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ABSTRACT

This is the sixth volume in a UNESCO series of comparative studies designed to establish the conceptual bases of the comparability of programs and degrees at various stages of training and to ascertain the general criteria for determining international equivalences in order to simplify recognition of degrees or diplomas obtained at other institutions in an individual's home country or abroad. This volume presents the results of a study focused on training in the engineering sciences. Countries involved in this study include the U.S.S.R., the United States, The United Kingdom, India, and France. The report includes discussions of trends in the development of higher engineering education, analyses of curricula in the countries surveyed, and conclusions regarding the survey. (PEB)

Studies on international equivalences of degrees

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Comparability of engineering courses and degrees

A methodological study

by Antoly I. Bogomolov

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Preface

This publication is the sixth in the series entitled *Studies on International Equivalences of Degrees*, the idea of which was approved by the General Conference of Unesco at its thirteenth session in 1964.

These are comparative studies which set out to establish the conceptual bases of the comparability of studies and degrees at the various stages of training and to ascertain the general criteria that will make it possible to determine international equivalences, thus simplifying recognition of degrees or diplomas obtained in other institutions at home or abroad.

The present study assembles the results of a survey undertaken in a number of countries in which there exist one or more systems of training in engineering sciences. These systems were selected because they are prototypes of which many variants are to be found in countries belonging to different regions of the world.

The results that the survey revealed are set out in such a way as to facilitate comparison between the degrees and diplomas awarded for studies in engineering sciences in the different countries. The results may also be compared with those provided by the comparative analysis of studies and degrees in international law, which are the subject of the fourth volume in this series.

The preparation of the study was entrusted to Professor Anatoly I. Bogomolov, Head of the Department of Methods and Studies at the Ministry of Higher and Specialized Secondary Education of the Union of Soviet Socialist Republics.

The work is intended primarily for three categories of reader. first, for all those who, in one country or another, are responsible for assessing the level of training of people wishing to take up studies in engineering sciences or continue their studies or research in a new institution for the purpose of specializing in these disciplines, or of those who wish to use the engineering knowledge and training they already have professionally in an administration or business, at home or abroad; second, for students and research workers who want to know the systems of instruction in this discipline and the degrees obtainable on completion of the various stages, and lastly, for comparative education specialists and educational planners for whom the pages which follow can provide information and material for comparisons as regards studies and degrees in engineering sciences.

The Secretariat of Unesco wishes to express its gratitude to Professor A. I. Bogomolov and to all those who helped in the preparation of this work.

Contents

Problems concerning the comparability of diplomas

The broadening of close contacts among countries in solving fundamental scientific and technological problems with a view to ensuring the prosperity of a future society is an outstanding feature of our time.

In the past, major discoveries came from individual researchers who were not provided with adequate facilities for experimentation, the development of technology lagged behind that of science, and decades or sometimes centuries passed before such discoveries were placed at the service of mankind. Only a small fraction of people, drawn from the ruling class, had access to education in each country in the past, and for this reason education could not be a dependable vehicle for the transformation and development of society, there was no close relation between the economy of a given country and the orientation and academic excellence of its educational system. All this was bound to lead to a situation where each pedagogical and scientific school developed in isolation, and some institutions of higher learning, including the world's largest, were passive when it came to exchanging experience and incorporating progressive trends in training competent personnel and researchers from other universities of the same or some other country.

Now that the scientific and technological revolution is under way, science, technology and education are developing in a harmonious manner and at an ever-growing pace, and ideas formulated by scientists are translated into life and made to serve society within much shorter periods.

Society requires researchers and engineers to ensure that all discoveries should be made to benefit mankind as soon as possible. Large teams incorporating the talent of pure and applied scientists, test engineers and designers, technologists and specialists in other fields, have taken over from individual researchers whenever important scientific and technological problems are to be solved. Society is faced with ever-changing problems of world-wide significance, such as those involving the peaceful uses of atomic energy, space exploration, interplanetary travel, depollution of the atmosphere, and the development of supersonic aircraft, the solution of which is the concern of most, if not all, countries of the world, and problems of this magnitude can be solved much more quickly if researchers and practical experts of various countries pool and co-ordinate their efforts.

It can be presumed therefore that co-operation between countries for the joint solution of major scientific and technological problems will constantly expand. It is for this reason that countries need to have a clear idea of the scientific potential of specialists and researchers including those educated abroad or drawn from other nations whose qualifications are certified by diplomas or other appropriate testimonials.

Whether attempts to solve scientific and technological problems are crowned with success depends primarily on the structure and standard of training of researchers and specialists. It is no accident then that the problem of perfecting the system of education and raising its standard of tuition should be a major concern of governments, scientific circles and others, with international co-operation in this field also increasing. Countries exchange professors and lecturers to a growing extent so as to share experience in training expert personnel, more and more young people are sent to take a complete or partial course of studies at foreign educational establishments. Comparison of diplomas or, to be more exact, of levels of education would make it possible for institutions of higher learning to avail themselves of the experience accumulated in other countries, with the result that the over-all level of training of specialists in all countries would improve.

The growing rate of the scientific and technological revolution makes it necessary for the developing countries to obtain assistance from the advanced nations in training expert personnel and researchers in a number of specialities, with particular emphasis on new branches of science, technology and culture. The youth of the developing countries in which some of those branches have not yet been raised to the desirable level are eager to obtain education and scientific qualification in those countries where such branches have reached a high stage of development.

Insufficient information on the levels of education and training of teachers and researchers in various countries quite often results in a situation where, on returning to his country, a young specialist or researcher educated abroad is either not recognized as a suitable candidate to occupy a post for which he has in fact been trained or is offered a much higher position than he is actually qualified for. In other words, diplomas, degrees and academic titles awarded abroad are either underrated or overrated.

When admitting young people to educational institutions or providing them with an opportunity to obtain or improve their scientific qualifications, it is indispensable to know the level of education or the scientific qualification they have acquired in their own countries.

It would seem that the purpose of expanding international co-operation, raising the level of education, and rendering mutual assistance in training specialists and researchers will be served if there is recognized comparability of diplomas, certificates and other documents attesting to the qualification of specialists and researchers at all levels.

It is no less important for those hoping to study or obtain a degree or academic qualification abroad to be familiar with the comparability of diplomas so that they can plan their careers in the country where they will be working on completion of their studies or after qualifying as a practical expert or researcher.

The problem of the comparability of educational or scientific qualifications should be considered from two angles: university or academic, and administrative or legal.

University (or academic) comparability determines the eligibility of a candidate to go on to higher education or to undertake advanced research work if he has received an education or obtained a scientific qualification of a lower level at another educational institution or in another country.

Administrative (or legal) comparability is the term used when the civil service authorities, a professional association, an industry, or a research or educational institution wishes to assess a diploma with a view to establishing whether the holder meets the requirements of the position sought.

The bulk of graduates from higher educational establishments seek jobs in industry and various types of institution, so that it is administrative comparability that matters in the final analysis. However, the problem of comparability of diplomas should not be approached solely from the administrative or academic point of view. A university cannot train specialists and researchers without formulating the requirements that their graduates are supposed to meet in professional life. Hence the task of establishing university comparability and the task of determining administrative comparability seem to be mutually related.

A line of distinction between university and administrative comparability of diplomas is only drawn to counter the argument that studies to establish such comparability are doomed to failure in view of the autonomy of universities and their non-recognition of such attempts. It must be remembered that what firms and other institutions wish to determine is the functions that specialists and researchers can perform rather than the views of higher educational establishments on eligibility to proceed to higher academic degrees.

There is no doubt whatsoever that a solution to the problem of comparability of diplomas involves a host of difficulties and that it should be arrived at by easy stages and with some reservations at the initial stage. To begin with, the problem of comparability should not be extended to cover undergraduates who have attended or plan to attend lectures and undertake other types of academic activity in separate subjects. When tackling the problem of comparability, only those students should be considered who pursue their studies on the regular pattern and take a complete course on a full-time basis. Nor is it reasonable or even possible to compare the levels of education of 'regular' learners engaged in identical areas of study (in different educational establishments) in terms of separate years of study. In such cases, comparability of education should be established by universities with due regard to all local conditions prevailing at those institutions of higher learning at which the students concerned have studied or will pursue further studies.

The system of training specialists, teachers and researchers has its specific features in each country and has evolved historically in line with the specific economic, social, political and other local conditions.

The choice of disciplines in the training of engineers is governed in each country by the structure of individual industries and industrial enterprises as well as of scientific and cultural institutions. These structures are peculiar to individual countries, so that the lists of specialties in which higher educational establishments in each country train expert personnel do not coincide either. The patterns of majoring for undergraduates also differ from one country to another, to such an extent that it is extremely difficult to compare specialties and majors offered by institutions of higher learning in different countries.

But the difficulties do not end there. In some countries, such as the U.S.S.R., undergraduates are supposed to have on-the-job training in industry in line with the chosen fields of concentration. Hence, when they graduate from a higher educational establishment, they are immediately qualified, without prior probation, to claim permanent employment and carry out the functions prescribed for the positions they occupy.

In other countries, such as the United States of America, on-the-job training is not included in the curricula, and graduates from higher educational establishments are therefore obliged to go through an additional period of practical experience in firms before they can start their careers in industry.

It may be safely assumed that there are no two institutions of higher learning whose curricula and syllabuses would wholly coincide. The titles of courses an the distribution of study matter as between various subjects as well as the order in which they are taken differ as a rule between different institutions of higher learning in a given country, let alone between different countries.

Indeed, in some higher educational establishments, majoring starts as from the second year of study, in others from the third, and in still others from the fourth, and, accordingly, the set of general science subjects is taken at different levels, too However, on completion of the full course of studies, graduates from all these institutions of higher learning may have an education of identical level although the programmes for the second, third, or fourth year of study may differ as between these institutions, both in volume and content of schooling.

When discussing the comparability of levels of education, therefore, it is desirable to consider and compare only completed cycles of education for instance, complete general secondary education or individual stages of higher education, completion thereof being certified by an appropriate diploma or degree.

For all the variety of specialist and researcher training systems, it would be wrong to say that higher educational establishments of different countries have no common objectives, as was the case in the past. Today, schools of higher studies in all countries are called upon to educate, within the shortest time possible, creative minds who can make use of all that has been achieved by world science and technology to ensure further scientific and technological progress and the solution of new problems posed by society. One is inclined to agree with G. L. H. Bird when he affirms that:

> . . there can be considerable differences in the structure of engineering education and training between countries A, B . . . Z and yet these can be equal in esteem the professional engineer is equal in abilities and worth.[1]

1. G. L. H Bird, 'Some United Kingdom Traditions, Practices and Trends', *The Training of Professional Engineers Fifth International Congress of Engineers, 27 September to 1 October 1971*, p. 28, London, The Institution of Civil Engineers.

Indeed, if one considers the advanced countries having diverse educational systems, one is bound to admit that scientific and technological problems of an identical degree of complexity, such as the development of supersonic aircraft or space vehicles, are solved successfully by their respective national experts. It stands to reason then that different educational systems can provide for the training of top-level specialists and researchers of more or less equal standing. To carry the argument further, one may suggest that it is possible to elaborate integral criteria suitable for determining a level of scientific training to be achieved with different educational systems. It would seem reasonable that such criteria should be established for completed stages of education alone. Consideration will be given in the following chapter to patterns of higher education in various countries of the world against the background of this suggestion.

Requirements to be met in training engineering personnel

Specific conditions under which engineering personnel are trained exist not only in each particular country but also at each institution of higher learning. Even the term 'higher education' seems to denote different things to different people.

There are countries in which any education based on a complete general secondary education is referred to as 'higher'. In some countries, higher education comprises a number of stages, each stage entitling the student to an appropriate degree or diploma—on completion of two, four, five or six years of study. The period of advanced studies for the highest academic degree would in some countries be regarded as the final stage of higher education. Advanced training of specialists graduated from universities is often considered as continuing higher education.

Varying interpretations of the term 'higher education' lead to high-school graduates being awarded different qualifications. It is a common practice for technical educational establishments to award the qualification of 'engineer' to their graduates, but the word is accompanied by a modifying additive to denote a specific level of schooling. As a result, a wide range of terms is in current use, such as 'professional engineer' and 'master engineer' (Poland), 'shop engineer' and 'graduate engineer' (Hungary), 'engineer' and 'graduate engineer' (Federal Republic of Germany), 'pre-engineer' and 'engineer' (Romania), 'degree-engineer' (United States), '*étudiant-ingénieur*', '*ingénieur*' and '*docteur-ingénieur*' (France), '*ingénieur diplômé*' and '*ingénieur technicien*' (Switzerland), etc.

The terms 'secondary specialized education' and 'technician' have come into being in recent years. The appearance of these terms was prompted by the expansion of specialized secondary education as an intermediate academic level between general secondary and higher. As the scientific and technological revolution got under way, researchers and engineers capable of creating sophisticated equipment, machinery, instruments and constructions, began to be in great demand in industry, agriculture and other spheres of material production. To make the work of these men more efficient, technicians were brought in on a large scale as assistants on auxiliary operations.

However, no hard-and-fast line has so far been drawn between specialists who obtain the qualification of 'technician' and those who are awarded the degree of, let us say, 'pre-engineer' or 'graduate engineer'. Nor is there any difference in the denomination of educational establishments notwithstanding the fact that some of them are intended to train technicians and others graduate engineers Yet in both cases they are referred to as higher educational establishments.

Switzerland's *écoles techniques supérieures* enrol youths having an incomplete general secondary education (nine grades) and a practical training of four years [1] An educational establishment of this kind offers a three-year course on completion of which the qualification of *ingénieur technicien* is awarded.

Practical training carried out for four years consists in mastering a worker's trade, and it terminates in the award of a federal qualification certificate (*certificat fédéral de capacité*), which serves to testify that its holder has received knowledge sufficient to qualify as a skilled worker. The certificate can only be obtained by taking an examination, which is designed to verify knowledge and check skills in the following fields: (a) workmanship, professional knowledge, mechanical drawing; (b) calculation techniques, computation, native tongue, economics.

The contents of the examination lead one to conclude that practical training does not complete general secondary education and that therefore a graduate from such an educational establishment, who is entitled to the degree of *ingénieur technicien* after three years of study, has not even a complete general secondary education.

In his article, H. A. Gonthier goes on to suggest that the content of the training programme for *ingénieurs techniciens* (non-university level) in Switzerland should be altered towards improving the general-education, scientific and engineering aspects of schooling, and raising the entrance and leaving levels of the higher technical schools at the expense of practical training. Only if this is done can engineers of this category be recognized abroad, including the Common Market countries. It has already been laid down in Switzerland as a first step towards this goal that a technician engineer is no longer expected to have experience as a worker and that he should not be assigned an 'executive' role in the shop but should rather undertake counselling and guidance activities.

In French-speaking Switzerland, graduates from the higher technical schools are entitled to take an examination to obtain the degree of *Bachelier Technique.* Those failing may sit for an examination for a federal qualification certificate.

H A Gonthier admits that the practical training of Swiss technicians does not differ in principle from that of skilled workers and consists in developing manual skills for four years. Those completing the course are also entitled to a federal qualification certificate, which makes them eligible for a two-year course of theoretical schooling in one of the following three fields of concentration: mechanics, microtechnology and electronics engineering, with a choice between construction and exploitation.

Summing up the situation as existing in Switzerland, H. A. Gonthier says:

> . la hiérarchie dans les professions techniques supérieures comporte trois échelons: les ingénieurs diplômés, les ingénieurs techniciens et les techniciens.

1 See: H A. Gonthier, 'L'Organisation d'une Formation Pratique dans l'Industrie au Benefice des Ingenieurs de Niveau non Universitaire et des Techniciens', *The Training of Professional Engineers* . . ., op. cit.

Other examples could be cited to prove that different meanings are ascribed to the words 'higher' and 'engineer', and this undoubtedly further complicates the already omplex problem of formulating methods for establishing the comparability of diplomas, certificates and academic qualifications.

At this juncture the question arises of whether such designations as 'shop engineer', 'technician engineer' or 'pre-engineer' cannot be regarded as comparable to the qualification of technician. This has a direct bearing on the idea of revising the established practice whereby the word 'higher' is attributed to whatever level of educat on is fixed above 'general secondary'. In dealing with this problem it is also important to recognize that different qualifications are involved in the training of technicians and highly skilled workers.

There seems to be no objection to considering that secondary specialized education has different levels. But, in our view, the same can hardly be said with regard to higher education. The word 'higher' suggests only one interpretation. If higher education is taken to mean two different levels it would be more appropriate to classify the first level either as incomplete higher or as, say, secondary specialized of an advanced level. The word 'higher' suggests the final stage of education. The person who has received an education at this level embarks upon the road of independent creative activity and is expected to contribute to the development of science and engineering.

If the term 'higher education' is interpreted to mean only one thing, classification of engineers into professional, graduate, non-graduate groups and so on seems hardly possible. A person can be an engineer only if he holds a diploma attesting to higher education, in all other cases, i.e. if a lower level of education is involved, he should be regarded as a technician.

The time seems to have come to revise the description of individual levels of instruction by giving each one of them an appropriate definition and possibly arriving at a qualitative criterion.

It would also perhaps be expedient to determine a specific stage of schooling at which a specialist may be regarded as having completed higher education and beyond which he is expected to perfect his academic standard through various forms of advanced training.

To substantiate the above ideas, examples of technician training procedures will be given and statements by prominent scientists on the problems raised in the foregoing pages will be quoted.

Until recently, the category of technicians was treated in some countries on the same footing as that of highly skilled workers. The Education Act passed in the Socialist Republic of Romania on 13 May 1968 stipulates (Article 122) that technical and polytechnical institutes shall be charged with the task of training pre-engineers and pre-architects as engineering personnel intermediate between engineers and technicians (foremen). Appropriate arrangements have already been made in Romania.

In the U.S.S.R., the training of technicians, which dates back to the years preceeding the October Revolution, follows two distinct patterns, on the basis of incomplete general-education secondary school (eight grades) for three to five years (depending on the field of learning chosen) from 15 to 18 or 19 years of age, and on the basis of complete secondary school for two to three years (depending on the field of learning chosen). In the former case vocational training is accompanied by completion of general secondary education. Therefore those who receive a secondary specialized education on the basis of incomplete (eight grades) or complete (ten grades) secondary school have an identical level of education. They are awarded the identical qualification of technician and are all eligible for institutions of higher learning through competitive examinations.[1]

A White Paper published in the United Kingdom,[2] admits that it is a recent trend to regard British technicians as a particular category of specialists. Many thousands of men and women are already employed as technicians and their number is growing constantly.

Technicians are trained in technical colleges. Second-grade school-leavers not below 16 years of age who have obtained a general certificate of education, ordinary level (GCE 'O'), are eligible for admission to such colleges.

There were a mere 4,000 technicians in the United States in 1920; over 1 million technicians are employed in industry at present.[3]

The methods of training technicians in the United States are also changing. While in the past they were trained during the first two years of study both at universities and colleges as well as in specialized regional vocational schools, emphasis is now laid on the expansion of the network of regional schools, with the share of the universities in this programme gradually diminishing, as may be seen from the following:[4]

There were 2,200 technicians trained at universities and colleges in 1963; 4,000 in 1970; and there are expected to be 4,600 in 1974.

There were 24,900 technicians trained in specialized vocational schools in accordance with special programmes in 1963; 66,900 in 1970 and there are expected to be 82,300 in 1974.

The United States vocational schools' curriculum of training of electronics technicians, which is the most sophisticated specialty from the point of view of the amount of theoretical courses to be studied, is composed as shown in Table 1.

Each semester lasts for fifteen weeks, making a total of 675 tutorial hours and 1,080 practical. It would seem that this allows for no more than the training of technicians.

For a long time technicians were trained at relatively few schools in France

1 Skilled workers are trained on the basis of incomplete and complete secondary school in vocational training schools where emphasis is laid on helping young people to develop skills and acquire habits of undertaking working operations. Some of the vocational training schools provide their students with an opportunity to complete general secondary education. They offer special theoretical knowledge to students to the extent required by a skilled worker.

2 *Better Opportunities in Technical Education*, p. 5, London, HMSO, 1961.

3. *Historical Statistics of the United States*, p. 75, Washington D.C., 1960.

4 *Technical Manpower Requirements, Resources and Training Needs*, p. 65 8, Washington, D.C., 1966.

TABLE 1. The United States vocational schools' curriculum of training of electronic technicians

Title of course	No. of hours per week			
	Tutorial	Practical	At home	Total
First semester				
Engineering mathematics	4	—	8	12
DC circuits	3	6	6	15
Mechanical drawing	1	6	2	9
Communications equipment	3	—	6	9
Social sciences	3	—	6	9
TOTAL	14	12	28	54
Second semester				
Engineering mathematics	4	—	8	12
AC circuits	3	6	6	15
Fundamentals of electronics	3	6	6	15
Production processes	—	3	1	4
Technological reporting	1	—	2	3
Graphic analysis	1	3	2	6
TOTAL	12	18	25	55
Third semester				
Engineering sciences	3	3	6	12
Control circuits	1	3	2	6
Electronic circuit designing	3	6	6	15
Information theory	3	6	6	15
TOTAL	10	18	20	48
Fourth semester				
Research skills	—	6	3	9
Ultra-high frequencies and microwaves	3	6	6	15
Television circuits	3	6	6	15
Industrial electronics	3	6	6	15
TOTAL	9	24	21	54

as an extra activity combined with the training of skilled workers.[1] Later the situation changed radically. The demand for technicians in industry grew roughly twice as quickly as that for engineers, resulting in a larger output of technicians, who are trained at present on two patterns (a) a three-year course for students aged from 15 to 18 at secondary educational establishments; and

1. See P. Guillen, 'L'Organisation d'une Formation Pratique dans l'Industrie des Ingénieurs Diplômes et de leurs Collaborateurs Diplômés', *The Training of Professional Engineers . . .*, op. cit.

