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ABSTRACT

The recommendations contained in this report, and the suggestions for implementing them, should make it possible to set up an engineering school which is better adapted to the needs of modern Spain. The primary objective is to produce top-level staff who can make an effective contribution to industrial development; and to train students at the Seville School of Engineering to use the equipment placed at their disposal, to organize production, and to run a firm. Their education will be quite different from that provided by the other Escuelas Tenichas Superiores; and a period of adaptation will doubtless be necessary. (HS)

design for technological education

THE ESCUELA
TÉCNICA SUPERIOR
DE INGENERIOS INDUSTRIALES
OF SEVILLE

ORGANISATION
FOR
ECONOMIC
CO-OPERATION
AND
DEVELOPMENT

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- *to contribute to sound economic expansion in Member as well as non-Member countries in the process of economic development;*
- *to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.*

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The members of OECD are Austria, Belgium, Canada, Denmark, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

The activity which has resulted in this report was undertaken by the Directorate for Scientific Affairs, for and in co-operation with the Programme and Operations Division, of the Development Department.

The Directorate for Scientific Affairs has been established within OECD to take charge of the activities of the Organisation relating to scientific research and to the expansion and rational utilization of the scientific and technical personnel available so as to meet the needs arising from economic growth.

The Programme and Operations Division is responsible for the preparation and implementation of the technical assistance programme of the Organisation intended for certain of its Member or Associated countries (Greece, Portugal, Spain, Turkey, Yugoslavia).

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FOREWORD

The report on the Seville School of Engineering which is given here in final form clearly shows the value of the work done by OECD under its technical co-operation programme.

When the Spanish Authorities asked the Organization for assistance in implementing the reforms they were proposing for higher technical education, the matter was particularly urgent and important for two reasons. First, the introduction of the first National Plan for Economic and Social Development had shown that Spain would need an increasing number of high-level engineers in the coming years and that highly qualified personnel, on whose training the development plans depend, were essential to the economy. Furthermore, the 1964 Act on the reorganization of technical education entailed a basic revision of the curricula and duration of courses in the engineering schools, in order to take into account the latest theories and experiments in this age of continuous technical progress.

A remarkable team of notable personalities and experts, to whom we are sincerely grateful, worked on this report, which deals with a Higher Technical Education Centre. Among the engineering schools already created under the first Development Plan, now in its closing phase, this Centre, owing to its geographical position and range of special subjects, will certainly have the greatest influence in Spain.

The recommendations in this report certainly invo[illegible] changes and important innovations in the present cur[illegible]cula and [illegible]aching meth[illegible] [illegible]gher t[illegible]nical schools in Spain. The D[illegible] [illegible]te for [illegible]gher Technical Education however ensured that all of them were adopted, in their most essential aspects, so as not to detract from the value and scope of the results than can be expected from this set of reforms. In point of fact, so far as the Seville School is concerned, the educational programmes in this repo[illegible] were fully approved by a Ministry of Education and Science Decree of 28th July, 1967; an[illegible] [illegible]e principles and methods it recommends will be applied, as from the 1967-68 school y[illegible], to the second-year course.

A great deal is expected from this type of pilot experiment rece[illegible]ly started in Seville. All that now remains is to await its full development in order to as[illegible]ess the results, which, we are convinced, will lead to the applications of these principles in other technical training centres both in Spain and abroad.

MAD[illegible] November 1967

[illegible]er RUBIO

Director of H[illegible]gher Technical Education
Ministry o[illegible] Education and Science

PREFACE

Modern society is transforming itself so rapidly that the institutions set up to ensure its development are no longer able to adapt themselves to the requirements of the present-day world. The field of education, particularly at the higher level, is a striking example of this phenomenon.

Science, it has been said, has advanced more within the past ten years than since the beginning of civilization. Technological progress, at any rate, has revolutionized living conditions in the most-highly developed countries within recent years. Industry has come to be of paramount importance in the sphere of human activity, and is obliging society to adopt its methods and efficiency. The establishments responsible for training the people who give impetus to and at the same time implement such progress however have apparently not kept pace with this evolution.

In the most advanced countries, schools of engineering were foun[illegible] the nineteenth century in order to train young men to apply the laws of physics and chemistry to an industry in its infancy. Since that time, industry has developed enormously; its needs and its relatioship with society have evolved considerably - and yet the programmes and teaching methods used in engineering schools have remained virtually unchanged. Clearly, these must be brought up to date if technological, economic, and social progress is to continue.

It is common knowledge that the system of education is hard pressed to produce the ever-increasing numbers of engineers and technicians required to meet the needs of the economy; industry, in order to meet its own requirements, must call on men who, despite their experience, do not always have the proper training for management posts. But it should also be recognized that the training still being given to future engineers no longer corresponds to the functions they will be called on to assume in industrial organizations that are far more complex, differentiated and specialized than they were only twenty or so years ago.

In the first place, the range of technical knowledge has grown considerably; one has only to imagine the implications for the engineering profession of the new materials recently developed, of the new forms of energy, and of modern measurement and computation techniques. But if industry is looking for engineers with advanced training, it is not merely to give them purely technical functions; nowadays such tasks are often performed by people with technical training at a lower level, or even by machines. What industry wants is people with a rational turn of mind and the ability to use scientific methods and principles in solving problems that at one time would have been dealt with using ordinary common sense. Noteworthy in this respect is the growing importance of the social sciences - economics, sociology, psychology - in business management.

