could undertake research and make fundamental contribution to the advancement of technology.

VII. In order to secure these objectives, the structure of post-graduate courses should provide for two distinct courses, one to be designated as Post-graduate Diploma Course of one year's duration and another to be designated as Master's Degree Course of two years' duration. The essentials of the courses are: (a) Mathematical Studies to evolve mathematical models of physical situations; (b) Materials Technology to expound the concepts of physical properties of materials; (c) Instrumentation; (d) Rigorous theoretical and experimental analysis of a chosen field of engineering; and (e) Project work that may be either Research-oriented or Design-oriented. Emphasis on these components would vary depending upon whether it is the Diploma Course or Degree Course.

VIII. Every care should be exercised in the choice of fields or subjects for post-graduate study. Only those fields or subjects that are broad-based enough from the point of scientific content should be chosen for the Master's Degree course. For the Diploma course, the subjects should be of sufficient and immediate practical value to industry in respect of specialist personnel required.

IX. On the basis of the general principles now laid down for post-graduate studies, the existing courses in the institutions should be completely reorganised into Post-graduate Diploma and Master's Degree Courses. The subject now offered should also be re-classified.

X. Quality and standard should be the watch-word of post-graduate courses. These can be assured only when the number of students to be dealt with in each course is limited and the teachers give personal guidance to the students. The students should be selected on the bases of their mental ability, maturity, aptitude for advanced work and capacity for concentrated effort.

XI. Advanced research as a preparation for Ph.D. degree is a logical sequel to post-graduate courses. At this level, a candidate should demonstrate his competence to carry out research of an original nature. As a general rule, enrolment for Ph.D. Degree should be permitted only after a candidate has obtained Master's Degree. A minimum of two years' research work at an institution should be prescribed as an essential requirement for the award of Doctorate degree. In exceptional cases, however, a candidate of high ability may be permitted to enrol directly for Doctorate after the first degree, but in those cases, a minimum of three years' work should be prescribed.

XII. In certain special fields of technology, as for instance, Advanced Electronics, Metallurgy, etc. in which a high level of scientific competence is of great value, the post-graduate courses should also be opened to Master's degree holders in the appropriate branches of science.

XIII. In view of the limited resources available at present, especially in respect of qualified staff, the main bulk of post-graduate courses and research should be concentrated in the initial stages in a limited number of institutions to be chosen specially for the purpose and developed along correct lines. The activity may be extended gradually to other institutions depending upon their resources and abilities. Employment opportunities available to those who have qualified at post-graduate level should also be kept in view in expanding the facilities.

XIV. If in addition to institutions selected for post-graduate development on a large scale, any institution is able to establish co-operative relationships with industry or any other technical organisation and is in a position to conduct post-graduate courses on a limited scale, especially in respect of Diploma Courses in certain fields of immediate practical value to industry, that should be assisted under the national plan. At the rest of the institutions the existing conditions should be improved in order to enable them to enter the post-graduate field eventually. In particular, research projects may be sponsored which will create an atmosphere of higher academic work and enthuse the staff.

XV. The progress of post-graduate courses and research depends essentially on the quality and strength of staff appointed in the institutions. Special attention should be given by all institutions to this question. A radical change in the present staff structure as also in the administrative procedures relating to recruitment, promotions etc. is necessary. A number of professorships should be created in each major field to represent various branches of specialisation, opportunities of advancement should be created for younger teachers and merit promotions based on the quality of work done by individuals should be an essential feature of the organisational set-up of the institutions.

XVI. In view of the fact that all advanced studies and research in engineering are essentially team work on the part of scientists, mathematicians and technologists, special efforts should be made to establish departments of Physics, Chemistry and Mathematics in the institutions that should have a strong bias towards engineering and well-qualified staff who could collaborate with the engineering departments.

XVII. Adequate provision should be made in all post-graduate institutions for the supporting staff and the services of technicians, mechanics etc. should be freely available. A well-equipped library generously provided with current and back numbers of journals and periodicals and other types of scientific and technical literature, translation and documentation services is necessary in the institutions.

XVIII. For a vigorous growth of technology, institutions and industry should come closer and establish co-operative relationships between themselves. The various forms in which such relationships may be promoted may include: industry-sponsored research projects in the institutions; results of research carried out in the institutions to be made freely available to industry; technical and other data to be provided by industry to help in the project work of post-graduate students, appointment of the staff of institutions as consultants to industry; research and design office facilities in industry to be made available to post-graduate students; endowment of professorships and scholarships by industry; etc.

XIX. The question of conducting co-operative courses in association with industry should be examined by institutions whereby the technical and other facilities available in industry are utilised to the maximum extent possible in the post-graduate development.

XX. Better employment opportunities should be developed for those candidates who have completed post-graduate studies. To this end, industry, technical departments of government and other organisations should give their full support to post-graduate courses. In the recruitment of technical personnel, especially for positions of higher responsibility relating to research, design and developmental work, post-graduate qualifications should be prescribed as an essential requirement.

XXI. Industry and other organisations should sponsor their serving personnel to undergo post-graduate courses and improve their knowledge and competence in their respective fields of work.

XXII. All engineering colleges engaged in first degree courses should insist that their future teachers particularly at the senior level should possess post-graduate qualifications in order to be eligible for appointment. They should also send their present teachers who do not possess post-graduate qualifications to recognised centres of post-graduate studies to qualify for Master's degree.

XXIII. In the course of the next five years, facilities may be created for about 1,250 seats in Master's degree courses and about 500 seats in Diploma courses. The corresponding provision at Ph.D. level may be about 100 places.

XXIV. In order to attract candidates of high merit for post-graduate courses scholarships of the value of Rs. 250 per mensem should be awarded. For research scholars working for Ph.D., the value of the scholarships should be Rs. 400 per mensem provided they have taken Master's degree.

XXV. Post-graduate students and research scholars should be encouraged to do part-time teaching in the institutions as teaching assistants that would enable them to acquire teaching experience.

XXVI. In view of the fact that post-graduate engineering education is being expanded within the country, the present practice of sending abroad large numbers of scholars for Master's degree or equivalent courses, under the various Foreign Aid Programmes should stop, excepting in those fields in which our facilities have yet to be developed.

XXVII. Special provision should be made to allow teachers serving in technical institutions to do post-graduate courses on a part-time basis and wherever possible, exemptions from certain parts of the courses should be given to them. Similar provision should also be made to encourage technical personnel working in industry to do Diploma Course on a part-time basis.

XXVIII. For the formation of a detailed plan for the development of post-graduate engineering education and its implementation along the lines indicated by the Committee, a Board of Post-Graduate Studies in Engineering and Technology should be set up under the aegis of the All India Council for Technical Education. The Board should be representative of all interests concerned and vested with the responsibility of co-ordinating developments in the field on an all-India basis.

XXIX. The facilities for post-graduate studies and research developed under the national plan, at an institution should not be resricted to candidates belonging to a particular State or region but should be open to all candidates, subject to fulfilment of the prescribed academic requirements for admission.