TABLE 2 Breakdown of technical training activities

Types of academic activity	Total hours of study work	
	First year	Second year
Designing	180	180
Technology of production	30	30
On-the-job practice	135	195
Preparation	60	45
Organization of production	15	30
Metallurgy	60	—
TOTAL	480	480

(b) a two-year course for students aged from 18 to 20 upon completion of a secondary educational course.

The latter arrangement serves to train technicians of higher standing (*techniciens supérieurs*). The curriculum for training *techniciens supérieurs* stipulates 1,035 academic hours for each year of study, of which 555 hours are allotted to general-education disciplines and 480 hours to technical training.

Techniciens supérieurs are normally employed as assistants to engineers in realizing engineering projects. They are trained at technical *lycées*, formerly known as *écoles nationales professionnelles*. In 1965, the training of specialists of this category was begun in *instituts universitaires de technologie* (IUT), graduates from these institutes being awarded a *diplôme universitaire de technologie* (DUT).

According to R. Alquier,[1] professional maturity acquired through purposeful activity can bring the knowledge of *techniciens supérieurs* and specialists holding the *diplôme universitaire de technologie* to the level of applied knowledge, which places them on the same footing as *ingénieurs techniciens* in some countries.

In the Federal Republic of Germany, skilled workers receive advanced training to become technicians, primarily in off-work hours (part-time study). A network of technical schools (*Fachschule*) has been set up for this purpose, with a three-year course for part-time students and a one-year course for full-time students. To be eligible for a part-time course, an applicant must hold a certificate attesting to an eight-grade secondary education and have a service record of at least two years as a skilled worker or three years to be eligible for a full-time course. A person can become a skilled worker by going through an apprenticeship of three to three and a half years. The curricula of technical schools are not intended to offer students a more or less comprehensive general education. More than 75 per cent of the course time is allotted to mastering special technical subjects, i.e. to acquiring professional knowledge, which is facilitated by the long industrial experience young people possess when commencing their studies at such schools.

1. R. Alquier, 'La Formation des Ingénieurs et des Techniciens Supérieurs en France', *The Training of Professional Engineers* ..., op. cit., p. 23.

In addition to technical schools (*Fachschule*), there are engineering schools (*Ingenieurschule*) in the Federal Republic of Germany which admit young people with an incomplete secondary education and an apprenticeship of two years. The schools provide a three-year course, the instruction time being divided between the various sets of disciplines roughly as follows. 30 per cent for general science subjects (mathematics, physics, etc.), 50 per cent for special technical, and 20 per cent for social and economic (political economy, industrial organization and management, etc.). These figures prove beyond doubt that the engineering schools in the Federal Republic of Germany do not provide for completion of secondary education.

The ratio of graduate engineers to professional engineers, as trained by the engineering schools, is 1 : 2, and it is planned to bring this ratio to 1 : 4

A trend became manifest in the Federal Republic of Germany as far back as 1969 to re-organize the engineering schools to ensure a higher academic level of their curricula and syllabuses.

In his book *Vocational and Technical Education*,[1] H. Warren compares the content of schooling at educational establishments training technicians in the United Kingdom, the United States and the Federal Republic of Germany and arrives at the conclusion that the level of education in accredited junior colleges in the United States is bracketed between those determined by the ordinary and the higher national certificates awarded by technical colleges in the United Kingdom In the view of British experts, comparison of these levels of education is made difficult by the fact that the curricula of junior colleges in the United States contain a wider range of disciplines than those of technical colleges in the United Kingdom. At the same time it should be noted that courses are studied more thoroughly in British than in American colleges.

Warren believes that the technical schools (*Fachschule*) in the Federal Republic of Germany are lower in level than technical colleges in the United States and the United Kingdom, and concludes that the *Fachschule* actually graduate technicians.

Yet the level of education attained by graduates from the engineering schools in the Federal Republic of Germany is, in Warren's view, somewhat higher than that attained by British technicians holding the higher national certificate.

As has been pointed out earlier, if one attempts to analyse the curricula of secondary specialized educational establishments a great deal of difference will be found in the education of technicians both as regards the volume of study matter and its content.

For example, the total number of hours allotted at the secondary specialized educational institutions in the United Kingdom to theoretical studies leading to a higher national certificate amounts roughly to 2,000, with 1,500 hours being set aside for this purpose at the technical schools in the Federal Republic of Germany, 4,500 at the engineering schools in the same country, 4,400 at

1. H. Warren, *Vocational and Technical Education, a Comparative Study of Present Practice and Future Trends in Ten Countries*, p. 129. Paris, Unesco, 1967. (Monographs on Education, VI)

the techn al *lycées* in France, 1,000 at the regional professional schools in the United States and from 2,200 to 3,800 hours at the specialized secondary educational establishments in the U.S.S.R.

The largest amount of time devoted to laboratory work and on-the-job practice is in the technical schools of the Federal Republic of Germany and those educational institutions in the United Kingdom which award their graduates the higher national certificate. A larger proportion of instruction time at these establishments is devoted to operations normally performed by skilled workers, and practical habits required to perform working operations.

In a number of countries emphasis was previously laid on development of the network of secondary specialized educational establishments which enrolled teenagers holding certificates attesting to a secondary education at the level of seven to eight grades, but in recent years the trend has been towards secondary specialized educational establishments operating on the basis of complete secondary school as well as institutions which not only offer their students special knowledge but also give them a possibility of completing general education, provided they have graduated from an eight-grade secondary school.

It follows from the above that secondary specialized education is obtained in two ways:

1 Through vocational secondary education on the basis of seven to eight grades of secondary school, offering a relatively limited volume of special theoretical knowledge but providing for serious practical skills and a good knowledge of industry. An education of this kind is offered at the vocational training schools in the U.S.S R., technical *lycées* in France, technical schools in the Federal Republic of Germany, technical colleges in the United Kingdom at the level determined by the ordinary national certificate, and some others For all intents and purposes these educational establishments can be said to train skilled workers.
2 Through secondary specialized education of an advanced level (training of technicians) on the basis, as a rule, of complete secondary school, with provision for the study of theoretical disciplines and the acquisition of practical knowledge, to an extent sufficient to enable those concerned to carry out projects under the supervision of the engineers responsible for devising the projects, or to fulfil technico-economical and managerial functions in industry, construction and other branches of the national economy, likewise under the supervision of engineers. In some countries education of this kind is also provided on the basis of eight grades of secondary school, but in this case the duration of instruction is longer to allow students to complete general education and master the same amount of theoretical and special disciplines.

Those receiving secondary specialized education of an advanced level are eligible for universities and equivalent higher educational establishments.

Engineers with a higher education (graduate engineers) are trained on the basis of a complete secondary education in all countries.

An analysis of the duration of studies at university-type technical educational establishments in various countries, will reveal that the length of the course is roughly five to six years, the only difference lying in the arrangement of the course some institutions of higher learning practise a continuous (uninterrupted) instruction for five to six years (U.S.S.R.), others take it up in two or three stages (United States, United Kingdom, France), with on-the-job training being undertaken directly in commercial firms upon graduation from an institution of higher learning.

The United Kingdom and United States systems of education envisage two or three professional degrees, including those of Bachelor and Master, which are awarded on completion of a course of three to four and four to five years respectively. In addition to these, the Massachusetts Institute of Technology (United States) has introduced a degree of Engineer which can be obtained by holders of the degree of Bachelor following an additional course of study for approximately two years.

There is a trend in most countries to raise the academic standard of specialists trained for employment in industry. W. Leighton Collins[1] claims that engineers holding the professional degree of Master or the academic degree of Doctor are graduated by higher schools in the United States in ever-growing numbers. The ratio of Bachelor to Master to Doctor in engineering in 1970 was about 11.4 : 4.4 : 1.0; for 1978 the prediction is about 7.2 : 4.3 : 1.0.

Collins goes on to say in his article that:

> . . . to provide even the really able student with the tools required to work effectively on today's most challenging problems a coordinated fifth year of study leading to a Master degree becomes a virtual necessity, particularly for the student ambitious to assume a role significant in his profession. The fifth year of study would stress professional specialization, would be part of the basic education expected for entry into the profession, and would lead to a prestigious professional degree, perhaps to be called Master of Engineering. . . . Support personnel, the rapidly increasing number of graduates from four-year 'bachelor degree' engineering technology curricula and technicians, have relieved the engineer of many routine tasks and enable him to work at a higher technical level than in past years. A large industry questioned its managers of engineering, manufacturing, and technical marketing, and the study revealed 'that today's graduates possess more technical knowledge than their predecessors and that they expect to utilize it more effectively and more quickly than their counterparts of 15 years ago'. The study also indicated a need for engineers to understand the total business, to be aware of the contributions and interface with other functions, the need for interdisciplinary approaches, and the need for a systems approach.

Reasoning of this sort is worthy of consideration. Indeed, there is hardly an industry today in which an engineer would not be required to tackle a whole range of technological, theoretical, designing and other complex problems while ensuring the normal manufacturing process. If that were not the case, he would not be able to contribute to scientific and technological progress in the industrial enterprise he works for.

1. W. Leighton Collins, 'Professionalism in the Education of Engineers in the United States of America', *The Training of Professional Engineers . . .*, op. cit.

That is why the so-called 'shop engineer' or 'professional engineer' must be a pure scientist, a designer, an economist and a sociologist at the same time, just as a designer would not be able to create a machine without knowing the technology and economy of its production.

It would be appropriate in this connexion to recall the definition of the professional engineer given at the Conference of Engineering Societies of Western Europe and the United States in 1953. A professional engineer, it was claimed, is competent by virtue of his fundamental education and training to apply a scientific method and outlook to the analysis and solution of engineering problems. He is able to assume personal responsibility for the development and application of engineering science and knowledge, notably in research, designing, construction, manufacturing, superintending, management and in the training of other engineers. His work is predominantly intellectual and not of a routine character, mentally or physically. It requires the exercise of original thought and judgement and the ability to supervise the technical and administrative work of others. His education will have been such as to make him capable of closely and continuously following progress in his branch of engineering science by consulting newly published work on a world wide basis, assimilating such information and applying it independently.[1]

This definition describes vividly the high level of education of an engineer attained through a thorough study of fundamental disciplines and stimulation of his faculty for research The next stage of advancement of an engineer is his research career, i.e. proceeding to academic degrees.

A peculiar feature of the scientific and technological revolution is that it implies higher requirements which engineers should be able to meet, and raises the level of their education to that of graduate engineers, as was pointed out by the Working Group of the United Nations Economic Commission for Europe.[2]

Engineers must be specialists of exceptional quality at present, otherwise they might as well be assigned to the category of technicians. Therefore, only those higher-school graduates should be classed as engineers who by their level of education are entitled to proceed to initial academic degrees--a Candidate of Science, a Ph.D., etc.

While raising the scientific level of education of engineers one must not overlook the practical training which must be carried out in organic unity with theoretical schooling Practical training, which can take the form of a one-year probationary period at the industrial enterprise where a prospective engineer's professional activity is to take place, should be completed by the time he graduates from the higher educational establishment.

One is bound to agree with W. Leighton Collins[3] when he says that the

1. After I. E. Gerstle, S. H. Hutton. *Engineers. The Anatomy of a Profession. A Study of Mechanical Engineer in Britain*. p. 4 5, London, 1966.
2. After *The Political Quarterly*, No. 1, 1967, p. 49.
3. Leighton Collins, op. cit.

education of an engineer is a combination of the best efforts of educational institutions and industry.

The fundamental aim of practical training for would-be engineers is adequately described by R. A. Grossfeld[1] who suggests that practical training of undergraduates in industry should be designed to (a) favour human contacts outside the campus, (b) help the undergraduate to apprehend the general aspects of industrial life and the position of the engineer in the industrial environment, (c) demonstrate the technical and psychological obstacles likely to be encountered in the course of the development of practical plans, and (d) give precise ideas about the importance of phases of development and production.

To what extent an engineer is qualified for his post becomes evident when he actually pursues his career. However, successful professional life depends primarily on the level of education obtained at a higher educational establishment, as evidenced by the diploma. Hence, whenever the problem of comparability of diplomas comes up for discussion, it should be approached from the point of view of comparability of the levels of education at institutions of higher learning. To put it in a nutshell, when attempting to solve the problem of comparability of diplomas we shall do well to consider the theoretical and practical knowledge obtained by an engineer at an institution of higher learning rather than his achievements due to extra training directly in industry and to industrial experience, which may have made it possible for him to obtain an engineer's licence from a professional society.

All this naturally makes it necessary to determine the content of schooling and the length of instruction for a modern engineer of the type known as a graduate engineer in some countries.

In view of what has been said above, a graduate engineer, in our view, should, (a) have a fundamental schooling in a wide range of sciences and general engineering disciplines, have cognizance of modern scientific and technological achievements and be able to apply this knowledge under varying conditions to solve specific problems both in the field of technological processes and in designing new machinery and equipment, (b) have a knack for methods of research and experimentation both in laboratory and industrial conditions, (c) be an expert in his own professional area, (d) advance his educational standard incessantly and be familiar with methods of self-instruction, in order to keep his knowledge up to date in terms of the latest achievements of science and technology.

To what extent higher schools in various countries achieve the goal of training engineers meeting the above requirements will be shown in the following pages.

No less complicated is the problem of establishing a boundary between the periods in which a higher education is received and researchers are trained.

In a number of countries, graduates from institutions of higher learning

1. R. A. Grossfeld, 'L'Organisation d'une Formation Pratique dans l'Industrie au Bénéfice des Ingenieurs de Formation Universitaire', *The Training of Professional Engineers . . .*, op. cit.

who complete the first stage of schooling and obtain a Bachelor's degree are considered specialists having a complete higher education, and their further education with a view to proceeding to, let us say, a Master's degree (United States), is said to be associated with a graduate course or with a possible research career

The American *Report on Higher Education*[1] states that:

> A fundamental difference between undergraduate and graduate education is that we expect the former to be a generalized learning experience. . . . Graduate education is, presumably, training for a career.

It would seem that undergraduate education is also aimed at a career.

There are no changes in principle in the character of tuition at the second stage of a Master's degree course, as compared with the first stage.

What students of both the first and second stage are supposed to do is learn generally known achievements of science, technology and culture, and acquire a knack for correct methods of conducting research both theoretical and experimental thereby obtaining new results which may, however, have no decisive impact on the development of specific branches of science and technology.

It should also be borne in mind that the requirements which those proceeding to a Master's degree should meet differ a great deal In the United States of America, for example, a Master's degree is awarded at some institutions of higher learning after completion of a one-year course without any finalizing examinations and on presentation of a diploma paper, and at others after special examinations and presentation of a dissertation.

At the Massachusetts Institute of Technology (MIT), a Bachelor's degree holder, as pointed out above, has the option of choosing between the two possible lines of further study either proceeding to a Master's degree by taking a further one-year course, or proceeding to the degree of Engineer by taking a two-year course Hence, if the length of the course is what matters most, the degree of Engineer awarded by MIT is considered to be superior to that of Master.

Bernard Berelson, a prominent expert in the field of education in the United States, writes in one of his works[2] that an academic degree calls for a knack for research and an independently written paper, whereas the bulk of papers prepared with a view to obtaining a Master's degree today cannot be classified as research papers. They are ordinary course papers appropriate for fifth-year students.

In its report entitled *Goals of Engineering Education*, made public in January 1968, the Committee for Studying Engineering Education Goals, set up by the American Society for Dissemination of Technical Knowledge, arrives at the conclusion that, as the professional field is perfected and developed, an

1. *Report on Higher Education*, p. 36, United States Department of Health, Education and Welfare, 1971.
2. B Berelson, *Graduate Education in the United States*, p. 186, New York, N.Y., 1960.

academic degree which used to be regarded as 'higher' comes to be recognized as 'basic'. The report goes on to say that the committee recommends that the degree of Master be generally accepted as a basic degree for the professional field of engineering.

With reference to the United Kingdom, a study entitled *Les Etudes Supérieures, Presentation Comparative des Régimes d'Enseignement et des Diplômes*, prepared at the request of Unesco, says that the second stage of instruction lasting one year is aimed at enlarging knowledge and experience and leads to a Master's degree.

The third stage, intended for a more profound study in the specialized field and for independent research work, should be completed within a minimum of two years and terminates with the presentation of a dissertation for the degree of Ph.D.

In the section entitled 'France' the same study states that the second stage corresponds to that cycle of instruction for which a higher training certificate (*Certificat d'Etudes Supérieures CES*) is awarded Two years of study at the philological and natural science departments (*facultés de lettres et de sciences*) entitle a student to the degree of Master (*Maitrise*).

The third stage is that of majoring. Research work is conducted at this stage, which culminates in a higher education diploma and a doctoral degree of the third cycle (*Doctorat de Spécialité du Troisième Cycle*) in the specialized field chosen.

The doctoral degree of the third cycle of instruction is comparable to the higher education diploma (DES). In the case of the natural sciences departments, this degree is awarded after a course of at least one year, providing the candidate holds an advanced training diploma (natural sciences) (DEA).

It is further stated that this stage of instruction may be followed by research and, upon presentation of a dissertation, the degree of *Ingénieur-Docteur*, *Grade Universitaire*, *Doctorat*, or *Doctorat d'Etat* is granted.

It emerges from the study that the degree of *Licence* testifies to the completion of higher education at an intermediate stage of an extremely narrow specialized field, and the degree of *Maitrise*, to the completion of such an education at the level of the second cycle without writing a diploma paper and without taking on-the-job training at an industrial enterprise or an office in the field of concentration The holders of the degrees of *Licence* and *Maitrise* can hardly be classified as researchers, since they do not actually receive practical knowledge.

In the U S.S.R , the first academic degree is that of Candidate of Science in a chosen field of learning. Those who proceed to the degree of Candidate of Science are expected to possess a diploma attesting to higher education and to complete a three-year post-graduate course, prepare a thesis, which should include theoretical and experimental research, and defend the thesis in public. Before the thesis comes up for defence, its substance should be covered in articles in scientific magazines or published in the form of a monograph, and the candidate is also under an obligation to submit an abstract and circulate it to all research and educational institutions as well as to individual scientists engaged in the field of learning concerned.

The highest academic degree is Doctor of Science, and the procedure for obtaining this will be described below.

It stands to reason from this analysis that the degrees of Bachelor, *Licence*, Master and *Doctorat de Spécialité du Troisième Cycle* are professional degrees, while the first academic degrees include those of Candidate of Science, Ph.D., *Ingénieur-Docteur* and the like. This does not mean, however, that the academic degrees enumerated here are all comparable.

The award of professional degrees does not presuppose the solution of new problems, a contribution to the development of certain branches of science or the undertaking of large-scale theoretical and experimental research. They should therefore only be regarded as determining the level of education and the qualifications of a specialist.

Candidates for academic degrees who are prospective researchers (scientific workers) tackle only problems ensuring the further development of science, technology and culture. They utilize knowledge from new branches of science to the extent required to solve the scientific problems they are assigned.

Hence, the study of individual branches of science, technology and culture with a view to mastering scientific methods of research is the objective in the former case; the solution of new problems contributing to scientific and technological progress and an additional study of such achievements of the scientific world as are indispensable for the solution of the problem under study are the objective in the latter. To use a still briefer formulation, a student studies the known and masters the research methods, a candidate for an academic degree discovers fundamentally new elements in science and technology.

In view of the above it would seem reasonable for comparability of diplomas to be established at the following levels of education and candidacy for academic degrees:

Level 1. General secondary education, which ensures eligibility for a university or similar institution of higher learning.

Level 2. Secondary specialized (vocational) education on the basis of incomplete secondary education, which provides for some theoretical as well as practical knowledge in a specialized field and for the practical abilities required by a skilled worker. Those receiving an education of this kind can be employed in their occupational area in various branches of the national economy as skilled workers.

Level 3. Secondary specialized education of an advanced type, on the basis, as a rule, of complete general secondary education, providing for a fairly comprehensive general science and practical training. Those receiving an education of this kind can be employed in various branches of the national economy, design offices, research institutions and in the civil service, in the capacity of technicians, assistant engineers and even engineers entrusted with the supervision and control of technological processes, as well as the operation and maintenance of machinery, equipment and constructions.

Level 4. Higher education providing graduates with a high qualification as specialists and entitling them to fulfil independent work in their professional fields in industry, at research, design or other institutions in the Civil Service, or as tutors in educational establishments, as well as making them eligible to go on to post-graduate study or proceed to the first academic degree of Ph.D., Candidate of Science, *Doctorat d'État*, and the like.