XXX. An amount of about Rs. 10 crores should be provided in the Third Five-Year Plan for post-graduate development.

Sd./- M. S. Thacker
(Chairman)
Sd./- S. Bhagavantam
Sd./- G. K. Chandiramani
Sd./- N. S. Gupchup
Sd./- D. S. Kothari
Sd./- P. R. Ramakrishnan
Sd./- H. L. Roy
Sd./- B. Sengupto
Sd./- P. K. Kelkar
(Member-Secretary)

APPENDIX I

CHAIRMAN'S NOTE

It would perhaps be appropriate if, before deciding on the manner in which the Committee is to function and collect the necessary material on which to base its final recommendations, an attempt is made to view the entire problem of post-graduate training and research in the technological and engineering institutes from a wider angle.

A sense of urgency has been associated with this problem because of its unusual potential in pushing forward the development programme to which we are committed as a nation. If capital formation is the basis for sustaining most of the activity associated with economic growth, the pattern for which has been set by the Industrial Revolution, perhaps, the most effective instrument for translating that activity into wealth of production is technology in its broadest sense. Historically, the industrial revolution has provided the necessary foundation for the neo-technological revolution which has held sway over the entire world at the present time thus having an impact which is in some ways similar for all nations while in others widely different. For the under-developed countries it poses a challenge which has to be accepted simply as a matter of course for there is no alternative consistent with survival or with honour.

The most important aspect of the industrial development that has taken place in Europe and U.S.A. is that it has been a sustained growth over a very long period so that the Renaissance, the Industrial Revolution and the Neo-Technological Revolution form a composite pyramidal structure not only in the physical sense but also temporally. Successful attempts at planned accelerated growth have been made in the U.S.S.R. in Europe and Japan in Asia. In spite of many and substantial differences in approach, methods and nature of development, the common feature again in both the cases is the adherence to the pyramidal structure referred to above. This poses a vital question, the answer to which will more or less decide the nature of our objectives and the kind of efforts that have to be put forth. To state it differently, we must make a choice as to whether our industrial growth will have its basis more strongly in the 'neo-technological revolution' and thus arrive at a modified synthesis suited to our needs, our recourses and our genius having characteristics different from the classical synthesis as observed along the time axis in the process of development or, alternatively, stick to the known pattern and take the relevant steps. It may be useful to remember here that history may repeat itself but seldom reproduces itself.

The distinguishing characteristic of the neo-technological revolution is that it is concerned with a very wide range of materials which were previously unknown, or if known seldom used with special reference to their physical properties (mechanical—including sonic-thermal, optical, magnetic and electrical) and with extreme and quick changes in operating conditions. It is further characterised by solutions to all types of engineering problems in terms of transient conditions as well as the usual steady state criteria. The behaviour of matter in general is considered not only from the macro but also from the micro and the molecular points of view. This leads to an understanding of the manner in which properties of matter arise and how they can be produced at will. It further gives an insight in the use of new materials to form different types of combinations in energy transformation and communication systems. Thus, instead of engineering developing into a practice without necessarily in close association with science it first takes on the characteristics of science to develop into a technology. The other important factor is that all significant advances and development in techniques are a result not of the efforts of a single individual but of collaboration between persons trained in widely different disciplines. In fact, team work at all stages of development is the key to success.

Perhaps a striking though rather crude way in which one can appreciate the significance of the difference in approach in the old as compared with the new scheme of things would be to analyse from the engineering point of view the latest steam locomotive of the Canadian Pacific and the Boeing 707 jet liner.

The symbols which are characteristic of the industrial transformation in the classical pattern are iron as the material and the steam engine as the source of power. The most interesting aspect of the phenomenal industrial growth is that over large areas the practical men have no use for the scientist. If one takes a broad perspective view of the entire field of development from the middle of the seventeenth century to the end of the nineteenth century it might be observed that starting with an initial impulse which was simultaneously scientific as well as technological there has been a more or less parallel development of pure science on the one hand and the engineering practice on the other with a loose connection between the two which became closer as the century advanced.

Thus there were technological advances which were essentially the fruits of the creative effort of the engineer while at the same time one could observe in certain spheres science initiating technological advance based on engineering techniques.

The exhibition of 1851 was a landmark which showed clearly the tremendous potentialities of the machines and the power of the machine. It was essentially the triumph of the engineer. The next phase of advance can be characterised as the incorporation along with the art of manufacture, the science of measurement which made it possible to fabricate machine parts with extreme precision thus leading to the concepts of standardisation, interchangeable parts and mass production. The introduction of steel alloys for machine tools was obviously of the greatest importance in this connection. It is significant that one major invention of the nineties was the Parson's Turbine which was again in the field of machinery and shipbuilding where Britain was still well ahead of her competitors.

By the close of the nineteenth century the technological advance which owed its success more to science made itself felt especially in the newer fields of electrical engineering, organic chemical manufacture and the motor-car industry. There is evidence to show that the remarkable success of Germany in this context was in a large measure a consequence of her educational system.

Around the year 1884 Germany was estimated to have in industry 4,000 chemists trained in universities or polytechnics while Britain had only a handful. The most interesting point to note is that Germany reached a stage of development within about thirty years which had taken hundred years for the country which was first in the field.

The end of the nineteenth century marks an epoch where the phenomenal growth in the industrial mechanism in the classical sense was accompanied by new trends in technology which clearly indicated the shape of things to come in the twentieth century. Looked at this way, the neo-technological revolution almost seems an extension of the original industrial revolution. The collaboration between the applied scientists and the engineer was not only made closer but extended over new areas and in many new ways. In fact, the Age of the Advertiser had arrived.

It would be appropriate at this stage to examine very briefly the important elements which were essential for the building up of the industrial potential and growth of industrial production pertinent to the nineteenth century. From the national point of view the most important elements were the transport systems, the quantum of the responsibility accepted by the state government in the industrial development and the general set of values accepted by the community as a whole with regard to the process of accumulation of capital, technological knowledge and skills. The question of raw materials is complicated but there is not the slightest doubt that 'mining' and all that goes with it had the most profound influence on the growth of industrialisation.

The transport revolution is like an early stage of industrial revolution. It is difficult to over-estimate the importance of the part played by Britain in this behalf not only in Britain but in the rest of the world. Thus behind the 3,86,000 miles of railway which had revolutionised the world's communication by 1890 and behind the 75 million tons of shipping which entered and left Britain's ports that year lay its formidable basic engineering industries. The energy to bring about this great transformation in Britain was certainly not generated by state action, nor was it due to the faith of the people in the secular idea of progress current today. There are reasons to believe that a very substantial element in this context was Puritanism and all that it stood for. Accepting redemption at the end of time, it pushed aside the cyclical idea of time to replace it by modern time which is progressive, continuous and irreversible.

Believing that our best and most divine knowledge is based on action the practical ethics of Puritanism insisted on strenuous life and tireless labour. Everyone became conscious of the passage of each little minute and the parcelling of time into units which can be 'counted', can be 'saved', can become 'valuable' turned time into money. It is not surprising if a connection is drawn between Calvinism and the Genevan clock industry and the production of clocks and of scientific instruments in seventeenth and eighteenth centuries in England. Calvinist puritanism accepted tireless production of useful works for the welfare of mankind and the glory of God as the criteria for successful labour. This naturally created a very favourable atmosphere for the pursuit of scientific research and technological activity. The Royal Society which laid such emphasis on experiment had in 1663 sixty-eight members out of which no fewer than forty-two were Puritans. It can hardly be described as an accident that the successful establishment of foundries and mining industry in England was mostly the work of austere industrious Quaker families devoted to technological progress.

The industrial development in Britain depended on a large number of individuals with daring enough to undertake a tough job and see it through, irrespective of the difficulties in the way or the amount of hard work involved. The skill and the experience was widely diffused and the framework was established for new ideas being tried. It is no wonder that a great many of the inventions of the eighteenth and the nineteenth century were made by practical people. It was true in those days as now that mobility of material and persons, capital and management and the industrial set-up were equally important before a successful product could be put up. Nothing could illustrate this point better than the contrast which existed at this period between Britain and France in the rate at which inventions were adopted, developed and passed into industrial application. No nation in the world showed more vivid inventive genius than the French but a high proportion of their inventive talent proved abortive or was put to profitable use elsewhere—particularly in England and Scotland.

The phenomenal industrial growth was thus sustained by individual and private effort with the State hardly coming into the picture. As it turned out, the importance of comparable progress in technological education was not realised by the State and education was almost left to private initiative. Surprisingly enough, there was the great educational movement in British History, the mechanics 'institutes, which arose in 1820s'.. By 1841 there were some 50,000 members in over 200 institutions. Nevertheless, they failed to meet the need for popular technical education in Britain, nor did they have any, immediate and contemporary impact on British industry. The Society of Arts, which had come to the help of mechanics' institutes by amalgamating them into a nation-wide union started examinations for members. The 1856 papers, for example, included Principles of Mechanics (26 questions in a 3-hour paper) Practical Mechanics (26 questions in a 3-hour paper), Chemistry (9 questions in a 3-hour paper). It could not possibly be a matter of surprise if the rate of failures in these examinations was over 80 per cent.

It became clear to most thinking people that the State would have to take substantial initiative to put technological education on a proper basis. It is now accepted everywhere that a well-developed and integrated system of technological education is a potent instrument for not only sustained technological development but also for anticipating the future needs and bringing about planned growth in known as well as new fields. It would perhaps not be unreasonable to state that by the end of the nineteenth century there was not much evidence in Britain to show that this was realised either by the industry, the State or the universities. Even after the realisation came, the progress in higher education in science and technology was frustrated by two circumstances; the inadequacy of secondary education and the prejudices of older universities. A substantial school system was built up in the meanwhile in continental Europe which was feeding the polytechnics with future industrialists, technologists and manager. As a relevant piece of information it may be stated that at that time in the Zurich Polytechnic alone there were 60 professors and lectures compared with 12 at South Kensington

A relevant conclusion that can be drawn from what is stated above is that if Britain continues to be one of the foremost nations in the context of the nuclear age as it was in the context of the great initial industrial upsurge, it is not necessarily because of the special planned efforts in regard to technological education. Similarly, it has obtained its supply of first rate scientists, technologists and managers by strengthening and multiplying its classical pattern, instead of trying out new patterns with simultaneous emphasis on numbers and quality, the opportunities being wide-spread instead of being restricted.

Most of the advanced countries of the world have taken deliberate steps to link industrial progress with technological education and the numbers dealt with have been by and large far more in proportion. Even countries with very small populations have achieved remarkable progress in limited spheres where planned higher technological education was an essential element.

From all that has been said so far it seems the following broad conclusions can be drawn which should be of assistance in viewing the problem of post-graduate training and research in technology in its proper perspective:

A. Planned technological education on a national basis can become a potent factor in bringing about industrial transformation not only in a comparatively shorter duration but also in establishing a pattern of development more realistic in terms of the available resources both material and human.

B. The path between the scientists' laboratory table and the mechanics work-bench is often long and deceptive and yet it has to be kept not only open but capable of much greater mobility.

C. The most urgent need of the present is a machinery for the widest possible diffusion of the right type of technological knowledge and its applications. This problem will be insoluble unless some positive decisions are taken in connection with secondary education and language.

D. The attitude and the quality of mind which is associated with a 'research worker belonging to a research team' is to be deliberately cultivated on a very much wider front by suitably planned training programmes. The short term objectives would be:

(1) To make known processes and techniques adaptable to the local conditions, thus avoiding delay and frustration.

(2) To make use of instrumentation and control devices to overcome the lack of experience and experienced personnel.

(3) To make use of the existing knowledge, to bring about improvements and changes in current local practices and techniques.

(4) To be able to utilise more effectively a comparatively large proportion of persons trained at a very much lower standard.

(5) To make available persons with suitable industrial orientation for being employed in research organisations and training institutions and other places where development work is likely to be carried out.

E. No great transformation can take place unless latent energies of the people associated with it are released. The need for the psychological 'incentive' along with material 'incentive' has to be fully grasped before any estimate can be made regarding the possible results of any steps that may be taken.

From all that has been said so far, it would be obvious that the main objective of the post-graduate courses would be to make a body of engineers and technologists available whose outlook in general would be different from the classical, and who will be aware of the materials and their properties in the modern sense, who will be able to analyse an engineering problem from the point of view of energy transformation, and who in their normal duties will not hesitate to make the maximum possible use of instrumentation.

In order to have this type of training at the post-graduate level it would be necessary to modify the undergraduate courses also. Thus, assuming immediate steps are taken in this connection, the first batch of students fully trained will be available after seven years. They will take five years more to become effective in their employment which means this programme would take about twelve years for the satisfactory completion of its final phase. In the meanwhile, interim steps will have to be taken so that within the next two to three years supply of the type of persons indicated above will begin to be available in some measure. In addition to this, in the immediate future, sustained effort will have to be made to build up the right type of personnel at the teacher level as also at the level of the instrument mechanic.

It will thus be seen that we are given to the inescapable conclusion that the proper approach to the problem must necessarily be an integrated one involving the entire field of technological education from the base to the top. Further, it must be admitted that the older pattern of training programme deriving its inspiration from Britain may not give us the desired results. It has enabled us to establish equivalence at the abstract level and in terms of examination papers. At the creative level not much has been achieved.

Merely expanding the existing facilities even with certain modifications will, therefore, not meet the needs of the situation. Instead of allowing the [illegible] forces to work out a solution in the long run, it would be far better to anticipate the future and take appropriate steps now. This will obviously mean organisational and administrative difficulties will have to be faced.

In the light of what has been elaborated so far it would be useful to set down certain general considerations with specific reference to the organisation of research and post-graduate courses in engineering and technological institutions. It must be remembered in this connection that the main objective is to train a sufficient number of persons who as a result of this training are expected to make substantial contributions in accelerating the technological development in the country in the industrial field, as well as in research and educational establishments.