Level 5. The first academic degree of Ph.D., Candidate of Science, and the like.

Level 6. The second academic degree, such as a Doctor of Science in the U.S.S.R. and the other Socialist countries, and the like.

There is no hard and fast line between the various levels of education and candidacy for academic degrees. The levels traced above can only be regarded as statistical averages having a good deal of accuracy.

When trying to establish the comparability of diplomas it is indispensable to have some idea of what specific levels different kinds of diplomas are related to.

Trends in the development of higher engineering education

Now that the scientific and technological revolution is at its height and the volume of scientific information is growing incessantly, study matter is subject to constant change, new disciplines are being introduced in the curricula, and fundamental changes are taking place in the content and methods of instruction at all institutions of higher learning.

Hence, even if the curricula and syllabuses of two higher educational establishments are found to be identical at a given time this identity may cease to exist at a later date. Yet one cannot fail to observe a common trend in the development of higher schools the revision of curricula and syllabuses to lay emphasis on the general theoretical background of engineer training. In accordance with this aim, majoring is, as a rule, shifted to the senior years of schooling or sometimes beyond the actual university (college) course, in which case it takes place directly within industrial firms. In other words, the prevailing trend consists of making schooling in the fundamental disciplines the decisive component of the engineer training programme.

The department of education of the British Metropolitan Vickers Electrical Co. recommended that highly specialized subjects should not be included in the programme for the first professional degree, which should be primarily devoted to the study of the fundamental principles underlying the professional courses.

> It was desirable in this respect that a larger contingent of excelling undergraduates should take the programme of the fourth year of study.[1]

It was obviously presumed that the fourth year should be reserved for courses belonging to the fields of concentration

In line with recommendations of this sort, the traditional three-year course for the degree of Bachelor is to be extended by a year at some universities and technological institutes in the United Kingdom, in other words, a four-year course of theoretical study is being instituted at some colleges.

Experience proves that it is next to impossible to foresee problems that engineers will have to tackle in the future. Who could have predicted twenty or twenty-five years ago that the students of the time would develop supersonic aircraft or automatic devices to be delivered to planets of our universe for the

1. *The Complete Scientist*, p. 66, London, 1966.

transmission of valuable information? Those who ventured to discuss projects of this kind were said to be science-fiction writers bent on foreseeing a far distant future instead of predicting events to be witnessed by the living generation Therefore any attempt to visualize the problems that prospective specialists university students of the 1972 75 enrolments may have to come to grips with and, in the light of those problems, to specify the content of undergraduate training would be hopeless.

Study matter should be selected, at the present time, to cater for the possibility of extensive development of students' creative thinking, resourcefulness and faculty for applying theoretical and professional knowledge to finding original solutions in the most unpredictable situations. The students' memory need not be overloaded with study matter which does not serve the purpose of developing their creative thinking and resourcefulness and which is only needed to obtain specific solutions. Study matter of this latter character, which in most cases amounts to reference material, can be obtained by students from the information system which is constantly kept up to date One of the basic aims of an institution of higher learning is therefore to shape the programme of instruction so as to ensure that the student masters methods of singling out the required sub-system from the infinite system of knowledge, thus enabling him to solve essential problems posed by society in his future professional life Students must be taught to use the information systems to store solutions which they may have found and which can still be of use at a later date. In this connexion, the study of information systems and the development of techniques to employ them are an indispensable component of the programme intended to train the specialists of the future.

Employment of a wide range of technical aids and modern methods of teaching to intensify instruction and the individualization of tuition are a major concern in all technical schools and their departments. Problems involved in this field are considered to be the most important in pedagogics. The changing purposes and content of laboratory work constitute substantially new features in the training of engineers. Laboratory work tends to turn into experimental research.

In one of the issues of its *Bulletin*, the Massachusetts Institute of Technology expresses the same view when it says that laboratory subjects are intended to teach a technique of experimentation rather than illustrate the subject matter of lectures Illustrations are offered when demonstrating theoretical study matter during lectures.[1]

The task of the higher school is to find the most effective methods for developing the students' faculty for systematic independent renewal of their knowledge since it depreciates at an ever-faster pace. Hence the modern system of education must be capable of developing students' creative faculties, the habit of raising their level of education systematically and incessantly upon graduation from higher school for the entire duration of their professional life, it must be capable of instilling in them a taste for self-education.

1. After: *Technical Education in the USA*, London, 1962.

Practical training in the course of theoretical schooling and during probation after graduation from an institution of higher learning is an important part of the education of a creatively minded engineer. Practical training introduces a prospective engineer to the workshop atmosphere, helps him to understand the main aspects of industrial life and the position of an engineer in this environment, and makes it easier for him to apprehend technical and psychological obstacles to be surmounted when carrying out engineering projects under industrial conditions. It is through practical training that undergraduates learn methods whereby workshop teams translate engineering projects and designs into reality, and how to find more rational technological solutions. Again, it is practical training that is instrumental in fostering engineering intuition which enables an engineer to determine readily whether a specific engineering solution is technically and economically worth while, and, if need be, to make the appropriate corrections.

Practical training cannot serve its purpose unless it is extended beyond higher-school laboratories and workshops. True, an undergraduate must be given a chance to acquaint himself with the component parts of the technological process and to acquire practical skills while at a higher educational establishment, but such activity is no substitute for undergraduate industrial training or probation upon completion of the theoretical course at larger industrial units. Factory training and probation must be sufficiently long, well-organized and co-ordinated with theoretical schooling.

Despite the fact that the significance of practical training for the education of engineers is widely recognized, it is still neglected in some countries, and different points of view are voiced in this respect, for example, in Switzerland.[1]

Practical training is optional for undergraduates in some cases and is in fact postponed until they commence their professional activity in industry.

Great importance is attached to the practical training of engineers in the Federal Republic of Germany, where it is divided into two parts, a basic practical training course (*Grundpraktikum*) and a specialist practical course (*Fachpraktikum*).[2]

The basic practical training course of three months is to be followed in the college workshops and apprentices' workshops in industrial firms before the theoretical course begins. This part of practical training is intended to give the students an idea of materials and how to treat them, as well as of the technology of production in the field of learning chosen.

The specialist practical course is undertaken as a rule in industrial firms after a basic study course of one to two years. This three-month course may take place during vacations.

The specialist practical course is aimed at obtaining. (a) professional knowledge of the production process, (b) knowledge of technical interrelations as well as economic, organizational and social interrelations in production and

1. See R. A. Grossfeld, op. cit.
2. See P. Borner, 'Praktische Ausbildung – wesentlicher Bestandteil der Ingenieurausbildung in der Bundesrepublik Deutschland', *The Training of Professional Engineers* . . ., op. cit.

management, (c) notions of the particular features of a specific manufacturing unit, and (d) human experience as a prerequisite for professional activity.

The specialist practical course completed, students are required to work at an industrial enterprise for six months.

The sandwich system in the United Kingdom and the co-operative programme in the United States are both intended to ensure organic unity between theoretical schooling and practical training.

The above considerations lead one to conclude that practical training does constitute an essential component of the education of the modern engineer.

In the U.S.S.R., industrial training is required in all branches of engineering study and generally takes place at the end of each year of study, amounting to an aggregate of at least six months.

The completion of the course in a higher education establishment and the defence of a diploma project (diploma paper) are followed by a one-year probation period in an industrial enterprise to which the young engineer is sent to work as a staff member. The content of probationary activity is determined by a programme worked out by the industrial enterprise concerned on the basis of the standard programme elaborated by the industrial ministry in question and approved by the Ministry of Higher and Specialized Secondary Education of the U.S.S.R. Probation is the final stage in the education of engineers before post-graduate education (advanced training).

An efficient academic staff, composed of people actively engaged in research who maintain personal contact with undergraduates, is another essential condition for the successful training of highly qualified specialists.

The length of the course may vary, as pointed out above.

Engineer training at higher educational establishments in the United States comprises several stages:

Stage One. Theoretical schooling (without factory training) for four years, during which time a paper meeting the requirements laid down for a Tech.B. is prepared and submitted. Should factory training accompany theoretical schooling (co-operative programme) the over-all length of the course is extended by one year.

Stage Two. Theoretical schooling (also without factory training) for one year, during which time a paper meeting the requirements laid down for a Tech M. is prepared and submitted.

At the Massachusetts Institute of Technology, Stage Two may last for two years if a student wishes to proceed to an Engineer's degree.

In all cases graduates from higher school undergo additional training in the form of probation in industry.

To sum up, the over-all length of the course to train an engineer of any denomination (less probation in industry) lasts from four to six years.

Engineer training in the United Kingdom also comprises two stages:

Stage One. Theoretical schooling at universities and colleges for three years or at colleges of advanced technology for four years, terminated by preparation and submission of a paper meeting the requirements laid down for a Tech B.

Stage Two. Additional schooling for one year to enable students to claim a Tech.M.

In both stages, factory training in industry lasting one to two years is provided for.

In the case of some specialized fields of learning which involve subject matter of extreme complexity and which are closely related to actual industrial production, a specific type of instruction is practised, this is the 'sandwich' course, consisting of alternate periods of college education and factory training. This form of instruction, which has assumed impressive proportions, takes two forms.

The first is what is called the 'thick sandwich'. Under this arrangement students are required to work in industry for one year. Then come three years of full-time study This period over, the students are again sent to industry for probation, which is combined with theoretical schooling. In other words, the system functions on the formula 1 3 1, the over-all length of the course being five years.

The second form is the 'thin sandwich', which stipulates six-month alternate periods of industrial training and theoretical schooling for four to five years. In this way the over-all length of theoretical schooling comes to twenty-four to thirty months.

If one takes into consideration that ordinary educational establishments reserve thirty to thirty-two weeks for the theoretical course in each study year, it appears that both the 'thick' and the 'thin' sandwich patterns provide for an over-all theoretical course roughly equivalent to between three and four years of study

Those who wish to proceed to an M.Sc. can avail themselves of the Bosworth course[1] which provides for nine months of instruction and a brief period of factory training in preparation for this degree in a specialized technology (mechanical engineering and electric power engineering).

Thus, those seeking a Master's degree must study for five to six years, including practical training before or during the theoretical course.

In France, engineers are also trained in two or three stages, with the over-all length of the course being five to six years

In the U S S R , engineer training occupies five to six years straight without any intermediate stages After preparing a diploma project (diploma paper) and defending it before the State Examination Board, the student is awarded an Engineer's qualification. He must then undergo probation at the place of his future professional activity, during which time he studies the specific features of its production, technology, organization and economy, wage policy, labour protection arrangements, etc.

It is impossible to establish exact periods within which engineers can be

1 See *First Bosworth Report Education and Training Requirements for the Electrical and Mechanical Manufacturing Industries*, London, HMSO, 1966.

trained, and a difference of a half year or so is possible either way. The length of training depends on the fields of major study, methods of tuition and many other factors. Thus, for example, in the U.S.S.R. the most sophisticated specialties requiring an extremely high level of mathematical training or a thorough knowledge of computer equipment and techniques employed in new branches of industry, call for a particular arrangement whereby engineers are trained in two stages: first, for five to six years, during which time a diploma paper is prepared and submitted for the qualification of engineer in the professional area chosen, and second, for two years, during which time another diploma paper is prepared and submitted for the qualification of engineer mathematician. However, exceptional cases of this character should be considered separately.

In view of what has been said above it would seem that the problem of comparability of diplomas, certificates and education cannot be solved in a formal way by comparing the syllabuses of individual disciplines and the instruction time allotted to the study thereof. The level of education depends not only on the study courses and their contents but also on how they match one another and whether instruction time is divided among them harmoniously. It depends on the entire structure of tuition, methods of teaching, academic qualification of the teaching staff, and many other factors.

All this prompts the idea of establishing integral criteria to determine the academic level of education and the standard of training of specialists.

Each branch of instruction (engineering, medicine, philology, etc.) will have criteria of its own, yet methods of arriving at them may prove to be common to all branches. A method of determining an integral criterion as applicable to technical education is described in the following pages.

Criteria determining the level of engineering education

All things considered, it is the total number of hours S_t allotted to compulsory classes with an academic adviser that determines the over-all level of education in the first place. Hence, the total amount of compulsory classes with an academic adviser S_t expressed in terms of hours is one of the basic criteria of the level of education.

These hours S_t are distributed in accordance with the curriculum among many disciplines which can be grouped as follows: (a) general science and general engineering disciplines; (b) professional disciplines; (c) humanities.

Group (a) comprises: (i) all courses of abstract (pure) and applied mathematics; (ii) all sections of physics; (iii) all sections of chemistry; (iv) theoretical mechanics (statics, kinematics and dynamics of solids); (v) political economy.

Group (b) includes: (i) descriptive geometry and graphics (or mechanical drawing); (ii) strength of materials, including theoretical elasticity (statics and dynamics of elastic body); (iii) constructional mechanics (statics and dynamics of elastic systems and their stability); (iv) mechanics of fluids and gases; (v) electrical engineering; (vi) thermodynamics, including heat transfer; (vii) theory of machines (applied mechanics); (viii) information systems (computers, systems of automatic control and the like).

The groups of general science and general engineering disciplines determine the academic standard of education. There is a current view that it is not reasonable to place these subjects in two different groups. True, they could all be considered general science disciplines in the case of technical areas of study. However it is not, in principle, of critical importance whether the general science and the general engineering disciplines are separated into two groups or regarded as a general science group. What is important to emphasize is that there is a unanimous opinion that the general science and general engineering disciplines constitute the foundation of engineer training. When studying these disciplines the students develop their creative thinking to the fullest capacity. The scope of the engineer's professional area is also determined by the volume and content of the general science and general engineering disciplines which underlie all professional subjects. These same groups teach students to handle information systems and computers which have come to be the engineer's principal tool in his professional activity.

It is interesting to note in examining the curricula and syllabuses of leading technical institutions of higher learning in the more developed countries, that the titles of general science and general engineering disciplines as well as the distribution of study matter among them do not coincide. Yet if one summarizes all the study matter which should be related either to the general science group or to that of general engineering disciplines, it appears to be more or less identical both in volume and content provided the length of the course is five to six years long. Therefore, when establishing comparability of education, consideration should be given to the share of the general science and general engineering disciplines in the engineer training curriculum. This share will be the basic characteristic of the academic level of education of specialists at the institution of higher learning concerned.

The idea of comparing the syllabuses of identical disciplines with a view to establishing whether or not they are uniform as to content seems hardly practicable. It would require an immense amount of work for each specialized field of learning, and it can be asserted that coincidence would not be registered for a single discipline. When examining the curricula and the over-all pattern of tuition at engineering departments it is essential to determine a point of paramount importance whether conditions have been created under which the student, along with the thorough theoretical schooling that he obtains in the sciences, is given the possibility of developing his ability to proceed from general ideas, at times vaguely formulated, to specific solutions useful for society.

In the case of some higher educational establishments, the programmes are so brief that it is quite impossible to judge the volume and content of a course with any degree of accuracy.

The Civil Engineering Department of the Massachusetts Institute of Technology may be taken as an example. Its courses 1.01 (Engineering Mechanics), 1.03 (Engineering Analysis) and 1.04 (Analysis and Design) are summarized below.

1.01 Engineering Mechanics. Static behaviour of rigid and deformable bodies with primary emphasis on deformable systems.

. . . .

1.03 Engineering Analysis. Mathematical formulation of engineering problems, solutions and physical interpretations of results. Differential equations.

1.04 Structural Analysis and Design I. The analysis of determinate and indeterminate structural systems and the design of structural elements. Basic force-deformation relationships for member elements.[1]

Sixty academic hours of compulsory classes and 120 for preparation are provided for Course 1.01, 60 hours of compulsory classes with tutor and 120 of preparation are provided for Course 1.03, and 90 hours of compulsory classes with tutor and 90 hours of preparation are provided for Course 1.04.

These courses are essential for the training of a civil engineer, and the teaching time allotted thereto can be considered sufficient. However, such laconic syllabuses make it impossible to judge the content of the courses. Intuition alone prompts the conclusion that the level of the above courses is

1. *Massachusetts Institute of Technology Bulletin 1970/71.*

sufficiently high For this reason, the level of undergraduate training can only be determined by the number of academic hours allotted to the study of various courses.

The fundamental course is also important from the point of view of determining the level of development of a student in a specific branch of science. If, for example, the over-all number of hours allotted to the course of higher mathematics in identical fields of major studies is the same at two institutions of higher learning, with emphasis being laid on probability subjects at one institution and on vector algebra at the other, it may be safely presumed that the level of mathematical schooling is the same at both institutions. Even if it appears that the programmes for identical subjects are absolutely identical at both institutions (which is most likely not the case), their realization depends in the final analysis on the lecturer, his scientific standing and the pedagogical school he abides by, and it is wishful thinking to expect that different lecturers can present one and the same course in an absolute identical way.

It would seem desirable to characterize each aspect of undergraduate training in terms of non-dimensioned parameters, for example, as a ratio of the total number of hours reserved for tutorial classes in the general science and general engineering disciplines to that stipulated for all tutorial classes for the entire period of undergraduate study at a higher technical school. In fact this particular parameter determines the share of this group of disciplines in the curriculum.

The share of the general science and general engineering disciplines can be derived from the following dependence:

$$K_1 = \frac{S_{se}}{S_t} \qquad (1)$$

where S_{se} stands for the total number of hours reserved for the study of general science and general engineering disciplines in the curriculum.

The relative share of the disciplines falling within the group of professional subjects and the humanities can also be derived from the formulae:

$$K_2 = \frac{S_p}{S_t} \qquad (2)$$

$$K_3 = \frac{S_h}{S_t}. \qquad (3)$$

Obviously, $K_1 + K_2 + K_3 = 1$.

The final stage of instruction is a diploma paper (or a diploma project), which is supposed to be an independent piece of serious research, a dissertation, arousing theoretical interest and having applied significance This work should testify to the maturity of a higher school graduate and his ability to solve important engineering problems. Whatever new device an engineer is expected to create he does a the initial stage in the process of de gning. His design should be aimed at solving the problem of developing machinery or structures, meeting the requirements of society and, at the same time, respecting criteria reliability, longevity, economy, safety in production and maintenance and a number of other features. Many requirements prove incompatible. for example, it is sometimes impracticable to ensure both longevity and economy. An engineer is obliged to seek optimal compromise solutions, and a student's skill in finding such solutions is an important indicator of the level of his training.

The share of a diploma paper (or a diploma project) can be derived from the formula:

$$K_4 = \frac{S_d}{S_t} \qquad (4)$$

where S_d is the number of hours allotted to the preparation of a diploma paper.

It is not feasible to train a highly skilled specialist, a creator of new achievements in science and technology, under the present conditions unless theoretical schooling is organically related to practical training while the future specialist is still an undergraduate and unless the student learns to combine theoretical research with staging and analysing experiments both in laboratory and factory conditions. Ties between theory and practice should be consolidated during laboratory work, tutorial classes, seminars, and which is of paramount importance—in the course of factory training.

At the initial stage, an engineer is concerned with design, at the second stage with reproducing his design in nature. He elaborates technological processes, and in so doing aims at ensuring the high quality of an article to be manufactured within the prescribed time, in the required quantity, and in compliance with the design requirements. To be able to do so, he must make a thorough study of production while still an undergraduate.

To begin with, factory training introduces the student to the atmosphere in which he is destined to carry out his professional work. A student must be able to appreciate and assess the work done by a workman, the economy and development prospects of the branch of industry or the industrial enterprise concerned, he must have a knack for the technology of production, and must be able to find ways of raising the productivity of labour and intensifying production. While engaged in a specific task at an industrial enterprise, he must conceive a general idea of the over-all activity of the enterprise.

Higher schools can implement this programme if undergraduates are given a chance to do factory training directly in industrial enterprises while they take the theoretical course.

The relative share of industrial training can be determined on the basis of the number of hours (or weeks) reserved for factory training in relation to that envisaged for all theoretical studies (less preparation time), as follows.

$$K_5 = \frac{S_{tr}}{S_t}. \qquad (5)$$

One can hardly speak of serious training in terms of experimental research if an undergraduate is not required to carry out a sufficient volume of laboratory work as well as work in experimental shops where he can use all sorts of measuring and other types of modern instruments and equipment.

The share of activity of this kind can be derived from the following ratio.

$$K_6 = \frac{S_l}{S_t} \qquad (6)$$

where S_l is the number of hours reserved for laboratory work and work in experimental shops.

The entire process of tuition can be divided into two parts: compulsory classes with an instructor in charge (including lectures, seminars, practical and laboratory work) and preparation or out-of-class work. Each of these parts is assigned specific academic time in terms of hours.

The undergraduates' creative thinking is fostered most effectively in the course of preparation, which is supposed to aim at elements of research during the initial stage of tuition and develop into full-scale research of both a theoretical and an experimental character in the last year of study.