The programme of research and development work, therefore, must necessarily be subordinate to this basic requirement. Looked at from the point of view of technology, research as such may be broadly considered as either basic research or applied research and it would be conceded that the training programme should be mostly directed towards applied or technical research. It is quite possible that a certain amount of basic research would be equally necessary, but then it would be in general to what might be described as 'background applied research'. It may be emphasised that in the present set of circumstances it would not be possible or proper to encourage research with the sole desire to add to the existing fund of knowledge however worthy such an objective might be from a purely scientific point of view. The main purpose is to develop ability to adapt, modify and process successfully what is known, to suit any given set of circumstances and thus evolve new techniques and products. This obviously means that the efforts are to be concentrated not on doing anything spectacular as on trying to diffuse as widely as possible in depth as well as in expanse specialised and advanced knowledge for the purpose of utilising local resources both human and material to the maximum advantage. As has been stated earlier an examination of the pattern of industrial growth in advanced countries reveals that great changes are the product of countless steps of evolutionary development.

Perhaps the manner of approach to training in research as indicated above might be appreciated if a comparison is made with the need for training in mathematics. There is no question that mathematics as a discipline for the training of mind is unrivalled. But that does not mean that one must pursue the study of mathematics in the same manner as would a mathematician.

As a natural corollary to what has been stated above it would be seen that the type of research programme and the training in research method, that would be appropriate can only be organised provided facilities exist to bring together several disciplines in technology as well as in science, both in terms of staff as well as equipment. It appears that for anything useful to come about there is a critical minimum size in staff and equipment which has to be exceeded.

Similar considerations as indicated above would hold good in relation to post-graduate courses as well. It will be inconsistent with the main objective to organise courses which are essentially practice-oriented, process-oriented or product-oriented. They should normally be in those fields where a technology has a distinct character of its own which it derives from the scientific and engineering content in it and where several disciplines have contributed to its growth. Alternatively, it may be in a field which has wider applications than what its narrow specialisation would indicate. Post-graduate courses are not just an extention of undergraduate courses but something radically different both as regards the concept as well as execution.

It may be remarked that if the criteria indicated above are applied, the number of possible post-graduate courses under the present scheme of things would be smaller than what one might expect from the current practice. One is tempted to emphasise that there is another fundamental consideraion that vitally decides the success or otherwise of any programme of research, post-graduate and development work. A certain atmosphere is very essential for this type of activity. This atmosphere depends on the attitude of authorities and the set of values that guide their actions. It is not so much the physical existence of facilities as the manner in which these are made available that decides the final outcome. The atmosphere which induces men to do creative work is sensitive to 'tracer quantities'. Men with ability, idealism and experience will always prefer right atmosphere even if it means less of everything else to affluence in a set-up which is not of the right type.

In all that has been said so far, no mention has been made regarding the profound influence which defence requirements have on science and technology. More than one half of the total expenditure on research and development in Great Britain is incurred on defence research and development. This aspect, therefore, should receive its due consideration in any proposals that finally emerge as a result of the deliberations of this Committee.

Some of the important considerations summarised

(1) Defence requirements have been the most potent factor in developing industrial potential.

(2) Britain has not made any attempt to use planned technological education as an instrument for achieving rapid development of the industrial potential in any particular field.

(3) Industrial production in the modern sense is closely related to advertising techniques.

(4) The older pattern of industrial growth depends on an hierarchy of apprenticeship. The maintenance and transmission of skills depend on practices that have restrictive and monopolistic tendencies. It was during the last war that it became apparent that training periods could be curtailed substantially, and new methods of training evolved so that persons with very little previous background could be fitted into the industrial pattern without undue strain.

(5) All the industrially advanced countries of the world (including Japan) lie in the temperate zone. Countries situated nearer the equator have yet to evolve the pattern of industrial activity and production more amenable economically sound in relation to their climatic conditions.

(6) For the older pattern of growth the number of highly trained persons required was small. Such people were required mostly for research and development work.

A few extracts from some recent publications which give relevant material of interest

(a) In a paper read to Section F of the British Association in 1956, Mr. E. Rudd gave these preliminary results of a D.S.I.R. sample inquiry into research and development expenditure in 1955.

Government direct work	120 mn	} 235 mn
Government contracts	115	
Universities research associations, etc.		16
Industry		74
Total expenditure in 1955		£325 (+80)mn

(b) Discussion regarding shortage of trained personnel (Britain)

The breakdown by three types of industry was as follows:—

Type of industry*	Percentage complaining of any shortage of (Crucial shortage in brackets)			
	Scientists	Engineers	Designers Draughtsmen	Lab. Assistants
Traditional	23 (0)	13 (0)	20 (10)	13 (0)
Engineering	32 (2)	45 (10)	59 (20)	29 (2)
Modern	61 (2)	45 (10)	55 (12)	50 (2)

*Under traditional we include extractive industries, baking, building and construction, cotton wool, and jute processing, pottery, cutlery, paper, printing, furniture, and shoe-making. In Engineering we include industries based on the engineering advances of the last century, associated mainly with prime movers—machine tools, pumps, motors, aircrafts, heavy electrical equipment and production machinery. In modern we include heavy and fine chemicals, radio, electronics, scientific instruments, man-made fibres, and nuclear products.

(c) Comparison of educational facilities

"The following table shows very approximately the contrast between the U.S.A. and the U.K. 'educational pyramid'; the figures are roughly representative of recent years though an exact comparions cannot be made because of the deficiencies of educational statistics and the difference in age-distribution between the countries."

	Great Britain Actual numbers (thousands)	Corresponding numbers for G.B. if the propensity to enter higher education (15+) were the same as in the U.S.A.	
At school 5—14	6,900	5,900	
At school 15 upwards	360	1,500	1,750
At university for first degree or diploma (full time)	75	550	700
At university for higher degree	10	60	65

(d) An example of static approach to changing circumstances

"The difference may be seen by comparing the railways (a static industry) and cotton and linen (which are in decline) with the electronics industry. The decision to abandon steam traction on the railways was reached with painful slowness, and its execution may now be delayed by the difficulty of recruiting new technical staff to an unfashionable industry. From the users' point of view, rail transport has progressed little in speed or convenience during the last half-century and indeed it has often retrogressed. There is no real doubt (in Great Britain) about the continuing need for railways, and the measures, commercial and technical, needed to maintain their attractiveness are not difficult to discover. Yet railway management appears to have found it extremely difficult to reach definite decisions, to put them into effect speedily and in sufficient measure, and to persuade the public and the Government of their necessity. We doubt if the cold hand of Government control is a sufficient explanation of this, though it has undoubtedly made a bad problem worse. Positions of responsibility in railway management are usually reached by seniority, and in a static industry there is little inducement for lively minds to come in from outside."

(e) Educational System and the trained personnel required by industry

"In particular, we note that there is a constantly increasing demand for scientists and techonologists. In the early stages of the application of science to industry a few scientists are engaged mostly in basic research; later a large number is required to provide for industrial applied research—this is the stage now reached by Britain; and finally a much larger number still is needed, in the control of production processes—a stage reached by the U.S.A. We have no doubt that many more scientists and technologists must be trained, if Britain is to consolidate her industrial research and apply it in complex processes; but we think that it will be very difficult to increase the supply without considerable changes in the educational system."