If the total number of hours reserved for compulsory classes with an academic adviser be designated by S_t and independent out-of-class work (preparation) by S_{pr} we arrive at the following characteristic ratio:

$$K_7 = \frac{S_{pr}}{S_t}. \qquad (7)$$

In view of the fundamental changes in the training of specialists, traditional methods of teaching are bound to undergo substantial modernization. This modernization should be based on the principle of maximum intensification of tuition, which can be obtained primarily through a wide use of technical educational aids, such as films, slides, television, radio, audio- and video-recording, computers, teaching machines, etc. The new methods of teaching, such as audio-visual and programmed teaching, which rely to a large extent on technical aids, go a long way not only towards intensifying tuition but also towards individualizing schooling. Until recently, tuition at any stage of public education proceeded from the principle of ensuring progress for a learner with an average ability to study and an average efficiency. In this way, the education of learners with better achievements and efficiency than so-called 'average' students was, as it were, contained, while poor learners exerted themselves too much and still failed to master study matter thoroughly. Such methods of tuition can no longer be accepted. Each learner is expected to acquire a certain minimum knowledge and level of creative thinking. If a learner lacks the academic background needed to assimilate this knowledge, individual classes should be arranged for him to ensure that he masters the knowledge and study matter required of a useful specialist. Extra classes should also be arranged for learners possessing a higher-than-average background to ensure that, within the prescribed length of the course, they obtain knowledge which corresponds to their ability and which will necessarily be above the prescribed minimum.

The ability of a higher educational establishment to use educational technology on a large scale and to make arrangements for schooling in a wide range of alternate disciplines and subjects at the undergraduates' option makes for a high level of undergraduate training. Industrialization of the methods of tuition will require re-shaping of the entire pattern of education, and appropriate training of the academic staff.

If the total number of hours for which technical aids are used be designated by S_{ta}, the index of their utilization can be expressed by the following coefficient.

$$K_8 = \frac{S_{ta}}{S_t}. \tag{8}$$

Any pattern of higher education is bound to fail unless the academic staff has the necessary qualifications. Hence it is reasonable to assume that the academic standard of specialist training depends on the academic staff of the higher school concerned. The ratio of the number of lecturers awarded the first academic degree (Ph.D., Candidate of Science, and the like) and the second academic degree (Doctor of Science in the U.S.S.R.) denoted by P_{deg} to the total number of professors and lecturers on the teaching staff expressed by P, or:

$$K_9 = \frac{P_{deg}}{P} \tag{9}$$

is therefore the determining factor of the academic standard of training of specialists.

All parameters $K_1, K_2 \ldots K_9$ are non-dimensioned, and can therefore be summed up. However, their significance in determining the level of education will obviously be different. For this reason, each parameter K_i should be multiplied by a coefficient giving its relative significance in determining the academic level of engineer training. Then proceeding from dependences (1–9) we obtain.

$$K = \alpha_1 K_1 + \alpha_2 K_2 + \ldots + \alpha_n K_n$$

or

$$K = \sum_{i=1}^{i=n} \alpha_i K_i \tag{10}$$

where K is what may be called an integral criterion determining the academic level of education and the standard of engineer training at the institution of higher learning concerned.

Young specialists' probation does not form part of this criterion since it is envisaged as a rule in nearly all countries.

It would seem that coefficients α_i should be determined by a poll among higher school experts on a ten-point grading scale, taking due account of the experience accumulated by individual institutions of higher learning in various

TABLE 3. Numerical values of coefficients (α)

General science and general engineering disciplines	10	Factory training	6
Professional subjects	8	Laboratory work	8
Humanities	4	Independent preparation	10
Diploma design (diploma paper)	10	Technical aids	6
		Academic staff	10

countries. We would recommend that the numerical values of the coefficients shown in Table 3 be used.

Integral criterion K can be determined with a larger or smaller number of its components, so that their number is designated through n in general formula (10). The relative significance of each component, i.e. value α_i, can also vary though it does not change anything in the final analysis. What is important is to be able to define the method of determining the integral criterion of the academic level of education and standard of engineer training with non-dimensioned parameters, as well as the relative share of each parameter in the over-all value of this criterion.

When elaborating a curriculum it is extremely important to arrive at the most harmonious combination of individual components which the training of engineers comprises.

An exceedingly large volume of general science disciplines at the expense of professional subjects will be as detrimental to the level of engineer training as an unreasonable curtailment of the general science disciplines in favour of the professional. For this reason the values of coefficients α_i should be determined with a view to bringing the individual groups of disciplines and types of academic activity into proper balance.

The influence of independent preparation is taken account of in a summarized manner. However, this extremely important type of academic activity is manifold in character and can therefore be differentiated into three main types.

An engineer's professional activity has specific features. Whereas a scientist enhances people's knowledge and lays the foundation for the creation of material values, the engineer's basic task is to reproduce such values in nature. An engineer is called upon to calculate and design machinery, instruments and structures, elaborate technological processes to reproduce designed objects in nature—all this on the basis of experimental data or, perhaps, by engineering intuition. Engineering intuition should be developed even at the initial stage of undergraduate training. When he starts on his professional career, an engineer begins to accumulate experience. In this connexion it may be observed that course designing (or course papers) containing elements of a research character as well as actual research carried out by undergraduates both theoretically and experimentally, is a most important component in the making of an engineer.

All this activity, apart from compulsory consultations for course papers and course projects and their discussion, is supposed to be conducted within the time limit reserved for preparation, i.e. to fit within S_{pr}. Thus, the total number of hours S_{pr} reserved for preparation is made up of three components:

1. Working at disciplines, including fulfilment of small assignments, participation in discussion groups, taking examinations, etc.:

$$K'_7 = \frac{S_{pr1}}{S_{pr}}. \tag{11}$$

2. Course projects (papers):

$$K''_7 = \frac{S_{pr2}}{S_{pr}}. \tag{12}$$

3. Research work:

$$K'''_7 = \frac{S_{pr3}}{S_{pr}}. \tag{13}$$

The significance of each of the parameters K'_7, K''_7 and K'''_7 in the shaping of a creative engineer also varies, as in the other cases.

The assessment of independent preparation can therefore be characterized by a non-dimensioned integral criterion to be derived from the formula:

$$K_{pr} = \beta_1 K'_7 + \beta_2 K''_7 + \beta_3 K'''_7 \tag{14}$$

Coefficients β_1, β_2 and β_3 in this formula determine the significance of each type of preparation in the development of a student's creative thinking, the values of which are indicated here as a rough approximation. work on study matter of lectures, discussion classes, examinations, 6, course papers (projects), 8; and research work, 10.

In the final analysis, the volume of knowledge obtained by students is governed by the length of the course or, to be more exact, by the total number of hours reserved for compulsory classes with an academic adviser and for independent preparation. Therefore, apart from integral criterion K, it is desirable to determine the numerical values of S_t and K_{pr}, which are of extreme importance in establishing the comparability of training and which indicate the total number of hours allotted to compulsory classes with an academic adviser and to independent preparation respectively.

It follows from the above that the academic level of education in a given field of study at two universities can be considered identical provided S_t, K and K_{pr} have identical values in both cases.

Exact coincidence of these criteria calculated for different institutions of higher learning is hardly possible, but if the difference in their values does not exceed 5 to 10 per cent it may reasonably be argued that the academic level of education at the higher educational establishments concerned is identical and the diplomas awarded by them are comparable. The degree of possible variation of S_t, K and K_{pr} also calls for further study.

We shall now undertake an analysis of the curricula of some institutions of higher learning in various countries in order to illustrate the method proposed above

Analysis of the curricula of institutions of higher learning

Any such analysis is difficult since the curricula are made up on different patterns and with a varying degree of detail. In some countries the content of independent preparation is not officially stipulated. Differentiation of individual types of preparation (research, designing, etc.) is lacking in some cases. Information on the utilization of technical aids is scarce. There is no data on the strength of the academic staff. However, the purpose of this work is to establish a method of determining the comparability of diplomas, rather than to elaborate a draft agreement between specific countries.

In view of the fact that much of the information needed for a thorough analysis is lacking, we will attempt to determine two criteria (S_t and K) for various institutions of higher learning.

Higher technical schools of the U.S.S.R.

The curricula of all institutions of higher learning are under review at the present time. However, on the whole they will maintain their patterns and the basic direction adopted in the training of specialists of high standing in the U.S.S.R.

Men and women have equal rights of access to institutions of higher learning and anyone is eligible who has completed a course of secondary education and passed the finals for the matriculation certificate. There is also an entrance examination at the institution of higher education to which admission is sought. Admission is on a competitive basis, three candidates normally competing for one place.

Applicants for admission take entrance examinations in the disciplines determining the field of learning for the specialty chosen, and also in Russian (or the native tongue in which tuition is conducted) and literature.

Compulsory and optional classes (lectures, laboratory and practical work, seminars, etc.) under the guidance of professors and tutors are stipulated at all institutions of higher learning for 36 hours a week in the first to the fourth year of study and for 30 hours a week in the fifth and sixth years.

The amount of home assignments, course projects (papers), research work, work at the study matter of lectures, preparation for examinations is so planned as to ensure that the student completes roughly 6,500 hours of independent preparation during the theoretical courses, examination sessions and factory training for the entire duration of studies (5½ years). It goes without saying that this figure has been determined on the basis of the average student's work capacity.

Let us analyse the curriculum for the specialized field designated 'Technology of Machine-building, Metal-cutting Machine-tools and Tools' offered by the Moscow Higher Technological School (MHTS).

The length of the course is 5½ years. Of the entire course, 244 weeks (85.3 per cent) are reserved for instruction and 42 weeks (14.7 per cent) are allotted

TABLE 4. Academic hours allotted to compulsory study work (MHTS)

Discipline Subject	No. of hours	Discipline Subject	No. of hours
General science and general engineering disciplines		Electrical equipment of machine-tools	42
Calculus	455	Theory of cutting	85
Computers in engineering and economic calculations	54	Cutting tools (calculations and construction, production technology, automatic change and control)	220
Physics	299	Technology of mechanical engineering (principles of technology of mechanical engineering, technological principles of automatic assembly lines, technology of machine production)	230
Chemistry	141	Principles of device construction	56
Theoretical mechanics (statics, kinematics and dynamics of solids)	191	Fundamentals of automatics	56
Strength of materials	210	Automatic machines and devices (principles of design, automatic control unit, mechanisms)	140
Descriptive geometry, mechanical drawing and drawing	247	Automation of industrial processes	70
Technology of metals and other constructional materials	230	Principles of artistic designing	28
Science of materials	102	Industrial economics	56
Theory of machines and mechanisms	87	Industrial organization, planning and management	98
Machine elements	126	Labour protection	42
Fundamentals of interchangeability, standardization and technical measurement	54	Alternatives	130
Hydraulics and hydropneumatic drive	87	TOTAL	1,431
General electrical engineering and industrial electronics	193	*Humanities*	
Thermodynamics and heat transfer	68	Social sciences (except political economy)	280
Political economy	140	Foreign language	210
TOTAL	2,684	Principles of Soviet law	28
Professional subjects		TOTAL	518
Lifting and transportation machines	34	*Physical training*	140
Calculations and composition of metal-cutting machine-tools	90		
Hydraulic and pneumatic equipment of machine-tools	54	GRAND TOTAL	4,773

to vacations. Of the total number of 244 weeks reserved for instruction, theoretical study takes up 165 weeks, or 67.6 per cent, factory training, 30 weeks, or 12.2 per cent, sessions, 33 weeks, or 13.5 per cent, and diploma work, 16 weeks, or 6.7 per cent.

The total number of hours envisaged for the compulsory theoretical classes $S_t = 4{,}709$ hours.

This time is distributed among the various types of academic activity as follows: lectures, 2,600 hours, or 55.2 per cent, laboratory work and experimental workshops, 849 hours, or 18.2 per cent, practical (or seminars), 1,260 hours, or 26.6 per cent.

Academic hours (S_t) allotted to compulsory study work are distributed as shown in Table 4.

Undergraduates are expected to complete the following course projects during the period of instruction: the theory of machinery (in the fifth semester); machinery features (sixth semester), lifting and transportation machines (seventh semester), cutting tools (calculations of a project, technology of production, change and control automation) (eighth semester), machine-building technology (ninth semester), automatic machines and devices (tenth semester), and industrial organization, planning and management (eleventh semester).

Each project consists of 3 sections dealing with design, technology and economy. The subject matter is laid down in 3 to 5 sheets of drawings and an explanatory note setting forth all calculations as to design, technological processes and economic substantiation with variants.

A project should involve novel elements and the student is expected to reveal his faculty for independent research, both theoretical and experimental.

All projects prepare a student for the completion of a major work—a diploma paper or diploma project, which he prepares on completion of the theoretical course.

In some cases, the results obtained in the preparation of course and diploma projects are made use of in industry, especially when urgent problems of practical interest are tackled.

The above-mentioned coefficients, characterizing the academic level of education, have the following values for this speciality studied at MHTS General science education

$$K_1 = \frac{S_s}{S_t} = \frac{2{,}684}{4{,}773} = 0.562. \quad (1)$$

Professional training

$$K_2 = \frac{S_p}{S_t} = \frac{1{,}431}{4{,}773} = 0.300. \quad (2)$$

Humanitarian education:

$$K_3 = \frac{S_h}{S_t} = \frac{658}{4{,}773} = 0.138. \quad (3)$$

Diploma project:

$$K_4 = \frac{S_d}{S_t} = \frac{16 \text{ weeks} \times 6 \text{ days} \times 10 \text{ hours}}{4{,}773} = 0.201. \quad (4)$$

On-the-job training:

$$K_5 = \frac{S_{tr}}{S_t} = \frac{30}{165} = 0.182 \text{ (in terms of weeks).} \quad (5)$$

Laboratory vork:

$$K_6 = \frac{S_l}{S_t} = \frac{849}{4{,}773} = 0.178. \quad (6)$$

Preparation:

$$K_7 = \frac{S_{pr}}{S_t} = \frac{6{,}500}{4{,}773} = 1.36. \quad (7)$$

Technical aids and facilities employed in tuition:

$$K_8 = \frac{S_{ta}}{S_t} = 0.50. \quad (8)$$

Ratio of academic staff holding academic degrees of Candidate or Doctor of Science and academic titles of associate professor and full professor.

$$K_9 = \frac{P_{\deg}}{P} = 0.56. \quad (9)$$

In accordance with equation (10) (page 40) and Table 3 we can determine the integral criterion of the level of training of MHTS graduates:

$$K_{MHTS} = \sum_{i=1}^{i=9} \alpha_i K_i = 10 \times 0.562 + 6 \times 0.300 + 4 \times 0.138 +$$
$$+ 10 \times 0.201 + 6 \times 0.182 + 8 \times 0.178 +$$
$$+ 10 \times 1.36 + 6 \times 0.50 + 10 \times 0.56$$
$$K_{MHTS} = 35.4.$$

The curriculum of the course 'Electrical Power Stations' offered at the Moscow Power Engineering Institute (MPEI) is given below.

The length of the course is 5½ years and comprises. training, 240 weeks, or 84 per cent; and vocation, 46 weeks, or 16 per cent.

The total number of weeks set aside for study work is. theoretical study work, 153 weeks, or 63.9 per cent; on-the-job training, 35 weeks, or 14.6 per cent, sessions, 31 weeks, or 12.9 per cent; and diploma project, 21 weeks, or 8.6 per cent.

The total amount of preparation equals $S_{pr} = 6{,}200$ hours.

TABLE 5. Academic hours allotted to compulsory study work (MPEI)

Discipline/Subject	No. of hours
General science and general engineering	
Calculus	514
Fundamentals of machine computation	56
Computer systems in engineering and economic calculations	48
Physics	306
Chemistry	136
Mechanics	216
Theory of electrical engineering	350
Descriptive geometry and mechanical drawing	124
Industrial electrical engineering	96
Technology of metals and other constructional materials	84
Materials in electrical engineering	48
Measurement in electrical engineering	64
Political economy	140
Scientific training	92
TOTAL	2,274
Professional subjects	
Electrical machines	193
Electrical circuits	94
Electrical installations	56
Transition processes in electrical systems	174
High-voltage equipment	115
Relay protection	84
Automation of power systems	96
Electrical equipment of power electrical stations	146
Operating conditions of work of power electrical stations	106
Economics of power engineering	58
Industrial organization, planning and management	99
Labour protection (safety)	40
Alternative	247
TOTAL	1,508
Humanities	
Social sciences	280
Foreign language	210
The fundamentals of Soviet law	28
TOTAL	518
Physical training	140
GRAND TOTAL	4,440

The total number of hours allotted to compulsory theoretical study work conducted by professors and lecturers is $S_t = 4{,}400$ hours.

Time distribution among the various types of academic activity is as follows: lectures, 2,105 hours; laboratory work, 772 hours; and practical, 1,563 hours.

The time allotted to compulsory study work is distributed as shown in Table 5. Undergraduates prepare projects during the course in. the theory of machines and design of machine elements (fifth semester), electrical circuits (sixth semester), electrical machines (seventh semester), power generating equipment (eight semester); electrical equipment of power stations (ninth semester), operating conditions of electric power stations (tenth semester). industrial organization, planning and management (tenth semester).

Each project dealing with mechanics is aimed at elaborating a design and the technological processes needed for the manufacture of designed units, along with calculations for strength and the relevant economic calculations. In the case of electrical engineering projects, electrical circuits are elaborated along with appropriate technical and economic calculations, technological processes are developed, and problems of maintenance are solved.

The results obtained in the preparation of certain projects involving urgent problems of practical interest, are made use of in industrial production.

Each project contains elements of research, both theoretical and experimental, and prepares the student for a major undertaking a diploma paper or diploma project, which is a serious piece of researching or experimental designing.

The above coefficients which characterize the academic level of education for this course at MPEI have the following values.

General science education.

$$K_1 = \frac{S_{se}}{S_t} = \frac{2{,}274}{4{,}440} = 0.512. \tag{1}$$

Professional training:

$$K_2 = \frac{S_p}{S_t} = \frac{1{,}508}{4{,}440} = 0.340. \tag{2}$$

Humanitarian education:

$$K_3 = \frac{S_h}{S_t} = \frac{658}{4{,}440} = 0.148. \tag{3}$$

Diploma project:

$$K_4 = \frac{S_d}{S_t} = \frac{21 \text{ weeks} \times 6 \text{ days} \times 10 \text{ hours}}{4{,}440} = 0.284. \tag{4}$$

On-the-job training:

$$K_5 = \frac{S_{tr}}{S_t} = \frac{35}{135} = 0.229 \text{ (in terms of weeks)}. \tag{5}$$

Laboratory work:

$$K_6 = \frac{S_l}{S_t} = \frac{774}{4{,}440} = 0.174. \tag{6}$$

Preparation:

$$K_7 = \frac{S_{pr}}{S_t} = \frac{6{,}200}{4{,}400} = 1.40. \tag{7}$$

Technical aids and facilities employed in tuition.

$$K_8 = \frac{S_{ta}}{S_t} = 0.50. \tag{8}$$

Ratio of academic staff holding academic degrees of Candidate or Doctor of Science and academic titles of associate professor and full professor.

$$K_9 = \frac{P_{deg}}{P} = 0.52. \tag{9}$$

In accordance with equation (10) (page 40) and Table 3 we shall determine the integral criterion, namely:

$$K = \sum_{i=1}^{i=9} \alpha_i K_i = 10 \times 0.512 + 8 \times 0.340 + 4 \times 0.148 +$$

$$+ 10 \times 0.284 + 6 \times 0.229 + 8 \times 0.174 +$$

$$+ 10 \times 1.40 + 6 \times 0.50 + 10 \times 0.52$$

$$K_{MPEI} = 36.2.$$

The comparison shows that $S_{t\ MHTS}$ differs from $S_{t\ MPEI}$ by 7 per cent while the difference between K_{MHTS} and K_{MPEI} is 2.2 per cent. Consequently the professional level of training at these higher educational institutions is identical The experience of the Moscow Higher Technological School and the Moscow Power Engineering Institute confirms this identity. But separate elements of the integral criterion have different values. The above-mentioned examples show that integral criteria may be estimated for different higher educational institutions and for different specialties.

However, comparison of the curricula and programmes of two higher educational institutions in the same country does not solve the difficulties in establishing comparability of education. Even the total number of hours envisaged for compulsory classes with a tutor and independent preparation vary with an identical level of engineer training. This circumstance is largely explained, first, by different pedagogical schools and, second, by different specialized fields of engineer training, which, incidentally, have been singled out intentionally.[1]

Higher educational establishments of the United States

A student must complete a 4-year course of theoretical schooling to be entitled to a Bachelor's degree. He must complete some 120 credit units, or roughly 360 credit hours, for this period. One credit unit is approximately equal to 45 hours of a student's academic work (compulsory with a tutor and preparation).

The curriculum for a Bachelor's degree at the Massachusetts Institute of Technology is for a course of 4 years and consists of 2 sections: (a) general institute requirements uniform for all fields of study, and (b) departmental programmes relative to the specific fields of learning (see Table 6).

MIT awards the degrees of Bachelor, Master and Engineer as well as doctoral degrees in 38 branches of science In addition, it offers post-graduate and post-doctoral study programmes in the fields of engineering sciences, management

1 The integral criteria do not incorporate the indices that characterize the significance of one-year industrial probation in the education of the engineers.

TABLE 6. General institute and departmental requirements for a Bachelor's degree (MIT)

Ref. No.	Title of discipline/subject	Credit hours (including classes)		
		Compulsory	Preparation	Total
General institute requirements				
5.01	Chemistry	5	7	12
8.01/8.02	Physics I/II	10	14	24
18.01	Computing mathematics	8	16	24
18.02	Humanities	24	48	72
	TOTAL	47	85	132
Departmental requirements—civil engineering				
1.00	Communication systems	6	6	12
1.01	Engineering mechanics	4	8	12
1.02	Engineering materials	6	6	12
1.03	Engineering analysis	4	8	12
1.04	Structural analysis and Project I	6	6	12
1.05	Fluid mechanics	6	6	12
1.06	Soil mechanics	6	6	12
1.07	Analysis of indeterminate systems	4	5	9
1.08	Geotechnology	6	6	12
1.09	Civil engineering	6	12	18
8.03	Physics III	5	7	12
18.034	Differential equations	3	9	12
	TOTAL	62	85	147
Compulsory laboratory work		12	—	12
Optional		23	46	69
	GRAND TOTAL	144	216	360

and social sciences. Several programmes for degrees are offered at each of its 23 departments.

The disciplines available in the junior years lead to a B.Sc., those in the senior years, to a B.Tech., S.M., M.Arch., M.C.P., various Engineer degrees,[1] Ph.D. and SC.D.

The academic year lasts for 2 terms, each 15 weeks long. Each freshman prepares a report on his achievements and his work in each subject. This is submitted for assessment to his tutor in the middle and at the end of each term. The student sits for an examination at the end of each term. Registered undergraduate students of outstanding ability may take examinations for advanced standing during the examination periods in each term.

1. Engineer degrees. Chemical Engineer, Electrical Engineer, Engineer in Aeronautics and Astronautics, Marine Mechanical Engineer, Materials Engineer, Mechanical Engineer, Metallurgical Engineer, Mineral Engineer, Naval Architect, Naval Engineer, Civil Engineer, Nuclear Engineer, Ocean Engineer.

The basic fields of learning offered for students in the junior years of study are as follows: engineering; architecture and planning; management, humanities; social sciences; natural sciences

The general institute requirements consist partly of special sections of the natural sciences and partly of the humanities and the social sciences, all sections of these disciplines being elective.

Each departmental programme consists, in part, of a grouping of subjects in the areas of professional interest to the course or courses represented by that particular department and, in part, of additional opportunities for the student to take subjects of his choice. By institute rule, time for electives is available to every student in the first, third and fourth years. Every student can use these elective opportunities to follow special interests and to deepen or broaden his educational background. Programmes may be arranged to prepare undergraduates for advanced study in interdisciplinary fields such as astrophysics, communication science, and space science and technology.

Additionally, some students follow what is called a co-operative programme, which includes on-the-job training and is equal to 8 credit hours.

The co-operative programme therefore consists of 368 classes composed of: 144 compulsory classes; 216 preparation classes; and 8 on-the-job training classes Consequently, the total number of academic hours equals 360 × 15 = 5,400, of which 144 × 15 = 2,160 (tutorial) and 216 × 15 = 3,240 (preparation). On-the-job training equals 8 × 15 = 120.

To proceed to a Master's degree, an additional tuition for 1 year, or 66 credit hours, is required The curricula and programmes of a course leading to a Master's degree are, as a rule, individual so that it is hard to distribute them among the sets of subjects and types of academic activity. Time distribution among the types of academic activity in the same proportion as for Bachelor's will be as follows: 66 × 15 academic hours = 990 academic hours, of which 22 × 15 = 330 academic hours (tutorial) and 44 × 15 = 660 academic hours (preparation).

Thus, a student enrolled at MIT should study for a period of 5 years to be awarded a Master's degree and should complete 6,390 hours in all, that is 5,400 + 990 = 6,390 hours, of which 2,160 + 330 = 2,490 hours (tutorial) and 3,240 + 660 = 3,900 hours (preparation); plus 120 hours, on-the-job training (for students following co-operative programmes) and 270 hours for dissertation work.

To be awarded an Engineer's degree, a student should study for an additional 2 years following the Bachelor's degree, complete the minimum of 162 credit hours during these 2 years and submit a dissertation. Time distribution is as follows: a total of 162 × 15 = 2,430 hours, of which 54 × 15 = 810 hours (tutorial), and 108 × 15 = 1,620 hours preparation.

Hence, to be awarded the qualification of Engineer, a freshman is expected, in accordance with the co-operative programme, to complete, a total of 360 + 162 = 522 credit hours, of which 144 + 54 = 198 credit hours (tutorial) and 216 + 108 = 324 credit hours (preparation); or in academic hours: $S_t = 198 \times 15 = 2{,}970$ hours (tutorial) and $S_{pr} = 324 \times 15 = 4{,}860$ hours (preparation);

plus S_{tr} – 120 hours of on-the-job training (for students following co-operative programme) S_d = 18 15 = 270 hours for completion of dissertation.

The total number of hours can be divided according to groups of disciplines as shown below.

Group of general science subjects. physics (10 credit hours), chemistry (5), calculus (8), seminars in these disciplines (6), alternative (9) total = 38 credit hours.

Communication systems (6 credit hours), engineering mechanics (6), engineering analysis (4), structural analysis (5), fluid mechanics (6), analysis of indeterminate systems (4), physics III (5), differential equations (3) total = 40 credit hours.

The above gives a grand total of 78 credit hours or S_t = 78 15 = 1,170 academic hours, professional subjects for engineer training, 42 + 54 = 96 credit hours or S_p = 96 15 = 1,440 academic hours, humanities, 24 credit hours or S_h = 24 15 = 360 academic hours. The integral criterion for this speciality may be determined as follows:

General science education:

$$K_1 = \frac{S_{sc}}{S_t} = \frac{1{,}170}{2{,}970} \approx 0.394. \qquad (1)$$

Professional training:

$$K_2 = \frac{S_p}{S_t} = \frac{1{,}440}{2{,}970} = 0.485 \qquad (2)$$

Humanitarian education·

$$K_3 = \frac{S_h}{S_t} = \frac{360}{2{,}970} = 0.120. \qquad (3)$$

Diploma project.

$$K_4 = \frac{S_d}{S_t} = \frac{270}{2{,}970} = 0.091. \qquad (4)$$

On-the-job training:

$$K_5 = \frac{S_{tr}}{S_t} = \frac{120}{2{,}970} = 0.040. \qquad (5)$$

Laboratory work:

$$K_6 = \frac{S_l}{S_t} = \frac{180}{2{,}970} = 0.061. \qquad (6)$$

Preparation.

$$K_7 = \frac{S_{pr}}{S_t} = \frac{4{,}860}{2{,}970} = 1.64. \qquad (7)$$

In the absence of any specific data on the scope of employment of technical aids and facilities in tuition and on the numerical strength of the academic staff (that is the number of professors and lecturers, including those holding Ph.D. and S.D.), the same values have been adopted in calculation K_8 and K_9 as for the higher educational establishments of the U.S.S.R.

Technical aids and facilities.

$$K_8 = \frac{S_{ta}}{S_t} = \frac{1{,}485}{2{,}970} = 0.5. \qquad (8)$$

Academic staff.

$$K_9 = \frac{P_{dcs}}{P} = 0.56. \qquad (9)$$

The integral criterion will be derived from formula (10) (page 40) and the value of α_i from Table 3, as follows.

$$K_{MIT} = \sum_{i=1}^{i=9} \alpha_i K_i = 10 \times 0.395 + 8 \times 0.485 + 4 \times 1.120 +$$

$$+ 10 \times 0.09 + 6 \times 0.040 + 8 \times 0.06 +$$

$$+ 10 \times 1.64 + 6 \times 0.5 + 10 \times 0.56$$

$$= 34.95 \approx 35.0.$$

It should be recalled that $K_{MHTS} = 35.4$ and $K_{MPEI} = 36.2$. The over-all number of hours allotted to tutorials during the entire period of training for the above-mentioned institutions will be as follows.

$$S_{tMHTS} = 4{,}773; \; S_{tMPEI} = 4{,}440; \; S_{tMIT} = 2{,}970.$$

Thus the academic level of education provided by the Massachusetts Institute of Technology with a 6-year course under the co-operative programme (assuming that the requirements demanded of candidates applying for the Engineer degree are met) is comparable to that possessed by graduates from the Moscow Higher Technological School (MHTS) and Moscow Power Engineering Institute (MPEI). However, the over-all amount of study material for students of MIT is smaller than in the case of MHTS and MPEI. The difference becomes less pronounced in the case of students taking additional courses from advanced programmes.

The integral criterion determining the training of Bachelors of Science at MIT for 4 years roughly equals $K = 25$.

In terms of disciplines studied, as already noted, it is impracticable to establish comparability of diplomas from the curricula and syllabuses.

The structure of the Mechanical Engineering Department provides for 3 main fields of study in engineering mechanics: (a) material science and mechanics, (b) fluid mechanics and thermodynamics, (c) systems and constructions.

TABLE 7. Bachelor's degree programme in engineering mechanics

Ref no	Discipline/subject	No. of credit hours		
		Compulsory	Preparation	Total
	General institute requirements			
	Chemistry			12
	Physics			24
	Calculus			24
	Humanities			72
	TOTAL			132
	Departmental programme—required subjects			
2.01	Solid mechanics	4	8	12
2.02	Principles of system dynamics	4	8	12
2.03	Dynamics (hydraulics)	3	6	9
2.201	Fluid mechanics	4	8	12
2.30	Mechanical behaviour of metals	5	4	9
2.60	Applied thermodynamics	3	6	9
2.672	Experimental engineering I	4	2	6
2.673	Experimental engineering II	4	2	6
2.731	Constructional engineering	6	6	12
2.861	Constructional engineering and materials	8	4	12
8 03	Physics III	5	7	12
18.304	Differential equations	3	9	12
	Thesis (report)	9	—	9
	TOTAL	62	70	132
	Restricted electives materials			
3.13	Science of materials I	7	5	12
3.141	Science of materials II	7	5	12
	TOTAL	*14*	*10*	*24*
	or			
	Thermodynamics			
2.403	Thermodynamics	4	8	12
2.42	Elements of classical and statistical thermodynamics	4	8	12
	TOTAL	*8*	*16*	*24*
	Unrestricted electives			
	Unrestricted electives			72
	GRAND TOTAL			360
	Planned electives			
	Majors for all students			
8.04	Principles of quantum physics			
6.141	Introduction to electronics			
	or			
2.13	Electromechanical fields and systems			

	Mechanics
2.06	Vibration
2.071	Introduction to solid mechanics
2.652	Experimental analysis of pressure
2.862	Fundamentals of machine tools
	Materials
2.398	Research of materials
	Fibres, polimers, textiles
2.901	Science of polimers
2.903	Principles of textiles and processes science
2.904	Dynamics of processes with fibres
	Fluid mechanics
2.202	Dynamics of gases
	Heat transfer
2.50	Heat and mass transfer
2.53	Heat problems
	Heat systems
2.611	Elementary internal combustion engines
2.612	Internal-combustion engines
2.614	Laboratory work on internal combustion engines
2.643	Air conditioning
2.644	Air conditioning
2.646	Refrigerating machinery
	Dynamic systems and control
2.13	Electromechanical fields and systems
2.14	Principles of control system
	Construction
2.00	Introduction to engineering systems
2.711	Geometric construction
2.732	Principles of construction
2.733	Special problems of systems and construction
	Laboratory work
2.654	Physical measurement analysis
2.67	Construction and experiment
	Simulation of physical systems
2.10	Elementary programming and computers
2.101	Physical models and engineering systems I
2.724	Nomography
	Mathematics
18.05	Advanced computing mathematics for engineers
18.06	Advanced computing mathematics for engineers
	Biomedical engineering
2.74	Problems of biomedical engineering

TABLE 8. Bachelor's degree programme

Ref no.	Discipline subject	No of credit hours		
		Compulsory	Preparation	Total
	MECHANICAL ENGINEERING, COURSE II-A			
	General institute requirements			
	Chemistry			12
	Physics			24
	Computing mathematics			24
	Humanities			72
	TOTAL			132
	Departmental programme			
2.01	Solid mechanics	4	8	12
8.03	Physics III	5	7	12
18.034	Differential equations	3	9	12
	Theses	9	—	9
	TOTAL	21	24	45
	Electives (five of the following list)			
3 141	Material science			
	or			
3.13	Material science I	7	5	12
2.02	Introduction to system dynamics	4	8	12
2 03	Dynamics	3	6	9
2.201	Fluid mechanics	4	8	12
2 30	Mechanical behaviour of materials	5	4	9
2 403	Thermodynamics			
	or			
2.42	Elements of classical and statistical thermodynamics	4	4	12
2.60	Applied thermodynamics	3	6	9
2.672	Experimental engineering I	4	2	6
	Experimental engineering	4	2	6
2.731	Engineering construction	6	6	12
2.861	Engineering construction and materials	8	4	12
	Restricted electives			57
	Unrestricted electives			60
	MECHANICAL ENGINEERING CO-OPERATIVE PROGRAMME (COURSE II-B)			
2.151	Industrial practice			40 hours per week (or 8 credit hours)
2.952	Industrial practice			

Students of the junior years of study are offered 2 programmes. Completion of a programme makes a student eligible for the degree of B.Sc. in engineering mechanics or the degree of Engineer (see Table 7).

Students intending to acquire industrial experience may take course II-B. Factory work equals 8 credit hours of laboratory work in the selected subject.

Students of exceptional ability can follow an advanced study programme for junior undergraduates, candidates being selected at the expiration of the first year of study. When in the third and fourth year, students so selected take specialized subjects, including many subjects of the graduation year. On completion of the fourth-year programme, these students possess knowledge exceeding that of candidates for a Master's degree.

The students who enter on their studies of the graduation year normally hold an equivalent of a Bachelor's degree in engineering mechanics in an acknowledged engineering school, or sometimes choose fields of concentration which cross regular disciplinary lines. In any case the students are supposed to study the following subjects (either all or some of them), applied mathematics, hydraulics, dynamics, thermodynamics, electrical circuits, electromagnetic fields, materials.

This list of disciplines proves that emphasis is laid on the general science education of prospective Masters and Engineers.

If one compares the list of subjects offered at the mechanical engineering department of MIT with that stipulated for the machine-building specialty at MHTS it will be immediately apparent that this method does not work in establishing comparability of diplomas. Major fields of study, the names of subjects, distribution of study matter among the subjects everything is different.

A similar conclusion is unavoidable when one compares the curricula of institutions of higher learning in, say, France with those of universities in the United States or the U S S R , as will be demonstrated later.

At this juncture we can only reiterate our assertion that integral criteria are the one possible solution.

Set out below are some of the requirements that candidates for a Master's degree must meet.

A student who has a Bachelor's degree in the same department in which he has enrolled for the Master's degree, or who has had comparable preparation elsewhere, may obtain the Master's degree in 1 year.

A student who completes the requirements for the Bachelor's degree at the institute with substantial extra advanced credits in graduate subjects may, upon application, be granted a relaxation of the normal residence requirement (apart from thesis) and may be recommended for the Master's degree upon completion of the academic requirements.

The degrees of Master of Science, Master in Architecture, and Master in City Planning are awarded upon satisfactory completion of an approved programme of study comprising at least 66 subject units, of which 42 units must be in 'A' subjects, and the completion of an acceptable thesis.

Those who proceed to an S.M. in textile technology specialize in one of the following fields of study: engineering chemistry, chemistry, engineering mechanics, industrial physics, and business and engineering management.

The choice of a specialized field of learning is subject to approval by the relevant departmental committee on graduate students.

The entire programme of training for a Master's degree comes up for approval by the committee and the graduate registration officer.

To be recommended for a Master's degree, students must have an adequate educational background in addition to a satisfactory knowledge of the academic programme of the graduation year and an acceptable level of research skills.

In an approved programme for a Master of Science degree, if 34 units of 'A' subjects and the thesis are in a single field of science or engineering (as determined by a departmental committee on graduate students), the degree is recommended in the specific field in which the student has specialized, otherwise, the degree is recommended without specification of the field.

The student studies a programme composed of subjects selected by himself, which more often than not do not coincide with those offered at the engineering mechanics department. The choice of subjects should be approved by a special faculty counsellor with a view to establishing their significance

The objective of a programme leading to a Mechanical Engineer degree is a more advanced level and a broader range of competence in engineering and science is required than for the Master's degree. A candidate for this degree must sit for an examination.

The three basic requirements for a Doctor of Science and Doctor of Philosophy degree are (a) completion of a programme of advanced study, including a general examination, (b) demonstration of proficiency in modern foreign languages, and (c) completion and oral defence of a thesis on original research.

The list of requirements, which those proceeding to the degrees of Bachelor, Master and Engineer must meet, bears out the previous conclusion that the degree of Engineer constitutes the final stage of higher education upon completion of which a candidate can switch over to a research career. A successful research career and completion of a significant piece of research entitles the holder of an Engineer's degree to proceed to a D.Sc. or a Ph.D., which are of comparable scientific level.

Higher educational establishments of the United Kingdom

Full-time study for between 3 and 4 years leading to a final examination for a Bachelor's degree is the basic form of instruction at the first stage of education at universities. Under this arrangement, the curricula do not provide for on-the-job training and it is merely recommended that students should seek jobs in industry during vacations.

In the course of theoretical studies for 3 to 4 years, the students' practical training amounts to work in laboratories or experimental shops, with only one-third of the teaching time being reserved for this type of academic activity. remaining two-thirds are divided approx ately equally between lectures and calculation exercises conducted under the guidance of a tutor.

In the case of some specialized fields of learning, which involve subject matter of extreme complexity and are closely related to actual industrial production, a specific form of instruction is practised. This is the 'sandwich' course, consisting of alternate periods of college education and factory training, of which mention was made earlier.

College graduates completing their course of study on the 'thin sandwich' pattern are awarded a Higher National Certificate and accorded the right to take a final university examination for the degree of Bachelor or—after a 1-year probation in industry to take an examination for a Higher National Diploma. This diploma is comparable to the degree of Bachelor.

As pointed out above, the full-time study course of 3 years in the specialized engineering fields has now been replaced with a 4-year course at some institutions of higher learning

Those holding the degree of Bachelor (Honours) and proceeding to a Master's degree must, as a rule, take a 1-year course and complete a thesis.

Master's degree theses, like diploma papers at the Soviet institutions of higher learning, must contain research sections, which are prepared as a rule directly at universities (colleges) The faculty may allow a candidate to prepare his thesis at another institution provided he submits conclusive evidence that the thesis has been completed by him independently.

A Master's degree course can follow two patterns: (a) a simplified examination, with emphasis laid on the completion of research, or (b) a sophisticated examination along with a piece of research of limited volume.

There is no requirement whereby a thesis must be defended; it is merely discussed in a commission which includes experts from other educational institutions.

Those holding the degree of Bachelor (Honours) or Master are eligible on reaching the age of 23 to 27 for the highest degree– that of Ph.D. Holders of a Bachelor's degree must study certain subjects and complete a thesis under the Master's degree programme all within 1 year. This means that such candidates are obliged to take 2 courses during their doctoral studies a Master's and a Doctor's degree course while those already holding the degree of Master take only the latter course.

Those who proceed to a Doctor's degree must, as a rule, have a record of service in industry of at least 2 years While doing the doctoral course for 2 to 3 years, candidates are expected to take a series of examinations and to complete a thesis.

The highest academic degree in the United Kingdom is the degree of Higher Doctorate It is awarded to scientists holding a Ph.D. for original research of exceptional merit The award is made by a special commission, subject to approval by the senate of the university concerned.

We will now consider the curricula of some faculties of the University of Salford.

FACULTY OF CHEMISTRY AND APPLIED CHEMISTRY

Duration of the academic year. 32 weeks. The total amount of teaching time for students in stream 'E' is shown in Table 9.

The total volume of study for the entire period is as follows total compulsory studies with a tutor, $S_t = (27 + 29 + 28 + 20) \times 32 = 3,328$ hours, of which $(15 + 18 + 16 + 13) \times 32 = 1,984$ hours (lectures), $(10 + 8 + 8 + 6) \times 32 = 1,024$ hours (laboratory work) and $(2 + 3 + 4 + 1) \times 32 = 320$ hours (tutorial). Independent work equals $S_{pr} = (4 + 2 + 3 + 4) \times 32 = 416$ hours. Diploma project equals $S_d = 7 \times 32 = 224$ hours. The curriculum for this stream as per groups of subjects is given in Table 10.

Those fulfilling the study programme with honours and completing at least 60 per cent of credit work in each subject are awarded the first professional degree of Bachelor (Honours) of the first, second or third level, and those completing at least 40 per cent, the degree of Bachelor, Ordinary Level. Those holding the degree of Bachelor (Honours) may go on to further study at the university with a view to obtaining the second professional degree that of Master. Some Bachelors, Ordinary Level, are classed in Group One and may go on to further study at the university for the second professional degree of Master.