(f) Industrialisation in Japan

"It is true that Japan's industrialisation was more largely a matter of transplanting and adapting to Japanese conditions the techniques already developed in the West than of making primary contributions to the world's stock of knowledge. Yet borrowing of this sort calls for more than rotelike absorption. It involves purpose, criticism and a creative synthesis. It entails persistent trial and error and the risking of fortunes both large and small, in a setting which offers rewards for success. New modes of production are apt to encounter subtle and powerful resistance. And this may take the form not only of political disorder or indifference to material progress, but a deeper hostility to the habits of mind and social arrangements which these modes require. Even within a single country the degrees of assimilation may be uneven among various regions and occupations. The case of Japan itself will illustrate this fact.

If Japan's experience teaches any single lesson regarding the process of economic development in Asia, it is the cumulative importance of myriads of relatively simple improvements in technology which do not depart radically from tradition or require large units of new investment. The big, modern establishments with its concentration of capital in advanced forms of technology was essential in many fields, of course. It provided the framework of economic growth in the form of railways and steam shipping, coal and electric power, the metallurgical industries, banking and insurance. It enlarged the opportunities in foreign trade; it was indispensable to the building of industrial war potential. Much of the real substance of Japanese economic growth, however, is found in the more modest types of improvements which were more easily and pervasively adopted, more economical in cost, and often more productive of immediate returns in income. For any poor country beginning to industrialise, one of the crucial problems is to introduce and spread such innovations as widely as possible."

(g) Comparative Student Enrolments—US—USSR—GB

"In the U.S., Russia and here students at university institutions normally take a first qualification around 21-22 years of age, in the U.S. and Great Britain this qualification is called a Bachelor's degree, in Russia a Diploma. The number of these graduates in 1954 was:—

	Pure Science	*Applied Science*
U.S.	23,500(144)	22,500(137)
U.S.S.R.	12,000(56)	60,000(280)
G.B.	5,200(105)	2,900(57)

The figures in brackets express the number per million of the population.

(h) Comparative Student Enrelments in West Germany and other Countries

There is some controversy about the relative standards in the three countries. Mr. R. A. Butler said in the House of Commons on June 21, 1954 that a number of American first degrees are not up to our own average; that is fair comment. Estimates of the standard of the Russian diplomats vary (these estimates are based on the study of syllabuses, examination papers, theses—which resemble the Oxford science schools). Some qualified observers judge that the diplomas are about the same standards as our degrees, some put them slightly higher.

Corresponding figures for other countries of Western Europe in 1954:—

	Pure Science	*Applied Science*
West Germany	3,450 (67)	4,450 (86)
France	1,760 (41)	2,988 (70)
Switzerland	215 (44)	399 (82)
Italy	2,436 (45)	2,200 (45)

The normal course for a pure scientist in these countries is four years and for an applied scientist five; the age of graduation is 23-24. The standard is generally about a year more advanced than our own first degree. If we take comfort because our graduates are slightly better trained than the Americans, Italians, French and Swiss have a similar edge on us."

(i) Post-Graduate

For the sake of completeness, here are the approximate annual outputs of those getting a research degree after three years post-graduate work—in England and America they are called Ph.Ds, in Russia Candidats:—

U.S.A.	3,500
U.S.S.R.	4,500
G.B.	900

These figures are directly comparable. Any deficiency in the American standards disappears at this level; and the Candidates' theses (apart from the cyrillic alphabet) would be acceptable in Ann Arbor or Bristol.

Two obvious conclusions follow from the above figures, one of world significance, one of local.

(i) While the Russian production of pure scientists is numerically modest, they are now training per year more applied scientists than the U.S. and Western Europe put together.

(ii) While the production of pure scientists in this country is relatively high, we are training considerably less applied scientists than West Germany, and probably about the same as Italy. Compared with the U.S. we are well behind; compared with Russia we are not in the same class."

(j) Science specialisation

In England, from the age of 15, a science specialist need not read a work in any other language; so far as that goes, he need not read a work outside scientific subjects in his own. This extreme of specialisation does not exist anywhere else. There is no equivalent to our 15—19 year-old preparation for university scholarships; and our university science course, as well as being the shortest in Europe, are also the only one exclusively scientific. (*e.g.* in Sweden, as in Russia, the science undergraduates take serious courses in languages—and similarly elsewhere.)

At 19, the ordinary English Science student knows more of science than his contemporaries anywhere—and less of anything else. At 21 or 22, when he graduates, he is nearly but not quite, as well educated scientifically as Italians or Germans graduating a year later. Apart from the gain of a few months, however, there is nothing else in favour of our fanatical specialisation, and a good deal against. It helps the tendency to regard scientists as a separate species; that tendency is, of course, dangerous to the whole culture, and ought to be resisted, not encouraged. Our system of specialisation also helps to make scientists more inelastic, even within science; it is one of the reasons why so many of our ablest men get into a premature academic mould. By 19, a lot of our good students are already so conditioned that they want to be pure scientists or nothing; and that makes it harder for us to get enough bright minds into applied science.

(k) "By modern standards, a remarkably small proportion of our population gets to universities. Much the biggest loss of talent happens at 15 and 16; usually after the G.C.E. (O) examination. For each boy and girl who finishes up at a university, there must be at least four or five who take jobs in banks, local government offices, the whole range of minor executive jobs which, as I have said already, we do so well. We do them well because a lot of the occupants are working far beneath their capacity, and stay so all their lives. Go into an American bank or town hall and compare the functionaries with their opposite numbers here."

(1) "These are our pure scientists, though, we have been for less successful in getting such men into applied science Our specialised

education, our academic emphasis the climate of our culture, all combine to lead our scientists of vocation into pure science; as for men of high ability who are not scientists of vocation, the same forces combine to keep them out of science altogther. So we have only a driblet of men of the highest ability going into applied science. There are some—we give them less prestige than we give most professionals—and they are the people who, more directly than any others, keep up economically afloat.

We do not deserve even those we get; but we get only a fraction of what we need. It has been our greatest weakness, ironically enough, ever since we got scientific industry going. We have, never understood it, nor the kind of men who shape it. Engineers have always remained outside the culture, even more than scientists. Yet, in intellectual difficulty and aesthetic satisfaction, many of the problems of applied science compare well with those of pure (*e.g.* the guided missile is, in strictly intellectual terms, a most distinguished aesthetic performance.) To manage a larger factory today requires an orchestration of skills—intelligence, temperament, force, imagination, a touch of daring. Such men are rare in any society; in ours we do not recognise their existence. It was thought a good joke among litterateurs when Russians took to writing novels about industrial life with snappy titles such as "Ferro-concrete": and yet it does not need much comprehension to tell one that such subjects might be as apt for novel writing as, say, obsessional rape in North Africa. No, the mistake was not that the Russians should write those novels, but that they had to write them so badly."

(m) Older Metallurgist: "If your suggestions are followed, there will soon be no metallurgists of the old school left. That would be a pity, after all, we have done something. The alloys of the last fifty years have been good alloys and they were made by men like me."

Young Scientists: "There we can both agree. The older metallurgists were great men—so were the Elizabethan sailors. But the greatness of the latter did not lie in the fact that they used boats with sails that was the technical method of their day and it was succeeded by steam and oil. You are living at the time when the principles underlying the structure and properties of metals and alloys are at last being discovered, and you must not complain if this leads to a new attitude towards the work, and if the new attitude leads to new technical methods. You and your friends may well be proud to call yourselves the last of the older metallurgists. Your achievements are secure, and the alloys you made were good alloys—they were very good alloys, and time alone will show if the younger scientists are able to produce better".

APPENDIX II

List of institutions visited by the Committee

1. P.S.G. & Sons College of Technology, Peelamedu, Coimbatore.
2. Government College of Technology, Coimbatore.
3. Coimbatore Institute of Technology, Peelamedu, Coimbatore.
4. College of Engineering, Trivandrum.
5. Indian Institute of Science, Bangalore.
6. College of Engineering & Technology, Jadavpur University, Calcutta.
7. Department of Applied Chemistry, Calcutta University, Calcutta.
8. Department of Applied Physics, Calcutta University, Calcutta.
9. Institute of Radio Physics and Electronics, Calcutta University, Calcutta.
10. Bengal Engineering College, Sibpur, Howrah.
11. Indian Institute of Technology, Kharagpur.
12. Engineering College, Banaras Hindu University, Varanasi.
13. College of Mining & Metallurgy, Banaras Hindu University, Varanasi.
14. College of Technology, Banaras Hindu University, Varanasi.
15. Department of Pharmaceutics, Banaras Hindu University, Varanasi.
16. University of Roorkee, Roorkee.
17. Thapar Institute of Technology, Patiala.
18. Punjab Engineering College, Chandigarh.
19. Indian Institute of Technology, Bombay.
20. Victoria Jubilee Technical Institute, Bombay.
21. College of Engineering, Poona.
22. Department of Chemical Technology, Bombay University, Bombay.
23. Bihar Institute of Technology, Sindri.
24. Indian School of Mines, Dhanbad.
25. College of Engineering, Guindy, Madras.

26. A.C. College of Technology, Guindy, Madras.
27. A.C. College of Engineering and Technology, Karaikudi.
28. College of Engineering, Annamalainagar.
29. Birla College of Engineering, Pilani.
30. Faculty of Technology and Engineering, M.S. University, Baroda.
31. Birla Viswakarma Mahavidyalaya College of Engineering, Anand.
32. L.D. College of Engineering, Ahmedabad.
33. College of Engineering, Osmania University, Hyderabad.
34. Department of Chemical Technology, Osmania University, Hyderabad.
35. Shri Govindram Sakseria Technological Institute, Indore.
36. Laxminarayan Institute of Technology, Nagpur.
37. College of Engineering, Jabalpur.
38. H.B. Technological Institute, Kanpur.
39. University College of Engineering, Bangalore.
40. Government College of Engineering, Anantapur.
41. Government College of Engineering, Kakinada.

APPENDIX III

List of Institutions Conducting Post-Graduate Courses in Engineering and Technology

(Courses which were not processed through the Post-graduate Committee of the A.I.C.T.E. up to 30th April, 1959 are shown marked*)

Name of the Institution	Subject	Date of sanction by A.I.C.T.E.	Starting date	Total student out-put up to July 1961	Duration of the course	No. of students on roll in 1961-62
1	2	3	4	5	6	7
L. M. College of Pharmacy, Ahmedabad.	*Pharmacy	..	1953	32	2 years.	7
L.D. College of Engineering, Ahmedabad.	Electrical Machine Design	1953	1955	7	2 ,,	10
Indian Institute of Science Bangalore.	(*i*) Automobile Engineering	1954	1956	10	1½ ,,	3
	(*ii*) Power Engineering (Electrical) . .	..	1947	58	2 ,,	21
	(*iii*) *Power Engineering (Mechanical) .	..	1947	43	2 ,,	11
	(*iv*) Foundry Engineering	1954	1956	40	1½ ,,	13
	(*v*) *Power Engineering (Civil & Hydraulics)	..	1947	34	2 ,,	13
	(*vi*) High Voltage Engineering	1954	1956	21	1½ ,,	8
	(*vii*) Soil Mechanics and Foundation Engineering.	1955	1957	17	1½ ,,	11
	(*viii*) Electronics Engineering . .					
	(*ix*) Acoustical Engineering . .					
	(*x*) Line Communication Engineering					
	(*xi*) Ultrashort and Microwave Engineering	1954	1956	13	1½ ,,	15

1	2	3	4	5	6	7
	(*xii*) *Aeronautical Engineering . .	..	1942	134	2 years	12
	(*xiii*) Internal Combustion Engineering .	1953	1953	36	2 ,,	9
Faculty of Technology & Engineering, Baroda.	(*i*) *Highway & Bridges	..	1956	2	2 ,,	9
	(*ii*) *Advanced Irrigation & Hydraulics .	..	1956	1	2 ,,	6
	(*iii*) *Public Health Engineering . .	..	1958	2	3 ,,	9
	(*iv*) *Soil Mechanics	..	1961	..	2 ,,	3
	(*v*) *Electrical [illegible]	..	1956	..	2 ,,	13
	(*vi*) *Mechanical [illegible] . .	..	1956	..	2 ,,	6
Department of Chemical Technology, Bombay University, Bombay.	(*i*) Food Technology	1954	1957	9	1½ ,,	
	(*ii*) Chemical Engineering . . .	1959	1961	39 (By research upto 1961)	1½ ,,	
	(*iii*) *Textile Chemistry	..	1961	Do. 40	1½ ,,	
	(*iv*) *Technology of Intermediates & Dyes	..	1961	Do. 25	1½ ,,	
	(*v*) *Technology of Plastics	..	1961	Do. 25	1½ ,,	54
	(*vi*) *Technology of Pigments, Paints & Varnishes	..	1961	5	1½ ,,	
	(*vii*) *Technology of Oils, Fats & Waxes .	..	1961	Do. 12	1½ ,,	
	(*viii*) *Technology of Pharmaceuticals & Fine Chemicals	..	1961	Do.) 20	1½ ,,	
Victoria Jubilee Technical Institute, Bombay	(*i*) Automobile Engineering . . .	1956	1956	4	2 ,,	5
	(*ii*) Industrial Engineering & Industrial Administration (Industrial & Production Engineering)	1956	1957	4	3 ,,	57
	(*iii*) Advanced Textile Technology . . .	1956	1956	8	2 Terms (Full time) 4 Terms (Part-time)	8 2
	(*iv*) *Electrical Engineering	19[illegible]	1953	4	2 years	2