Factory training is not provided for at the higher educational establishments, and it is merely recommended that undergraduates should try to find jobs in industry during their vacations. Compliance with this recommendation is stimulated by the fact that graduates from universities or other institutions of higher learning who complete their course on a full-time basis with the first professional degree of Bachelor can only be admitted to an association (institute) of engineers in the professional field concerned if they have a record of service in industry of at least 1 year, roughly amounting to $S_{tr} = 1,600$ hours. Taking a special examination is a prerequisite for admission to an association, upon which a Bachelor may consider himself to be a fully fledged engineer.

With the academic year lasting 32 weeks, the over-all amount of teaching

TABLE 9 Total amount of teaching time for students in stream 'E' (in hours) per week

Year of study	Preparation	Projects	Hours of study work			
			Lectures	Laboratory	Tutorial	Total
I	4		15	10	2	27
II	2	-	18	8	3	29
III	3		16	8	4	28
IV	4	7	13	6	1	20

TABLE 10 Curriculum for the Faculty of Chemistry and Applied Chemistry as per groups of subjects

Subject	Hours per week[1]	
	Tutorial	Including laboratory
General science subjects		
General chemistry	10	5
Non-organic chemistry	3	—
Organic chemistry I	3	2
Organic chemistry II	4	3
Physical chemistry I	3	1
Physical chemistry II	3	1
Strength of materials	3	1
Mathematics I	4	—
Mathematics II	2	—
Mathematics III	3	—
Physics (electricity and magnetism)	2	1
Theory of machines	2	1
Hydraulics	3	1
Heat transfer	2	—
Heat and mass transfer	2	—
Electrical technology	2	1
TOTAL	51	17
Professional subjects		
Physical metallurgy	2	1
Fuel technology I	3	2
Fuel technology II	2	—
Fuel technology III	2	—
Heat engines I	3	1
Heat engines II	3	1
Industrial processes I	3	1
Industrial processes II	6	3
Industrial processes III	10	6
Industrial planning	2	—
Use of materials	2	—
Materials and constructions	2	
Organization and planning	2	—
Safety engineering, industrial situations and patterns	2	—
TOTAL	44	15
Humanities		
First year	3	
Second year	3	—
Third year	3	—
TOTAL	9	—
GRAND TOTAL	104	32

1 Preparation hours per week are as follows first year, 4, second year, 2, third year, 3, fourth year, 4 this gives a total of 13 In the fourth year, 7 hours are allocated to projects

time is distributed among the various groups of disciplines, compulsory classes with a tutor and preparation as follows:

General science group $S_t = 51 \cdot 32 = 1{,}632$ hours.

Professional subjects: $S_p = 44 \cdot 32 = 1{,}408$ hours.

Humanities: $S_h = 9 \cdot 32 = 288$ hours; total for compulsory classes, $S_t = 3{,}328$ hours.

Diploma project: $S_d = 7 \cdot 32 = 224$ hours

On-the-job training (for 1 year upon graduation). $S_{tr} = 1{,}600$ hours.

Laboratory work: $S_l = 32 \cdot 32 = 1{,}024$ hours.

Preparation: $S_{pr} = 13 \cdot 32 = 416$ hours.

The extent to which the technical aids are used, as well as the academic standing of the teaching staff, will be taken to agree with the parameters derived for the U.S.S.R. institutions of higher learning (MHTS and MPEI). $K_g = 0.50$; $K_o = 0.56$.

The parameters will then have the following values:

General science education:

$$K_1 = \frac{S_{se}}{S_t} = \frac{1{,}632}{3{,}328} = 0.490. \qquad (1)$$

Professional training:

$$K_2 = \frac{S_p}{S_t} = \frac{1{,}408}{3{,}328} = 0.420. \qquad (2)$$

Humanities education:

$$K_3 = \frac{S_h}{S_t} = \frac{288}{3{,}328} = 0.086. \qquad (3)$$

Diploma project:

$$K_4 = \frac{S_d}{S_t} = \frac{224}{3{,}328} = 0.066. \qquad (4)$$

On-the-job training:

$$K_5 = \frac{S_{rt}}{S_t} = \frac{1{,}600}{3{,}328} = 0.475. \qquad (5)$$

Laboratory work:

$$K_6 = \frac{S_l}{S_t} = \frac{1{,}024}{3{,}328} = 0.304. \qquad (6)$$

Preparation:

$$K_7 = \frac{S_{pr}}{S_t} = \frac{416}{3{,}328} = 0.125. \qquad (7)$$

Technical aids:

$$K_8 = 0.50. \qquad (8)$$

Academic staff

$$K_9 = 0.56. \qquad (9)$$

The integral criterion[1] will have the following value:

$$K = \sum_{i=1}^{i=9} \alpha_i K_i = 10 \times 0.490 + 8.0420 + 4 \times 0.86 +$$

$$+ 10 \times 0.066 + 6 \times 0.475 + 8 \times 0.304 +$$

$$+ 10 \times 0.125 + 6 \times 0.5 + 10 \times 0.56$$

$$K_{RCAT} = 24.4.$$

1. This integral criterion differs from those calculated earlier for the U.S.S.R.'s Moscow Higher Technological School (MHTS) and Moscow Power Engineering Institute (MPEI) and the United States' Massachusetts Institute of Technology (MIT), in that it includes probation which is due on graduation from the University of Salford (K_9).

Comparison of the curriculum of the Moscow Institute of Chemical Technology (course entitled 'Technology of Basic Organic Oil-chemical Synthesis'), the length of the course being 5 years, with that of the University of Salford, analysed above, also bears witness to the fact that the academic level of education at Salford is in all respects lower than that offered by MICT. This is evident from the analysis in Tables 11 and 12.

TABLE 11. Comparison of the curricula offered at the higher educational establishments of the U.S.S.R. and the United Kingdom

	Moscow Institute of Chemical Technology (U.S.S.R.)	University of Salford (United Kingdom)
Length of the course	5 years	4 years
The entire course includes the following types of academic activity		
Tutorial	143 weeks	32 × 4 = 128 weeks
On-the-job training	30 weeks	Students are recommended to take on-the-job training during vacations
Over-all amount of compulsory classes	4,493 hours	3,328 hours
Lectures	1,792 hours	1,984 hours
Laboratory work	1,502 hours	1,024 hours
Practical	1,199 hours	320 hours
Diploma project	960 hours	224 hours
Preparation	4,000 hours	416 hours

TABLE 12. Distribution of academic hours reserved for compulsory classes, by subjects

Subject	Moscow Institute of Chemical Technology (U.S.S.R.)		University of Salford (United Kingdom)	
	Total compulsory	Including laboratory	Total compulsory	Including laboratory
Calculus, mathematical simulation and computers	463	50	—	—
Descriptive geometry and mechanical drawing	126	—	-	
Mathematics I, II, III			288	-
Physics	306	162		
Physics (electricity and magnetism)	-		64	32
Physical metallurgy	—		64	32
Group of chemical subjects				
General chemistry	—	—	320	160
General chemical technology	126	46	—	-

Material structure	90	—	—	—
Non-organic chemistry	216	108	96	—
Organic chemistry	306	186	224	160
Physical chemistry	247	157	192	64
Analytical chemistry and physical and chemical methods of analysis	288	262	—	—
Colloidal chemistry	72	36	—	—
Fuel technology	—	—	224	64
Chemistry and technology of basic organic and oil chemical synthesis	288	178	—	—
TOTAL	*1,633*	*973*	*1,056*	*448*
Technical mechanics	234	18	—	—
Theory of machines	—	—	64	32
Strength of materials	—	—	96	32
Technical thermodynamics	54	12	—	—
Heat transfer	—	—	64	—
Heat and mass transfer	—	—	64	—
General electric engineering and principles of industrial electronics	140	50	—	—
Electrical technology	—	—	64	32
Heat engines	—	—	192	64
Hydraulics	—	—	96	32
Use of materials	—	—	64	—
Materials and constructions	—	—	64	—
Processes and apparatus of chemical technology	227	137	—	—
Theoertical principles of technological processes	68	—	—	—
Plant equipment and principles of designing	80	—	—	—
Principles of automation, and automation of industrial processes	98	36	—	—
Principles of construction	52	—	—	—
Fundamentals of safety engineering and fire-fighting equipment	62	12	—	—
Industrial processes	—	—	608	320
Industrial planning	—	—	64	—
Safety engineering, industrial situations and patents	—	—	64	—
Industrial organization and planning	98	—	—	—
Chemical engineering economics	54	—	—	—
Organization and management	—	—	64	—
Political economy	140	—	—	—
Humanities	416	—	288	—
Electives	88	—	—	—
Physical training	140	—	—	—
GRAND TOTAL	4,479	1,450	3,328	1,024

Students of the Moscow Institute of Chemical Technology are expected not only to learn the disciplines mentioned but also to work out a series of comprehensive course papers (projects) as follows fifth semester on theory of machines, seventh semester on processes and apparatus of chemical technology, eighth semester on automatics and automation of industrial processes, ninth semester on industrial equipment, and on industrial organization, planning and management.

Emphasis is laid in all course projects on the specific features of chemical industry For this reason, structures are designed and calculated to take account of operation and maintenance in different environments and with large fluctuations of temperature, pressure, etc Chemical technological processes, their automation and economic aspects are also stressed.

As in other institutions of higher learning, projects often tackle urgent problems of practical significance and their findings are made use of in industry.

Each project contains elements of theoretical and experimental research, which serves the purpose of preparing students for the completion of a final major work a diploma paper or diploma project

The integral criterion for the Moscow Institute of Chemical Technology is $K = 30.4$

The above analysis shows that the length of the course and the volume of chemical subjects are less than at the Moscow Institute of Chemical Technology, while factory training is not included in the Salford curriculum at all

Unfortunately, the graduate course programme for those wishing to proceed to a Master's degree is not available. If, in proportion to the new length of the course (five years), the basic indices are raised by 25 per cent, it would seem that a student proceeding to the degree of Master is supposed to complete (starting from the first year of study): 3,328 × 1.25 = 4,160 hours (compulsory classes with a tutor), of which 1,024 × 1.25 = 1,280 hours (laboratory work).

No assumption is here made for lecture time since we can safely presume that academic work in the Master's degree course takes the form of experimentation at laboratories and a diploma paper (thesis).

The curriculum for the course 'Technology of Chemical Engineering' for stream 'C' of the University of Salford is given in Table 13. This curriculum differs but little from the one previously analysed and discussed, and all the conclusions arrived at in reference to that curriculum are valid in this case

The University of Salford awards the Higher National Diploma (HND) to graduates who successfully complete the study programme.

All higher educational establishments of the U.S.S.R., including the Moscow Institute of Chemical Technology, award a uniform document Higher School Graduation Diploma to students who successfully complete the study programme, and Higher School Graduation Diploma (Honours) to those who complete credit work for 75 per cent of all the curriculum subjects with the highest mark (5) and for the others with 4, and who defend their diploma papers with the highest mark, 5.

TABLE 13. The curriculum of the course 'Technology of Chemical Engineering', stream 'C', University of Salford

Subject	Total no. of hours per week		Subject	Total no. of hours per week	
	Compulsory classes	Including laboratory		Compulsory classes	Including laboratory
General science subjects			Fuel technology I, II and III	7	3
Non-organic chemistry	2		Heat engines I and II	6	2
Organic chemistry I and II	6	3	Industrial processes I, II and III	19	10
Physical chemistry I and II	6	2	Factory planning	2	—
Mathematics I, II and III	7	–	Engineering laboratory work (tutorials)	3	2
Physics (electricity and magnetism)	2	1	Construction materials	3	—
Theory of machines	2	1	Processing of materials	2	—
Hydraulics	3	1	Organization and management	2	—
Heat transfer	2		Safety engineering, industrial situations and patents	2	—
Heat and mass transfer	2				
Electrical technology	2	1			
Strength of materials	3	1			
Applied mechanics	3	2			
TOTAL	40	12	TOTAL	54	22
Professional subjects			Humanities I, II, III	9	–
Physical metallurgy	2	1	Preparation	14	–
Technical drawing I and II	6	4	Designing	7	–
			GRAND TOTAL	124	34

Higher educational establishments of India

Secondary education does not follow a uniform pattern in India: there are schools with 11 and 10 grades. For this reason the universities offer preparatory courses at which prospective applicants for admission to higher school take what is called a pre-university year to complete the programme of the eleventh grade of secondary school. The certificate awarded on completion of a preparatory course (Pre-University Examination) and the High School Certificate awarded on completion of 11 grades of secondary school make applicants eligible for a university.

Engineers are trained at technical colleges and institutes. Some of the colleges are subordinate to universities.

The colleges specializing in the technological fields (such as Bihar Technical and Calcutta Engineering Colleges, Bombay College of Chemical Technology) and existing within the framework of universities award their graduates the first professional degree of B.Tech.

The Danbad Mining Institute, the Madras, Bombay, Kharagpur and Delhi technological institutes, and some other institutions of higher learning award their graduates higher school graduation diplomas, of which some are comparable to that of B.Tech.

The length of the course for the degree of B.Tech. is 4 to 5 years. As in the higher technical schools of the United Kingdom, this degree is awarded with and without honours, depending on the academic attainments of the graduates. The Bachel r's degree programme provides for the study of general science and general engineering disciplines for 2 to 3 years and professional subjects for the last 2 years of study. Brief on-the-job training is envisaged by the course curricula.

On obtaining the degree of B.Tech , specialists are supposed to take industrial training for from 1 to 2 years, and thereafter are entitled to obtain posts as technicians

The qualification of engineer is awarded to Bachelors of Technology after they have worked in industry as technicians for some time and passed a candidate's examination at the relevant engineering society.

The curriculum arrangements at a number of larger technical institutions provide that on obtaining the degree of B.Tech. a graduate may go on to advanced study at these institutions

This additional course offers an option of 2 study areas. design (1 year) and research (2 years) Those specializing in design are awarded the diploma of design engineer, and those specializing in researching, the diploma of the second professional degree of M.Tech.

INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY

The institute was founded in 1958 and recognized as an institution of higher learning of university level entitled to award academic degrees and issue diplomas Schooling starts from the higher level of secondary school.

The undergraduate course lasts for 5 years and leads to the degree of B.Tech. The curriculum provides for what is called an integrated course which, in the insitute's view, ensures a reasonable composite study of the sciences, applied disciplines and professional subjects, and this arrangement makes it possible for prospective engineers not only to be competent specialists in industry but also to untertake invention

There is a 2-year post-graduate course for the degree of Master in aeronautics, chemistry, electric-power engineering, mechanics, engineering metallurgy, civil engineering and other fields. The institute also trains researchers at the Ph D level

The academic staff includes 285 lecturers and tutors, of whom half hold doctoral degrees.

An interesting feature of this and other higher educ itional establishments is that efforts are constantly being made to perfect the content and forms of instruction so as to update the technical knowledge imparted to prospective engineers. The curricula and syllabuses are subject to periodical revision to keep pace with scientific and technological progress. At the same time, the closest attention is paid to the study of fundamental disciplines which serve as a basis for the evolution of the syllabuses.

The curricula and syllabuses of the institute incorporate programmes in the sciences and the humanities, due account being taken of the above considerations. The disciplines of these groups are taken up in logical sequence and reasonable proportions all through the course of study.

A prospective professional engineer goes through 4 stages of instruction at the institute.

Learning the fundamentals of science as represented by physics, chemistry and mathematics (general science disciplines). At the same time, students are gradually introduced to the technical trades (mechanical drawing, shop-work, and the like)

Studying a group of general engineering subjects (dynamics, mechanics of fluids and solids, thermodynamics, electrical circuits, electronics, and some others). Emphasis is laid at this stage on obtaining broad fundamental knowledge that will help the student to appreciate the links existing between the sciences and the engineering disciplines.

Working at subjects in the field of concentration which will enable the student to develop his faculty for creating physical and analytical models in his mind and conceiving basic operating principles and an arrangement of components for a structure to be designed.

Studying the peculiar features of structures as a whole from the point of view of their operation, maintenance, economics and industrial aesthetics.

Students are required to write a dissertation, known as a home paper. The curriculum stipulates continuous study at all stages of the humanities and social sciences (such as ethics, logics, economics, industrial management) to meet the objectives of modern society and take account of the relations between man and machine, resources and their control.

A current plan to revise the whole pattern of instruction, including curricula and syllabuses, is expected to be completed very soon.

The Master of Technology course provides for 1 year of study work and another year for preparation of a thesis.

Each engineering department offers its students a set of selected groups of more or less rigid disciplines representing various fields of learning. Each group comprises required subjects and electives. The provision of a large choice of composite programmes allows the student to select the branch of science best attuned to his interests.

A project to unify the length of the courses and the syllabuses is at present under way. At most Indian higher educational establishments the first year is reserved for a preparatory course, including the fundamental sciences. On passing examinations in these disciplines the student is entitled to continue his studies.

The period of instruction at the Indian Institute of Technology (Bombay) may be divided into 2 stages:

Stage One: 5 years of instruction and 1 year's work in industry, leading to the degree of B.Tech

Stage Two (after the B.Tech. is obtained): a more thorough study of the various subjects and instruction in methods of conducting independent research. This stage leads to the second professional degree of Master in Engineering Sciences and lasts for 1 to 2 years for those holding a B.Tech. (Honours) and for 2 to 3 years for those holding a B.Tech. without Honours.

On completion of the second stage and having obtained the degree of Master, graduates can proceed to a Ph.D. The doctoral course is 3 years long. Requirements for a Ph.D. consist of preparing and defending a thesis, which should be a piece of major research occupying nearly 2 years. In fact, doctoral degrees should also be regarded as the first academic degrees when majoring is in a narrow specialized field involving research and fundamentally new scientific results.

The existing curricula of the Bombay Institute of Technology (which are under revision at the present time) give an idea of the engineer training pattern in India. The coming changes will not lower the academic level of education.

The institute's academic year is divided into semesters, each of 16 weeks. Examination sessions are held in the middle and at the end of each semester.

The curricula are organized on the following pattern: (a) general institute requirements uniform for all departments, to be completed within 2½ years (5 semesters) (see Table 14); (b) specific departmental programme for each department, to be completed over another 2½ years (5 semesters).

The total number of academic hours (2,704) reserved for completion of the general institute requirements (the first stage of instruction) is made up as follows: lectures, 1,136 hours (42.1 per cent); tutorial, 384 hours (14.2 per cent); practical, 1,184 hours (43.7 per cent). This academic time is allotted to various subjects as shown in Table 15.

If we arrange the academic hours according to groups of disciplines, we obtain the following figures:

General science and general engineering disciplines: 2,240 hours, of which 944 hours (42.1 per cent) lectures; 384 hours (17.2 per cent) tutorial, and 912 hours (40.7 per cent) practical.

Professional subjects: 224 hours, of which 32 hours (14.3 per cent) lectures; and 192 hours (85.7 per cent) practical.

Humanities: 240 hours, of which 160 hours (66.7 per cent) lectures; and 80 hours (33.3 per cent) tutorial.

TABLE 14. General institute requirements

Year of study	Semester	No. of hours per week			
		Lectures	Tutorial	Practical	Total
I	1	14	5	15	34
	2	14	5	15	34
II	3	14	5	15	34
	4	14	5	15	34
III	5	15	4	14	33

TABLE 15. Breakdown of academic hours reserved for completion of general institute requirements

Subject	Lectures	Tutorial	Practical	Total
Mathematics	288	160	96	544
Physics	256	80	216	552
Chemistry	192	64	192	448
Applied mechanics	64	32	48	144
Strength of materials	32	16	48	96
Fluid mechanics	32	8	24	64
Thermodynamics	48	16	24	88
Electrical circuits	32	8	24	64
Economics	64	—	32	96
Logics	32	—	—	32
English	64	—	48	112
Mechanical drawing	—	—	240	240
Shop technology (on-the-job training)	32	—	192	224
TOTAL	1,136	384	1,184	2,704

Instruction at the second stage is governed by the departmental programmes. The programmes of the Chemical Engineering Department and the Mechanical Engineering Department, which are responsible for the training of chemical engineers and mechanical engineers respectively, are given in Tables 16 and 19. Thus the total over-all amount of time available equals. 2,680 hours, of which 1,152 hours (42.8 per cent) lectures; 128 hours (4.9 per cent) tutorial; and 1,400 hours (52.3 per cent) practical. The time distribution per subject is given in Table 17.

Homework was introduced in the curricula to enable the student to apply his knowledge and skills to the solution of composite problems (such work often takes the form of completing a small design or a mechanical drawing). The content of homework differs with the specialized fields of the departments, and in some cases may consist of carrying out experimental research on a limited scale. Some departments require their students to prepare a critique or to process experimental data as their home assignment. The consensus of opinion is that the student spends more time on home assignment than is stipulated by the curricula. This is bound to affect his progress in other discip-

TABLE 16. Chemical Engineering Department Programme. total amount of time available

Year of study	Semester	No. of hours per week			
		Lectures	Tutorial	Practical	Total
III	6	15	3.5	16	34 5
	7	14	1.5	18 5	34
IV	8	15	3	17	35
	9	14	—	18	32
V	10	14	—	18	32

TABLE 17 Time distribution per subject

Subject	Lectures	Tutorial	Practical	Total
Mathematcis	64	16	32	112
Mathematics including machine computation	48	32	32	112
Principles of chemical engineering operation	128	—	120	248
Materials technology	48	16	48	112
Chemical processes	256	—	280	536
Industrial stoichiometry	—	—	64	64
Equipment design and drawing	—	48	272	320
Thermodynamics	96	—	96	192
Electrical engineering	32	8	24	64
Theory of machines and design of machine elements	32	—	24	56
Industrial organization including cost accounting	32	—	—	32
Electronics	32	8	24	64
Chemical engineering				
Economics	32	—	—	32
Kinetics	32	—	32	64
Works visits	—	—	32	32
Instrumentation and process control	64	—	64	128
Reactor design	128	—	128	256
Homework	—	—	128	128
Electives	128	—	—	128
TOTAL	1,152	128	1,400	2,680

lines and his attendance at classes. Some commentators hold that the tenth semester should be entirely reserved for homework, others believe that 6 to 8 months should be allotted to it.