1	2	3	4	5	6	7
	(*v*) *Mechanical Engineering	..	1959	1954	2 years	2
	(*vi*) *Civil Engineering	..	1959	..	2 ,,	7
Indian Institute of Technology, Bombay	(*i*) *Industrial Electronics	..	1958	10	1½ ,,	12
	(*ii*) *Electro-Vacuum Technology	..	1958	10	1½ ,,	11
	(*iii*) *Design of Chemical Plant	..	1959	5	1½ ,,	11
	(*iv*) *Technology of Fine Organic Chemicals	..	1959	5	1½ ,,	9
	(*v*) *Technology of Heavy Inorganic Chemicals	..	1959	3	1½ ,,	10
	(*vi*) *Technology of Silicates	..	1959	5	1½ ,,	4
	(*vii*) Electro-Chemical Technology	..	1959	3	1½ ,,	6
	(*viii*) *Ferrous Products Metallurgy	..	1959	3	1½ ,,	8
	(*ix*) *Soil Engineering	..	1959	5	1½ ,,	2
	(*x*) *Automation in Chemical Industrials	..	1960	..	1½ ,,	9
	(*xi*) *Technology of Cellulose & Paper	..	1960	..	1½ ,,	6
	(*xii*) *Technology of Fuels	..	1960	..	1½ ,,	4
	(*xiii*) *Structural Engineering	..	1960	..	1½ ,,	18
	(*xiv*) *Design of Electrical Machine & Switchgear	..	1960	..	1½ ,,	12
	(*xv*) *Machine Tools Designs	..	1960	..	1½ ,,	19
Institute of Radio Physics & Electronics, Calcutta University, Calcutta.	Advanced Electronics	1953	1951	110	3 ,,	56

1	2	3	4	5	6	7
P.S.G. & Sons Charity College of Technology, Coimbatore.	Electrical Machine Design . . .	1957	1958	19	1 2/3 years	10
Punjab Engineering College, Chandigarh.	Highway Engineering	1953	1957	32	1 plus period for thesis	10
Department of Pharmacy, Chandigarh.	*Pharmacy	..	1954	30	1 ,,	1
School of Planning and Architecture, Delhi.	(i) *Post-Graduate Diploma in Town & Country Planning.	1955	1956	26	2 ,,	21
	(ii) *Housing	..	1959	11	1 ,,	8
Indian School of Mines, Dhanbad.	(i) Mining Engineering	1953	1959	1	1 year	..
	(ii) *Applied Geophysics . . .	1957	1957	7	4 years after I.Sc.	13
	(ii) *Applied Geology	..	1954	48	Do.	11
Department of Chemical Technology, Osmania University, Hyderabad.	(i) *Chemical Technology . . .	..	1943	108	2 ,,	8
	(ii) Chemical Engineering . . .	..	1961	22	2 ,,	8
Government Engineering College, Jabalpur.	(i) Advanced Electronics	1953	1955	8	1½ ,,	5
	(ii) Carrier & V.F.Telephone Engineering	1954	1955	3	1½ ,,	2
	(iii) *Soil Mechanics & Foundation Engineering	..	1954	2	1½ ,,	N.A.
	(iv) *Internal Combustion Engineering .	..	1956	4	1½ ,,	N.A.
	(v) *High Voltage Engineering . .	..	1957	4	1½ ,,	N.A.
	(vi) *U.H.F. Engineering . . .	..	1953	2	1½ ,,	N.A.

1	2	3	4	5	6	7
College of Engineering & Technology, Jadavpur University, Jadavpur.	(*i*) Chemical Engineering . . .	1959	1950	9	1 year	3
	(*ii*) Food Technology	1954	1959	2	1 ,,	3
	(*iii*) *Mechanical Engineering . . .	..	1950	9	1 ,,	6
	(*iv*) *Electrical Engineering . . .	..	1950	1	1 ,,	..
	(*v*) *Civil Engineering	..	1959	1	1 ,,	..
	(*vi*) *Tele-communication Engineering .	..	1959	..	1 ,,	..
Indian Institute of Technology, Kharagpur.	(*i*) Farm Power & Machinery . . .	1953	1956	9	1 ,,	9
	(*ii*) Soil & Water Conservation . .	1953	1958	9	1 ,,	5
	(*iii*) *Technical Gas Reaction & High Pressure Technology . . .	..	1954	15	1 ,,	4
	(*iv*) High Poymer & Rubber Technology	1954	1958	5	1 ,,	3
	(*v*) *Synthetic Drugs & Fine Chemicals .	..	1958	5	1 ,,	2
	(*vi*) *Architecture & Regional Planning .	..	1955	18	1 ,,	13
	(*vii*) *Structural Engineering . . .	..	1955	44	1 ,,	8
	(*viii*) Water Power & Dam Construction .	1953	1955	41	1 ,,	9
	(*ix*) Soil Mechanics & Foundation Engineering.	1953	1955	13	1 ,,	3
	(*x*) Highway Engineering	1953	1955	15	1 ,,	..
	(*xi*) Harbour Engineering	1956	Not yet started	..	1 ,,	..
	(*xii*) *Municipal Engineering	..	1958	3	1 ,,	1
	(*xiii*) *Electrical Machine Design . . .	..	1955	21	1 ,,	5
	(*xiv*) *Control System Engineering . .	..	1958	5	1 ,,	3
	(*xv*) Radio Broadcasting Engineering . .	1953	1956	16	1 ,,	1
	(*xvi*) Ultra High & Microwave Engineering	1953	1957	5	1 ,,	4

1	2	3	4	5	6	7
	(*xvii*) *Industrial Electronics . . .	..	1958	4	1 year	1
	(*xviii*) *Applied Geology . . .	..	1955	13	2 "	7
	(*xix*) *Exploration Geophysics	..	1955	10	2 "	7
	(*xx*) *Geo-Chemistry	..	1958	2	1 "	3
	(*xxi*) *Non-linear Mechanics	..	1957	10	1 "	8
	(*xxii*) Foundry Engineering . .	1953	1958	12	1 "	3
	(*xxiii*) Industrial Engineering . . .	1953	1953	36	1 "	6
	(*xxiv*) *Machine Design	..	1956	13	1 "	3
	(*xxv*) Mechanical Handling . . .	1953	1954	13	1 "	..
	(*xxvi*) *Production Technology . .	..	1952	63	1 "	5
	(*xxvii*) *Refrigeration and Air Conditioning Plant Design	..	1957	5	1 "	1
	(*xxviii*) *I.C. Engines and Gas Turbines .	..	1956	4	1 "	1
	(*xxix*) *Ferrous Metallurgy	..	Not started	..	1 "	..
	(*xxx*) Industrial Physics	1954	1955	6	1 "	2
	(*xxxi*) *Meteorology	..	1956	3	1 "	..
	(*xxxii*) *Industrial Psychology & Industrial Relations	..	1958	5	1 "	2
	(*xxxiii*) *Applied Botany . . .	..	1956	7	1 "	2
	(*xxxiv*) *Combustion Engineering & Fuel Economy.	...	1952	53	1 "	8
	(*xxxv*) *Chemical Plant Design & Fabrication	..	1957	28	1 "	8
	(*xxxvi*) *Mechanism & Vibration . .	..	1955	4	1 "	..

1	2	3	4	5	6	7
H. B. Technological Institute, Kanpur	(i) Oils, Fats & Waxes	1959	1959	4	1½ yrs.	7
	(ii) Paints & Varnishes	1959	1959	4	1½ ,,	7
	(iii) Applied Microbiology . . .	1959	1959	1	1½ ,,	8
College of Engineering, Guindy, Madras.	(i) Dam Construction, Irrigation Engineering & Hydraulics . . .	1953	1956	37	1½ ,,	7
	(ii) Foundation Engineering & Soil Mechanics	1954	1958	29	1½ ,,	9
	(iii) Structural Engineering including Concrete Technology	1953	1956	45	1½ ,,	9
	(iv) Public Health Engineering . .	1954	1956	69	1½ ,,	14
	(v) Electrical Machines Design . .	1953	1956	24	1½ ,,	6
	(vi) *Internal Combustion Engineering .	..	1959	8	1½ ,,	5
A. C. College of Technology, Madras.	(i) Chemical Engineering	1959	1947	20 (By Research)	2—3 yrs.	9
	(ii) *Textile Technology	..	1953	..	Do.	3
	(iii) *Leather Technology . . . ,	..	1952	14	Do.	29
Laxminarayan Institute of Technology, Nagpur.	(i) Chemical Engineering . . .	1959	..	6	1 ,,	6
	(ii) *Oil Technology	..	..	11	1 ,,	3
Birla College of Engineering, Pilani	Advanced Electronics	1953	1955	21	1—2 ,,	11
College of Engineering, Poona .	(i) Dam Construction, Irrigation Engineering & Hydraulics	1953	1958	34	1 ,,	10
	(ii) Foundation Engineering & Soil Mechanics	1954	..	..	2 ,,	..
	(iii) Structural Engineering including Concrete Technology	1953	1955	4	2 ,,	7
	(iv) M.E. (Met.)	..	1952	2	2 ,,	2
	(v) Advanced Metallurgy	1953	1958	4	2 ,,	6
	(vi) *M.E. (Electrical)	..	1956	2	2 ,,	5
	(vii) *M.E. (Civil)	..	..	1	2 ,,	2

1	2	3	4	5	6	7
Roorkee University, Roorkee	(i) Highway Engineering	1956	1956	21	1 year	7
	(ii) Dam Construction, Irrigation Engineering & Hydraulics	1953	1953	45	1 „	16
	(iii) Foundation Engineering & Soil Mechanics	1954	1955	27	1 „	11
	(iv) Structural Engineering & Concrete Technology	1953	1953	67	1 „	12
	(v) Public Health Engineering	1954	1955	25	1 „	7
	(vi) Photogrammetric Engineering	1957	1958	13	1 „	6
	(vii) Applied Thermodynamics	1954	1956	59	1 „	17
	(viii) Electrical Machines Design	1954	1954	55	1 „	12
Department of Pharmacy, University of Saugar, Saugar	*Pharmacy	..	1957-58	6	2 yrs.	6
Bengal Engineering College, Sibpur.	(i) Foundation Engineering & Soil Mechanics	1954	1954	9 (for (i) and (ii))	2 „	4 (for (i) and (ii))
	(ii) Structural Engineering & Concrete Technology	1953	1955		2 „	
	(iii) Prime Movers	1953	1954	10	2 „	9
	(iv) Electrical Machines Design	1953	1954	11	2 „	2
	(v) Advanced Metallurgy	1953	1954	6	2 „	..
Bihar Institute of Technology, Sindri	Heat Engineering	1956	..	..	..	..
College of Engineering, Trivandrum.	(i) Dam Construction, Irrigation Engineer- & Hydraulics	1958	1958	14	1½ „	10
	(ii) Structural Engineering	1957	1958	15	Do.	9
	(iii) Electrical Machines Design	1956	1958	8	Do.	4

1	2	3	4	5	6	7
Department of Silicate Technology, B.H.U., Varanasi .	*Silicate Technology	..	1947	48	1 year	1
Department of Pharmacy, B.H.U., Varanasi . . .	*Pharmacy	..	1943	97	1½ yrs.	17
College of Technology, Banaras Hindu University, Varanasi .	Chemical Engineering	1959	..			
College of Mining and Metallurgy, Banaras Hindu University, Varanasi	(i) Mining Engineering	1953	..	..	..	..
	(ii) Advanced Metallurgy	1953	1957	2	1½ yrs.	10
Engineering College, Banaras Hindu University, Varanasi .	Electrical Machines Design	1954	1957		4	
J.V.D. College of Science & Technology, Andhra University, Waltair.	(i) Chemical Engineering	1959	1944	about 150-200	1 ,,	2
	(ii) *Chemical Technology with (a) Sugar and (b) Pharmaceuticals and Fine Chemicals	..	1939		1 ,,	..
	(iii) *Ore Dressing	..	1954		1 ,,	4
	(iv) *Electro-Chemical Technology .	..	1953		1 ,,	..

APPENDIX IV

This is only an illustrative list.

I. *Master's Degree course of two years' duration.*

	Electives
(1) M.E. (Civil)	Structural Engineering, Hydraulic Structures, Soil Mechanics and Foundation Engineering.
(2) M.E. (Mech.)	Machine Design, Heat Power Engineering, Engineering Mechanisms.
(3) M.E. (Elect).	Applied Electronics and Servo Mechanism, Power Systems Engineering, High Voltage Engineering.
(4) M.E. (Communication Engineering)	Advanced Electronics, Line Communication and Broadcasting Engineering.
(5) M.E. (Metallurgy) . . .	Physical Metallurgy, Process Metallurgy.
(6) M.E. (Chem. Engg.) . . .	Mass & Energy Transfer, Chemical Plant Processes etc.
(7) M.E. (Aeronautical Engineering) .	

II. *Post-Graduate Diploma Course of one year's duration*

Mechanical Engineering

1. Automobile Engineering
2. Industrial Engineering
3. Mechanical Handling of Materials
4. Production Technology
5. Foundry Engineering and Foundry Technology
6. I.C. Engines

Civil Engineering

1. Highway Engineering
2. Hydraulic Structures
3. Foundation Engineering & Soil Mechanics
4. Structural Engineering (including Concrete Technology)
5. Public Health Engineering (including Municipal Engineering)

Electrical Engineering

1. Power Systems
2. High Voltage Engineering
3. Control Systems

Metallurgy

1. Ore Dressing
2. Ferrous Metallurgy

Chemical Engineering

1. Rubber Technology
2. High Polymers
3. Paper Technology
4. Electro-Chemical Technology
5. Combustion Engineering and Fuel Technology]
6. Food Technology
7. Synthetic Drugs and Fine Chemicals
8. Technology of Heavy Inorganic Chemicals

APPENDIX V

Physical Targets and Financial Estimates for Post-Graduate Development in Engineering and Technology in the Third Five-Year Plan

A. *Physical Targets*

1. Number of Post-graduate seats to be arranged in stages .	1750 (includes 500 Diploma seats)
2. Number of research places for Ph. D.	100

B. *Financial Estimates*

	In Crores
1. Scholarships @ Rs. 250/- p.m. per seat for degree /diploma for post-graduate training for the plan period	2·55
2. Recurring expenditure for equipment, maintenance, consumables and additional staff for the plan period . .	1·50
3. Equipment and buildings for development of post-graduate courses	1·80
4. Provision for hostels at Rs. 5700 per student for additional post-graduate students	0·75
5. Lump-sum grant to engineering institutions for research and advanced work	1·40
6. Grants for consolidation and improvement of undergraduate courses in selected institutions with a view to developing facilities for advanced work at the appropriate time . .	2·00
TOTAL	10·00 (crores)

GMGIPND—L—40SRCA—L—5-2-62—1000