The total number of academic hours (2,704 + 2,680 = 5,384 hours) for the full 5-year course is broken down as follows. lectures, 1,136 + 1,152 = 2,288 hours (42.4 per cent); tutorial 384 + 128 = 512 hours (9.5 per cent), practical, 1,184 + 1,400 = 2,584 hours (48.1 per cent). Upon completion of the programmes of the third and fourth years of study, 6 weeks of on-the-job training is provided The aim is to acquaint students with actual industrial conditions (mechanical drawing, design, production, and counselling). It is believed at the institute that this is too short a period to enable students to acquire skills and develop a capacity for mechanical drawing. Emphasis is laid on problems involved in industrial organization.

On-the-job training equals:

S_{tr} = 6 weeks 2 training periods 5 days 8 hours = 480 hours

Time distribution according to groups of subjects is given in Table 18.

TABLE 18. Time distribution according to groups of subjects (in hours)

Subject	Lectures	Tutorial	Practical	Total
GENERAL SCIENCE AND GENERAL ENGINEERING DISCIPLINES				
General institute requirements				
Mathematics	288	160	96	544
Physics	256	80	216	552
Chemistry	192	64	192	448
Applied mechanics	64	32	48	144
Strength of materials	32	16	48	96
Fluid mechanics	32	8	24	64
Thermodynamics	48	16	24	88
Electrical circuits	32	8	24	64
TOTAL	944	384	672	2,000
Departmental programme				
Mathematics	64	16	32	112
Applied mathematics and machine computation	48	32	32	112
Fundamentals of engineering chemistry	128	—	120	248
Thermodynamics	96	—	96	192
Electrical engineering	32	8	24	64
Theory of machine and design of machine elements	32	—	24	56
Electronics	32	8	24	64
Kinetics	32	—	32	64
TOTAL	464	64	384	912
GRAND TOTAL	1,408	448	1,056	2,912
PROFESSIONAL SUBJECTS				
TOTAL	688	64	1,320	2,072
HUMANITIES				
Economics	64	—	32	96
Logics	32	—	—	32
English	64	—	48	112
TOTAL	160	—	80	240
PREPARATION				
TOTAL				128
WORKS VISITS				
TOTAL				32

Hence the total number of academic hours allotted to all types of academic activity equals 5,384 hours, of which, 2,912 hours (54.2 per cent) general science and general engineering disciplines, 2,072 hours (38.4 per cent) professional subjects, 240 hours (4.4 per cent) humanities, 128 hours (2.4 per cent) home (diploma) paper (thesis), and 32 hours (0.6 per cent) works visits. In addition, factory training is provided for 480 hours.

These figures prove that emphasis is laid on the study of general science and general engineering disciplines.

It is pointed out in the Preface to the Collection of the Curricula of the Indian Institute of Technology (Bombay)[1] that the content of the curricula and syllabuses is aimed at laying a solid theoretical foundation in the field of the sciences and the engineering disciplines.

The study of the engineering disciplines is designed to enable students to realize the basic problems of engineering in a generalized form instead of accumulating fragmentary knowledge or partial methods.

Professional subjects come up for study in the last $2\frac{1}{2}$ years and include theory, design and training in line with the specialized field chosen. The programme at this stage provides for laboratory experimentation, industrial training, home preparation, seminars, works visits, etc.

In order to find an integral criterion that would determine the academic level of education attained by graduates awarded a B.Tech. at the Indian Institute of Technology, Bombay, we shall calculate the parameters of the individual types of academic activity:

General science education:

$$K_1 = \frac{S_{sc}}{S_t} = \frac{2{,}912}{5{,}384} = 0.542. \qquad (1)$$

Professional training

$$K_2 = \frac{S_p}{S_t} = \frac{2{,}072}{5{,}384} = 0.384. \qquad (2)$$

Humanities education:

$$K_3 = \frac{S_h}{S_t} = \frac{240}{5{,}384} = 0.045. \qquad (3)$$

Diploma project

$$K_4 = \frac{S_d}{S_t} = \frac{128}{5{,}384} = 0.024. \qquad (4)$$

On-the-job training:

$$K_5 = \frac{S_{tr}}{S_t} = \frac{32 + 480}{5{,}384} = 0.096. \qquad (5)$$

1 *Syllabus of the 5-year Integrated Course for the Degree of Bachelor of Technology*, Bombay, Indian Institute of Technology, December 1966. *Report of the Senate Committee to Review the Undergraduate Programme*, Bombay, Indian Institute of Technology, 1971.

Laboratory work:[1]

$$K_6 = \frac{S_l}{S_t} = \frac{1,692}{5,384} = 0.314. \quad (6)$$

Preparation:[1]

$$K_7 = \frac{S_i}{S_t} = \frac{732}{5,384} = 0.138. \quad (7)$$

Technical aids and facilities employed in tuition:[2]

$$K_8 = \frac{S_{ta}}{S_t} = 0.50. \quad (8)$$

Academic staff:

$$K_9 = \frac{P_{deg}}{P} = 0,50. \quad (9)$$

K is derived from formula (10) page 40 and Table 3 as follows:

$$K = \sum_{i=1}^{i=9} \alpha_i K_i = 10 \times 0.542 + 8 \times 0.386 + 4 \times 0.045 + 10 \times 0.024 +$$
$$+ 6 \times 0.096 + 8 \times 0.314 + 10 \times 0.138 + 6 \times 0.50 +$$
$$+ 10 + 0.50 = 21,362$$
$$K_{III} \approx 21.4$$

If account is taken of the Master's degree course, the numerical value of this criterion can go up to something like $K_{III} \approx 31$.

It is extremely difficult to compare the content of subjects offered at the Bombay Institute with those studied at the Moscow Institute and the University of Salford, since the Bombay Institute curricula fail to use conventional terminology and are extremely brief. In some cases it is next to impossible even to identify fields of learning.

TABLE 19. Mechanical Engineering Department Programme

Year of study	Semester	Hours per week			
		Lectures	Tutorial	Practical	Total
III	6	14	2.5	13.5	30
IV	7	15	4.0	15.5	34.5
	8	14	4.0	15.5	33.5
V	9	15	—	16.5	31.5
	10	14	—	16.5	30.5

1. The over-all amount of practical (laboratory) training and independent preparation is tentatively differentiated by reference to the condensed syllabuses of the institute.
2. Technical facilities employed in tuition have been considered in terms of those at higher educational establishments of the U.S.S.R.

For example, course CHE-3250 'Industrial Stoichiometry' planned for 32 academic hours is defined as: 'Power and material balance in typical processes and operations' 'Stoichiometry', however, as a particular course, does not form part of the programmes at any of the higher educational establishments considered in this paper.

Course CHE-321 'Principles of Chemical Engineering Operations' is defined as:

The liquid system, properties, effect of compression and shear-equation of continuity, energy and momentum, flow of liquids in pipes, channels, patched and fluidized beds.

Flow past immersed bodies, storage, transport, pumps. The gaseous system: pressure and vacuum, flow of gases through pipes and patched beds, storage and transport. Non-Newtonian and two-phase flow.

This latter course is one of 'Fluid Mechanics'. In the case of the Soviet higher educational institutions these topics are included in the course entitled 'Processes and Apparatus of Chemical Engineering'.

TABLE 20. Time distribution as per subjects

Subject	Lectures	Tutorial	Practical	Total
Mathematics	32	16	—	48
Mathematics including machine computation	48	16	24	88
Electrical engineering	96	24	72	192
Theory of machines and mechanisms	96	8	72	176
Thermodynamics and combustion	32	8	24	64
Machine design and drawing	32	—	96	128
Workshop technology	32	—	24	56
Engineering metallurgy	32	—	24	56
Heat power engineering	64	16	48	128
Strength of materials	64	32	24	120
Principles of engineering production	192	—	192	384
Fluid mechanics	96	—	72	168
Machine design	64	32	144	240
Heat transfer	32	16	24	72
Refrigeration, air conditioning	64	—	48	112
Instrumentation and process control	64	—	48	112
Industrial organization, cost accounting	32	—	-	32
Electives	64	—	48	112
Visits, seminar	-	—	128	128
Report writing	16	-	—	16
Home paper (project)	—	-	128	128
TOTAL	1,152	168	1,240	2,560

For the Mechanical Engineering Department Programme the total number of academic hours (2,560) is divided as follows lectures, 1,152 hours (45 per cent); tutorial, 168 hours (6 6 per cent), and practical, 1,240 hours (48 4 per cent) See Tables 19 and 20.

Proposals for changes in the curricula are under discussion at the present time An academic year would consist of 2 semesters, 15 weeks of 5 working days each, providing for uninterrupted studies (lectures, tutorial, practical). The sixteenth week would be reserved for preparation, and the seventeenth, for actual examinations crowning the semester The number of lectures and the amount of practical training would be cut down On-the-job training would take place during the third and fourth years of study within a shorter period of 4 weeks.

The over-all amount of teaching time allotted to theoretical studies during the course, and the total number of hours per week according to study years, semesters and types of academic activity under the draft curriculum,[1] are as shown in Table 21 These figures show that the total number of hours (4,507.5) in a semester (the length of a semester equals 15 weeks) allotted to theoretical studies is as follows 1,950 hours (43 3 per cent) lectures, 495 hours (11 per cent) tutorial, and 2,062 5 (45.7 per cent) practical. Comparison of these figures with the relative parameters of the existing curricula is given in Table 22 The

TABLE 21 Number of hours per week according to study years, semesters and types of academic activity

Year of study	Semester	No of hours per week			
		Lectures	Tutorial	Practical	Total
I	1	10	4	14	28
	2	12	4	11	27
II	3	12	5	10.5	27 5
	4	12	5	10 5	27 5
III	5	14	5	12 5	31.5
	6	14	4	15	33
IV	7	14	3	14	31
	8	14	3	14	31
V	9	14	--	18	32
	10	14	—	18	32

TABLE 22 Comparison of draft proposals with existing curricula

Types of academic activity	No of hours reserved for theoretical studies in curricula	
	Existing	Draft
All types of academic activity	5,384 (100 per cent)	4,507 5 (84 per cent)
Lectures	2,288 (100 per cent)	1,950 (85 per cent)
Tutorial	512 (100 per cent)	495 (96 5 per cent)
Practical	2,584 (100 per cent)	2,602 5 (80 per cent)

1 *Report of the Senate Committee to Review Undergraduate Programme*, op cit., p. 28.

comparison shows that the draft curricula tend to reduce substantially the total number of hours allotted to theoretical studies and particularly to practical work and lectures. This trend is also evident from an analysis of the distribution of the total number of hours according to individual groups of disciplines and types of academic activity in the draft curriculum (Table 23).

It will be seen that the draft curriculum aims at a substantial curtailment of the academic hours earmarked for mathematics (from 544 to 300, including a reduction from 288 hours of lectures to 150), chemistry (from 448 to 330, including a reduction from 192 hours of lectures to 150, and a reduction from 192 hours of laboratory and practical classes to 135), etc.

The intention is also to set aside a large amount of time in the fifth year (preferably in the afternoon) for thesis work (home paper), so that students will not divide their attention between this activity and the study of programme subjects.

Should the draft curriculum take effect, the academic standard of training at the Bachelor's degree level will be maintained.

TABLE 23. The draft curriculum: general institute requirements, 2½ years, and the Chemical Engineering Departmental Programme, 2½ years

Subject	Lectures	Tutorial	Practical	Total
General science and general engineering disciplines				
Mathematics	150	150	—	300
Physics	240	75	202.5	517.5
Chemistry	150	45	135	330
Applied mathematics	60	30	45	135
Machine computation	60		60	120
Mechanical drawing	—	—	225	225
TOTAL	660	300	667.5	1,627.5
Professional subjects				
Departmental subjects	660	90	705	1,455
Electives	360	75	225	660
Non-departmental	120	30	90	240
Workshop	—	—	45	45
TOTAL	1,140	195	1,065	2,400
Humanities				
Economics	30			30
Economics and ethics	30		30	60
Logics	30		60	30
English	60		60	120
TOTAL	150		90	240
Home paper (project)			240	240
GRAND TOTAL	1,950	495	2,062.5	4,507.5

Higher educational establishments of France

School-leavers holding the *Baccalauréat* are not immediately eligible for institutions of higher learning, and must go through an extra period of training at preparatory departments set up in certain *lycées* for 1 to 3 years.

Studies at the *grandes écoles* are centred round the fundamental (general science and general engineering) disciplines, training of researchers being the main objective. Institutions of higher learning, such as the École Centrale des Arts et Manufactures, Châtenay-Malabry, train engineers chiefly for industry (technologists and designers) and managerial personnel, the main objectives of training being. (a) to enable students to form a scientific *Weltanschauung*; (b) to establish conditions for students to learn the fundamental engineering problems related to the branch of technology in which they specialize; and (c) to train prospective engineers for independent work.

In pursuance of this goal, instruction at the higher technical schools is of a high theoretical level and is based on methods of research to some extent at the expense of descriptive disciplines.

The higher educational establishments provide conditions for students to master methods of experimental research and to work on real problems and complex physical phenomena. All this goes a long way towards developing engineering intuition and resourcefulness.

The humanities, which help to reveal the urgent problems of modern society and equip specialists with the understanding needed when working with other people, play an important part in the technical education offered by institutions of higher learning in France.

All these objectives can be attained provided the faculty keeps in close contact with students and, at the same time, with industry and its latest developments.

Students are allotted time for independent work, which enables them to prepare reports, think over major scientific and technological problems, study scientific literature, and devise projects.

The curricula of institutions of higher learning provide, as a rule, for 3 stages of instruction in France at the present time, e.g. there are 3 stages in each major study area (physics and mathematics, physical chemistry, and biogeology) at the Natural and Exact Sciences Department of the University of Toulouse

Upon completion of the first stage of 2 years, students take an examination for the university diploma in the field of natural and exact sciences (*Diplôme Universitaire des Études Scientifiques*- DUES). A commission analyses the attainments of those students who complete the first stage programme and plans their further fields of learning, with due regard to their capacities.

The second stage (including examinations) also lasts for 2 years and leads to the degrees of *Licence* and *Maîtrise*.

The degree of *Maitrise* requires the student to pas iminations for 4 certificates-- Certificats C_1 and C_2 in the first year of s , and C_3 and C_4 in the second. The examinations are taken on completion of the relevant theoretical studies accompanied by laboratory practice and course (research) work.

Those passing the examinations for the degree of *Licence* in the first or second year of the second stage may be exempted from one of the certificates required for the degree of *Maîtrise*, and obtain the degree with only 3 certificates.

The third stage (2 more years) is reserved for those proceeding to a variety of doctoral degrees: *Doctorat de Spécialité de 3ᵉ cycle* (DS), *Docteur en Sciences Techniques*, and *Doctorat d'État*.

Candidates for the degree of *Doctorat de Spécialité de 3ᵉ cycle* must master a narrow specialized field of learning, and, as a prerequisite, obtain the *Diplôme d'Études Approfondies* (DEA) awarded after the first year of study at the third stage upon passing written and oral examinations in the major field of learning. A report setting out the research work completed during the year is discussed in the course of an interview and a thesis is presented and defended.

These requirements are sufficiently high for the completion of higher education and transfer to a research career leading to academic degrees.

As in other countries, the training of engineering personnel in France is also arranged through evening classes. Training of this type is offered, for example, by the Conservatoire National des Arts et Métiers. This institution has nearly 50 branches throughout the country and offers facilities to those in active employment who have a complete secondary education and wish to raise their qualifications and improve their scientific, technical and economic knowledge in off-work hours.

To maintain a high level of instruction, all those registered at the Conservatoire National des Arts et Métiers are required to complete a preparatory course (*cycle préparatoire*) for 1 to 2 years, during which time they are taught elementary mathematics and elementary physics.

Further instruction, following the pattern of the full-time studies, falls into 3 stages.

Stage 'A' lasts for 3 to 4 years. Students must complete 7 courses and receive 7 passes at this stage. Those receiving a pass for an extra (eighth) course are entitled to the University Technological Diploma (*Diplôme Universitaire de Technologie*: DUT) or the Technological Diploma of the Conservatoire National des Arts et Métiers (DT du CNAM), depending on the subject for which the extra pass was awarded.

The second stage (stage 'B') lasts for 2 to 3 years and consists of 5 courses for which students are required to receive passes. Those who obtain an extra (sixth) pass are awarded the Diploma of Higher Technical (Economic) Courses (*Diplôme d'Études Supérieures Techniques ou Économiques*: DEST or DESE).

The third stage (stage 'C'), which lasts for 1 to 2 years, involves an examination in a technical (or economic) discipline and completion of a diploma paper. Successful completion of the study programme of this stage leads to the *Diplôme d'Ingénieur* (or *d'Économiste*) *du CNAM*.

Each course is, as a rule, of an integrated type. 40 academic hours of lectures (including some broadcast by television) accompanied by seminars and independent preparation. The over-all volume of seminar work and independent preparation ranges from 80 to 120 hours. A good report on the 40-hour programme entitles the student to a pass, and on the 20-hour programme, to a 'half-pass'.

Practical training consists of making experiments and taking measurements at laboratories, and presenting reports on methods of applying the knowledge so obtained. Classes of this type are organized in cycles of approximately 20 academic hours, each class lasting for an average of 3 hours. Fulfilment of all assignments in these practical classes entitles the student to a pass for the 20-hour programme and a 'half-pass' for the 10-hour programme.

With a view to expediting the training of specialists awarded the *Diplôme d'Ingénieur* (or *d'Économiste*) *du CNAM*, students who excel in theoretical studies and practical training can be enrolled in a full-time department for a 1-year course. Those registered at the full-time department leave their jobs in industry for the year of study. The following requirements must be met by a candidate for registration as a full-time student: (a) a 3-year uninterrupted record of service in industry in the specialized field selected at CNAM, (b) the status of a student of CNAM or of one of its branches, for at least 2 years, (c) possession of a *Diplôme de Technologie du CNAM*.

A new procedure for obtaining the third-stage diploma was introduced as from the 1970/71 academic year, as follows.

A candidate for the diploma is required to pass a general examination consisting of 2 practical tests and 1 oral test, complete independent research work of a theoretical or laboratory experimental character, and defend it as a diploma paper.

The *Diplôme d'Ingénieur du Conservatoire National des Arts et Métiers* and the *Diplôme d'Ingénieur d'État* do not come in the same category.

The *Diplôme d'Ingénieur d'État* may be claimed by citizens of the French Republic of not less than 30 years of age, having a service record with industry of at least 5 years, including 2 years in posts requiring the general theoretical and technological knowledge of an engineer.

The *Diplôme d'Ingénieur du CNAM* can only be awarded to candidates who meet the specified prerequisites and requirements. No one may take an examination for the *Diplôme d'Ingénieur* without a service record in industry, evaluated by the professor in charge in terms of length and significance.

Each candidate for the diploma is required to obtain the consent of the professor in charge to contribute to the solution of the problems entrusted to the professor's laboratory or design office. In compliance with this procedure, the candidate submits to the professor a synopsis of his work not later than 6 months in advance of the general examination. If the candidate possesses the required practical and theoretical background to enable him to discharge the duties of an engineer, the professor assigns him work for which he is responsible.

In his testimonial, the professor in charge is expected to analyse the candidate's proposed work, its originality and its significance for science and industry. The professor also indicates the candidate's industrial experience and administrative ability. On the basis of these reports, the CNAM director authorizes the candidate to take the general examination (practical and oral tests) and complete a diploma paper

The duration of the practical tests should not exceed 8 hours. The tests may include a project or calculation of the details of design, solution of one or more problems, an analytical laboratory assignment, a critical analysis of documentation, a report on a technical assignment Two topics from the list of tests should fall within the candidate's professional field.

One of the assignments should be accompanied by a written composition to show the candidate's ability to express his ideas and thoughts in technical language In addition, the professor gives the candidate an oral test comprising a brief report by the candidate on a specific topic selected by the commission, followed by a broad discussion of the topic

Performance is assessed on a 12-point scale, with coefficients 5 and 3 for practical and oral tests respectively

The candidate is allowed to defend a diploma paper only if the integral mark obtained with due regard to the coefficients, comes to at least 96 points, with 6 points being the lowest possible mark for each individual test.

The final decision concerning the paper is taken by a commission presided over by the professor in charge The candidate must make an oral presentation of this paper and the commission of experts pronounces on its merits.

If successful, the candidate is awarded the *Diplôme d'Ingénieur du CNAM* stating the specialized field of learning.

Holders of the *Diplôme d'Ingénieur du CNAM* may proceed to the *Diplôme de Chercheur* or *Diplôme de Docteur-Ingénieur* Those obtaining a diploma of this kind are entitled to do academic work at higher educational establishments specializing in technical fields of learning.

It follows from the above that the duration of studies for the *Diplôme d'Ingénieur du CNAM* offered by this extremely variable system of evening classes at the Conservatoire National des Arts et Metiers ranges from 6 to 11 years

Those proceeding to the *Diplôme d'Ingénieur d'État* must meet another requirement, namely, employment in industry for a specified length of time, so that all in all it may take a candidate as long as 8 to 13 years to obtain this diploma Despite the rather lengthy course of studies under this system, the education offered is narrower and of a lower level as compared with that provided by the normal day-time pattern at the institutions of higher learning in France. None the less, CNAM graduates' practical skills seem to be much better than in the case of those who have completed their education on the full-time pattern.

A more detailed analysis of the curricula (full-time course) of the Institut National des Sciences Appliquées, Lyons (INSA), is given below

INSTITUT NATIONAL DES SCIENCES APPLIQUÉES

Studies at the institute under the full-time programme occupy 5 academic

TABLE 24. First stage programme (2 academic years)

Subject	Total no. of hours	Laboratory	Subject	Total no. of hours	Laboratory
Mathematics	645	—	Preparation for on-the-job training	16	—
Mechanics	105	—	TOTAL	196	—
Physics	540	180	French	60	—
Chemistry	270	90	Foreign languages	120	—
TOTAL	1,560	270	TOTAL	180	—
Mechanical drawing	60	—	Physical training and sports	120	—
Mechanical drawing and technology	60	—	GRAND TOTAL	2,056	270
Shop technology	60	—			

years and consist of 3 stages. For the first stage, the length of studies is 2 years.

In the first stage (see Table 24), considered as basic for all fields of study, students learn general science subjects, certain subjects of the general engineering group, and some of the humanities.

Classes in mathematics in the first year of study (at the rate of 11 15 academic hours a week) are conducted by television. The mathematics syllabus includes only differential and integral calculus, algebra, analytical and differential geometry.

The courses in physics, chemistry and mechanics are not extensive.

TABLE 25. Second-stage curriculum for the section 'Chimie Industrielle'

Subject	No. of hours for 2 years of study		
	Lectures and seminars	Laboratory	Total
Mathematics	30	—	30
Non-organic chemistry	90	240	330
Analytical chemistry	45	—	45
Organic chemistry	120	270	390
Chemical kinetics	60	45	105
Structural physical chemistry	120	90	210
Electrochemistry	60	—	60
Thermodynamics	90	90	180
Chemical technology	90	—	90
Instrumental methods of analysis	30	—	30
Crystallography	30	30	60
Electronics	60	60	120
Statistics	30	—	30
Humanities	80	160	240
TOTAL	935	985	1,920

However, the total number of hours stipulated by the curriculum for the study of mathematics, physics and chemistry is reasonably high.

Successful completion of the first stage entitles the student to go on to the second, in which students are registered for specific fields of concentration.

The second-stage curriculum of the Department of Chemical and Mechanical Engineering is given in Table 25.

Upon completion of the second stage, students are required, as a rule, to work for a probationary period in industrial enterprises, responsibility for the necessary arrangements resting with the Service de Liaison Étudiants-Entreprises set up by the Comité de Bienfaisance des Écoles et des Universités de Paris. The term of probation is extremely brief (4 to 6 weeks) but may be extended at the expense of the students' vacations. Under these conditions, probation cannot be regarded as an integral component of instruction, closely related to the content of theoretical schooling. As a result, INSA graduates have, as a rule, no industrial experience of any significance nor any direct knowledge of industry.

The third stage of instruction, lasting 1 year, is reserved for the subjects given in Table 26.

Independent preparation is stipulated at the rate of 10 hours a week all through the 5 years of study, to enable students to fulfil assignments and work at study material.

The total number of hours allotted to compulsory classes and independent preparation for the 5 years of study therefore amounts to: $S_t = 2{,}056 + 1{,}920 + 960 = 4{,}936$ hours, of which $270 + 985 + 585 = 1{,}840$ hours laboratory work; and $S_{pr} = 30$ weeks × 5 years of study × 10 hours = 1,500 hours preparation.

After the 1968 change-over to a five-year course of study, basic study areas were established in the training of mechanical engineers, and it was decided

TABLE 26. Third-stage curriculum

Subject	No. of hours		
	Lectures and seminars	Laboratory	Total
Industrial chemistry	60		60
Operations analysis and optimization	30		30
Automatics and control	30		30
Chemical technology		120	120
Analytical chemistry		120	120
Macromolecular chemistry	60		60
Reactor design	60		60
Humanities	30	105	135
Electives: organic and biological chemistry, macrochemistry and physical chemistry, chemical technology, non-organic chemistry	105	240	345
TOTAL	375	585	960

in particular that specialists in design, construction, and the technology of construction of machine-tools should be trained within the framework of the Section 'Mécanique Appliquée' (GM_1).

The bulk of graduates specializing in applied mechanics will be going to research institutions for permanent employment and it was therefore deemed desirable that mechanical engineers specializing in applied mechanics should meet the following requirements:

They should possess a sufficiently broad general scientific education and have some idea of how to realize in nature designs of industrial complexes involving large-scale use of machinery.

They should have a technical education, sufficiently compact and practical, to enable them to create the planned system of mechanisms and bring it to perfection, dealing with all difficulties encountered.

A set of subjects was selected and their volume decided upon, to ensure that mechanical engineers were trained to comply with the above requirements (see Table 27).

Taking into account the first stage of study, the distribution of the total number of hours (4,456) among the various type of academic activity will be as follows

Total number of hours allotted to the programme 4,456 hours, of which 630 hours (or 14.1 per cent) laboratory work; and 480 hours (or 10.8 per cent) projects.

Distribution of academic time per groups of disciplines: general science and general engineering, 2,415 hours (54.2 per cent); professional 1,531 hours (34.3 per cent); and humanities, 510 hours (11.5 per cent).

TABLE 27 Curriculum for the section 'Mécanique Appliquée' (second and third stages 3 years of study)

Subject	Total No. of hours	Subject	Total No. of hours
Mathematics	195	Lubricants	30
General principles of mechanics	165	Metallurgy and metals	90
Fundamentals of kinematics	30	Automatics	75
Oscillations	75	Technology of processing and production	165
Solids mechanics	195	Hydraulic and gas machines	120
Fluid mechanics	60	Designing	480
Thermodynamics	30	Laboratory work	360
Electrical engineering and electronics	60	Principles of simulation	15
Kinematics and dynamics of machines	45	TOTAL	1,335
		The humanities	
		Organization	210
TOTAL	855	GRAND TOTAL	2,400

The corresponding distribution laid down by the curriculum of the École Centrale des Arts et Manufactures at Châtenay-Malabry is as follows. general science and general engineering, 49 per cent, professional, 31 per cent, and humanities, including economic subjects, 20 per cent.

It follows from the above that the correlation between the general science, general engineering and professional disciplines is roughly the same as stipulated in the INSA curriculum. The difference appearing in the humanities programmes can be explained by the fact that some economic subjects (industrial organization and management) are classed among the professional disciplines in one case and the humanities in the other.

An analysis of the curricula of some other higher technical schools in France shows that there is no difference in principle concerning the appropriate pattern for engineer training. At the general meeting of the section 'Mécanique Appliquée' which took place on 10 May 1968, M. Bonvalet, Director-General of INSA, said that graduates from institutions of higher learning providing a 5-year course could obtain an additional or permanent education at specialized schools in France or abroad for example, at the Massachusetts Institute of Technology.[1]

This signifies that INSA does not provide for a complete engineering education.

In broader terms, engineering education can be divided into 2 stages:

First stage. theoretical study for 5 years followed by probation in industry as a prerequisite for taking an examination and completing a paper for the *Diplôme d'Ingénieur* of the institution of hig' :r learning concerned.

Second stage: study for 1 to 2 years for the *Doctorat du 3e cycle*.

It can be presumed then that studies for the degree of *Doctorat du 3e cycle* constitute the final stage of engineering education.

Analysis of the curricula prompts the conclusion that the degree of Engineer awarded by the Massachusetts Institute of Tech :ology is comparable to that of *Doctorat du 3e cycle* awarded by the higher educational establishme ts of Franc

1 *Option Génie Mécanique GM1, Project d'une Section d'Ingénieurs Mécaniciens Designée Provisoirement par GM1 et Établie par la Commission des Programmes de l'Actuelle Section Mécanique Appliquée*, p. 16 17

Industrial training for engineering degrees

The procedures for obtaining the qualification or degree of Engineer (*Diplôme d'Ingénieur*) testify to the prevailing view in all countries that training of engineers without on-the-job practice is inconceivable. Even though higher schools are not in a position to arrange planned factory training for undergraduates while they are engaged in theoretical study, such training is considered essential for graduates on completion of their theoretical schooling. Only if they go through industrial training can they be allowed to take the final examination and complete and defend a diploma paper (project) for the degree (title or qualification) of Engineer.

It would seem that the effect of factory training conducted upon completion of the theoretical course is reduced in as far as it is hardly possible to arrange it under a specific programme taking account of the general orientation in the formation of a versatile engineer, erudite not only in theoretical but also large-scale practical matters.

In the case of the higher educational establishments of the U.S.S.R., compulsory introductory training is stipulated for first-year students upon completion of the theoretical course and the subsequent examination, in addition to study of the technology of industrial production processes, which takes place at industrial-type workshops during the first to the third years of education. The aim of introductory training is to help the student form an idea of the specific features of the industry in which he is destined to be employed on graduation. Apart from arousing the student's interest in learning, such training helps acquaint him in depth with professional disciplines.

The second phase of industrial (technological) training occurs on completion of the third-year programme. Students are, as a rule, required to undertake workers' jobs at this time. The aim is to give them a chance to study the technology of production, equipment, machinery, devices and organization of work on the spot.

The third phase of industrial training comes after completion of the fourth year of study, at which time students are supposed to undertake engineering and technological duties in posts falling within the competence of the Chief Technologist, Chief Mechanic or Chief Economist of the industrial enterprise concerned.

The fourth phase is known as pre-diploma training. Students are expected during this phase to collect material bearing on their diploma papers (projects) at industrial enterprises.

Thus, the over-all length of undergraduate industrial training ranges from six to ten months (depending on the specialized field of learning) for the entire period of education.

Industrial enterprises are instructed to collaborate with specific institutions of higher learning in this respect, the appropriate directives being issued by joint orders of the Minister of Higher and Specialized Secondary Education and the ministers of the appropriate branches of industry. Students are entitled to grants from the institutions of higher learning, and the factories pay them a salary over and above the grant for work done as a non-academic assignment.

The factory managers are under an obligation to move the students from one working station to another, to make arrangements for lectures by leading factory specialists, and to provide conditions for the students to study industrial production (technology, organization and economics) as a whole and in its individual aspects. With this aim in view, training supervisors appointed by higher school and factory, are jointly responsible for the execution of the factory training programme approved by the higher educational establishments concerned on the basis of an organic link with theoretical schooling. With industrial training patterned along these lines, course papers (projects) are prepared on the basis of both theoretical knowledge and practical experience.

Factory training is also a rich source of material for diploma papers (project), which may prove of value not only theoretically but also practically and the results of many such papers are in fact utilized in industrial production.

When factory training takes place after graduation, it is divorced from theoretical schooling, and factory managements can hardly be expected to meet the requirements of higher schools in terms of training content and procedure; the schools, in turn, cannot keep industrial training under control so that it is in line with the eventual goal of training broadly oriented engineers.

One other important consideration must be mentioned: if a higher school graduate comes to a factory to work and his subsistence becomes the factory's responsibility, his employment will necessarily be geared to the interests of this factory. Industrial training can only be effective if it is organized and controlled by a higher school which regards it as an integral part of instruction

If students take jobs to study industrial production in vacation time, therefore, it may be said with certainty that, in the absence of any supervision by the higher school, there will be no significant raising of the level of practical training for engineers.

Academic degrees and titles

There are two academic degrees in the U.S.S.R.: Candidate of Science (in a specialized field of study) and Doctor of Science (in a specialized field of study).

Candidates of Science are trained, as a rule, through post-graduate study lasting three years and offered by higher educational establishments and research institutions. This is a specific form of training for highly qualified teaching personnel and researchers.

Those seeking registration for post-graduate study must be graduates of a higher school, pass a competitive entrance examination, and complete an essay which is approved by the department head concerned. In his essay, the intending post-graduate student is expected to justify his choice of subject for post-graduate study, stating why this particular theme should be studied at all and what contribution it can make to the development of science and technology. He should also give evidence of his familiarity with the proposed and adjacent fields of study.

Post-graduate students are required to sit for what is known as a Candidate's examination (in addition to the entrance examination), to complete a thesis and to defend it in public.

A thesis for the degree of Candidate of Science must contain new scientific and practical conclusions and recommendations and show evidence of the candidate's capacity to pursue further research studies without supervision, his competence in the field of study he is engaged in, as well as his knowledge of the problems covered by the thesis.

The post-graduate student pursues his studies on an individual plan approved by the Academic Council of the higher educational establishment or research institution concerned for the entire period of the post-graduate course. A supervisor selected from among those holding the degree of Doctor of Science is appointed to guide post-graduate students in their research.

A thesis for a Doctoral degree must be a fully independent piece of research, and show evidence of the solution of a major scientific problem and a significant contribution to learning in a practical field of study. A candidate for a Doctoral degree is not required to take any qualifying examinations, and no deadlines are fixed for the presentation of his work.

The degree of Candidate of Science is awarded by the Academic Council of the higher educational establishment or research institution concerned, having due regard to the results of the public defence. Compliance with the procedure for granting the degree is supervised by the Degree Awarding

Commission set up by the Ministry of Higher and Specialized Secondary Education of the U.S.S.R.

A person holding the degree of Candidate of Science or the academic title of Professor, who succeeds in defending a Doctoral thesis in public, is awarded the degree of Doctor of Science. The degree is awarded by the Degree Awarding Commission on the recommendation of the academic councils of higher educational establishments or research institutions.

The academic councils may accept a thesis for defence no sooner than three months after the candidate's last published work on the thesis. Those seeking the degree of Candidate or Doctor of Science must publish an abstract setting out the main content of the thesis and enumerating all published works on the topic, and circulate copies of the abstract to interested institutions and organizations as well as to individual scientists and specialists.

Official opponents are then appointed – at least two for a Candidate's thesis and three (all Doctors of Science) for a Doctoral thesis, and a qualified organization is designated – normally a research institution or a higher educational establishment to which the thesis is referred for examination.

In the light of the discussion of the thesis, the Academic Council takes a decision by secret ballot, requiring a qualified majority of the members voting.

It will be seen from the above that candidates for academic degrees have a complete higher education within five to six years, and are only required to reveal their ability in research and knowledge of the chosen field of study.

Whether or not an academic degree is awarded depends wholly on the scientific level of the thesis and on the extent of the contribution made to science, technology and culture, i.e. on the significance and scope of scientific achievements.

Depending on their academic or research activity, scientific workers may be awarded, apart from academic degrees, the following academic titles: (a) junior instructor in institutions of higher learning, and junior researcher in research institutions, (b) associate professor in institutions of higher learning, and senior researcher in research institutions, (c) professor in institutions of higher learning and research institutions.

Those holding a higher education diploma and having sufficient qualification for academic or research work are eligible for the academic title of Junior Instructor or Junior Researcher. The decision is taken by the rector of the institution of higher learning or the director of the research institution concerned, on the basis of a recommendation from the academic council arrived at by secret ballot.

The academic title of Associate Professor (Senior Researcher) may be granted to those holding the degree of Candidate of Science who have been appointed to a competitive post of associate professor at an institution of higher learning or of senior researcher at a research institution, who have remained in this post for at least one year, and who have completed and published during this time scientific works of significance for the development of science and technology.

The academic title of Professor may be granted to those holding the degree of Doctor of Science, who have been appointed to a competitive post of professor at an institution of higher learning or of professor or senior researcher at a research institution, who have remained in this post for a least one year, who have completed and published during this time scientific works of significance for the development of science and technology, and who have guided a number of students in their post-graduate studies

The academic titles of Professor, Associate Professor and Senior Researcher are awarded by the Degree Awarding Commission on the recommendation of the academic councils of the institutions concerned.

Professors and doctors of science who have been engaged in successful research for many years and who have solved a number of major problems, thereby making an outstanding contribution to the development of science and technology, are eligible for the degree of Honoured Worker of Science and Technology. This title is conferred by the Presidium of the Supreme Soviet of the constituent republic concerned on the recommendation of the academic councils of institutions of higher learning or research institutions.

The granting of this title is not dependent on the candidate's age since research achievements are the only criterion, but it usually goes to scientists of from 50 to 70 years old.

The study, *Les Études Supérieures. Présentation Comparative des Régimes d'Enseignement et des Diplômes*, to which reference has already been made, states in the section devoted to the United Kingdom that there are two distinct doctoral degrees (a) the Ph.D., which is awarded in many fields of learning after two or three years of study, completion of independent research work, submission of a thesis and passing one or two examinations; and (b) the Higher Doctorate, which is awarded to outstanding researchers who have held a Ph.D for many years and have a series of original works, most of them published, to their credit.

Both doctoral degrees are considered to be the highest academic degrees.

Institutions of higher learning award professional degrees and diplomas in the following sequence. *Diplôme Universitaire du 1^er cycle* after two years of study; *Diplôme* after three to four years of study, *Licence* in the fourth year of study, *Maîtrise* on expiration of the fourth year of study, *Doctorat de Spécialité du 3 cycle* after six years of study, and *Doctorat d'État* after eight years of study.

It will be noticed that the degree of *Docteur-Ingénieur* is not included in the list This is defined in the above-mentioned study as a degree of higher education, which is awarded following the completion of a two-year course of study and the defence of two theses reflecting the candidate's work on the practical application of science in technology. The degree is awarded provided the candidate holds a diploma attesting to an engineering education and three certificates attesting to advanced training.

This means that those proceeding to the degree of *Docteur-Ingénieur* are required to have a complete higher education. However, the level signifying the completion of higher education is not specified Despite the requirement that a document be presented attesting to a higher education, candidates are also required to take an additional course of study. Another point calling for comment is that candidates an only expected to be able to apply scientific knowledge to the solution of engineering problems The study tends to put the degree of *Docteur-Ingénieur* and that of *Doctorat d'État* on the same footing.

The study defines the *Doctorat d'État* as the highest degree in higher school. However, the degree of *Maîtrise* is not sufficient to make a candidate eligible for a *Doctorat d'État* which necessitates an additional course of study of at least two years.

In comparing requirements for the award of various academic degrees, we can only emphasize again that the existing patterns of training scientific personnel in the United States, the United Kingdom and France do not stipulate the award of degrees for attainments in research alone, as is customary in the U S S R , Hungary, Czechoslovakia and some other countries when the decision is taken to award a Doctoral degree.

On the basis of available information, it is difficult to pronounce judgement on the comparability of Doctoral degrees awarded in the United Kingdom and the United States, despite a fairly large degree of similarity in the systems of higher education and researcher training in these countries.

It can be asserted, however, that the requirements for the Doctoral degrees in the United Kingdom, United States and France, and the Candidate's degree in the U S S R are identical in character. It goes without saying that the scientific level of Doctoral theses in each country and of candidate's theses in the U S S R varies, and for this reason comparison should be undertaken in terms of the time it takes a candidate to complete a thesis and the levels of education he is required to possess. If this approach is adopted in assessing the levels of Doctoral and Candidate's theses, there seems to be no difference in principle.

The degree of Higher Doctorate in the United Kingdom is comparable in status to the degree of Honoured Worker of Science and Technology in the U S S.R.

Conclusions

The aim of this paper has been to analyse in broad terms the patterns of engineer training in the United Kingdom, India, United States, France and the U.S S.R for the purpose of arriving at a method of establishing comparability of levels of education rather than assessing the standard of specialist training. This investigation has proved, in our view, that it is necessary to establish an integral criterion to determine an academic level of higher education

However, it is in no way suggested that the proposals put forward are conclusive or absolutely correct.

It would be advisable to consider these proposals along the following lines.

Is it possible at all to establish an integral criterion for an academic level of education with non-dimensioned parameters?

Is there a possible way of establishing the components of a non-dimensioned parameter and determining their relative share in assessing an academic level of education?

It might be useful, for example, to establish a parameter characterizing the scope of research attempted by an institution of higher learning, in addition to one that would serve to assess the academic standard of its teaching staff.

Is it advisable to define boundaries between engineer and researcher training, and determine a level at which higher education is completed and research activity begins?

It would be extremely useful if Unesco could draw a dividing line between, on the one hand, the tuition of students, when prospective specialists master scientific knowledge to graduate from higher school and, on the other, the training of scientists, when fully fledged specialists engage in creative research activity and proceed to academic degrees that are only awarded for the solution of major problems and the discovery of new laws relating to the development of science and technology.

[A.15] ED.74/XXIII.6/A