Public opinion, with the help of OECD perhaps, has recently been made aware of the grave danger confronting countries with a shortage of engineers and technicians. Until the present, however, the main preoccupation has been to predict the number of engineers and technicians required by the various countries for their development effort, with a view to planning the growth of the different branches of education. The forecasting techniques thus developed make it possible to assert, for example, that 15 years from now, three, four, five times as many new engineers will have to be produced each year; this however is not enough, and thought must also be given to what type of engineer should be trained and what teaching objectives schools of engineering should adopt in order to produce people capable of building the future we want for the coming generations.

The Spanish government, which has requested assistance from the Organization in planning and putting into operation higher school of engineering, is aware of the complexity of this problem and of the need for tackling it with a new approach and an up-to-date outlook. This request was viewed with interest at OECD, where it was felt that such a study might well be used in other countries desirous of setting up or modernizing the technical education establishments vital to their economic development; the method used in planning the Seville school could well be applied in planning other types of education at other levels.

The study undertaken by OECD with the collaboration of an international group including economists and representatives of industry as well as teachers was based on established teaching principles which it attempted to apply to a domain in which tradition all too often wins out over educational considerations. Higher education is often of too theoretical and too general a nature; teachers tend to go off into abstractions, even when dealing with such subjects as industrial production, where they should stick to down-to-earth, factual reality. An effort was made in this study to define a type of training that would allow young engineers to come to grips with the most advanced scientific developments and apply them to problems in industry, while at the same time making them aware that industry involves more than just electronics, nuclear energy and computers and should first of all satisfy the basic and traditional needs of human society.

In Spain, as in many other countries, the prevailing opinion is that the engineer is first of all a competent mathematician whose main task, throughout his career, is to apply mathematics to industrial problems. This is why engineering schools put so much emphasis on mathematics, and more generally on subjects of a theoretical nature, whereas practical work sessions, in the workshop or laboratory are often treated as minor or even optional activities. This tendency is accentuated by the difficulty of planning practical work sessions, the cost thereof, and the recourse to professors from the faculties of sciences to teach the basic disciplines. And yet, the mentality of the engineer should be altogether different from that of the mathematician; in so far as the engineer is concerned, mathematics is for him no more than a tool which should not hide facts.

Future engineers should above all learn to observe and measure practical phenomena; they must become familiar with the experimental method. Practical workshop and laboratory sessions are designed to develop in students a taste for concrete achievement, to give them experience in transposing into practice simplified processes for transforming matter and energy, and teach them to set up an experiment and study the often unforeseeable details of actual mechanisms in a complex reality. Students should then learn to use the inductive method in formulating the laws of actual phenoma from data they have gathered themselves, to condense logical reasoning into mathematical equations which they may or may not be capable of solving on their own, and, above all, to be familiar with the limits of validity of formulae and to evaluate the results obtained by other people.

The practical workshop or laboratory sessions are also intended to develop a feeling for practical phenomena in future engineers. Rather than to develop skills in specific techniques for use later on in industry - techniques become obsolete or, at the very least, cease to be applied under the same conditions -, the objective is to impart, from the very outset of higher education, a certain familiarity with materials, machines and measuring apparatus.

Engineering training should not be confined to technical subjects; in the course of his career, the engineer may be called on to assume managerial responsibilities, and he should therefore be initiated in other sciences, such as the sociology of organization and industrial psychology, which are more difficult to apply than the laws and formulae of the exact sciences. This initiation should be more than just book learning: a logical mind can grasp the most complex physical laws or theories, whereas assimilating educational and sociological principles and putting them into practice involves influencing the attitude and behaviour of individuals. Applications are always more difficult to teach than theory; this is particularly true of the human sciences.

While the ideas on which this study is based are not new, they have rarely been incorporated in an overall scheme and materialized in a coherent plan. Clearly, their implementation will encounter some difficulty. It is now up to the Spanish teachers entrusted with this task to assimilate the teaching principles set out in this report, and to accept the spirit of these principles while adapting them to the specific conditions under which they are applied; this will doubtless entail a profound modification of syllabuses and teaching methods.

The experts who have collaborated in the preparation of this report are ready to assist the officials and teachers of the school in the difficult task of interpreting and adapting it; however, they have only limited possibilities for doing so and cannot assume direct responsibility in implementing it. The Spanish authorities have shown considerable interest in the project, methods and programmes being developed, and the experts are convinced that they are fully decided to go through with this experiment and organize the Seville school in line with the recommendations set out in this report. This is why there is so much interest in the development of the school: the Seville project reflects current thinking and will be an invaluable stimulant to progress in the highly difficult area of training management for industry.

G. Martinoli

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INTRODUCTION

The Spanish Government has expressed its desire to obtain assistance from the Organization, within the framework of the Technical Co-operation Programme, in making an inclusive study of the problems of technical education in Spain and in putting into effect the reforms necessary for implementing the objectives of the Economic and Social Development Plan.

Within the Spanish Ministry of National Education, the Directorate for Technical Education is responsible for the training of engineers at two distinct levels: the graduates of the Escuelas Técnicas Superiores represent a very high level; the people awarded diplomas by the Escuelas Técnicas Medias are given a comparable but less exhaustive training which, in view of its general and fairly theoretical nature, is by no means to be confused with that of a higher technician. The training of technicians, in the usual sense of the word and, a fortiori, of highly skilled workers, does not fall within the province of the Directorate.

Graduates of the Escuelas Técnicas Superiores enjoy exceptional status in industry and in the Spanish economy as a whole. Until the present, young men desiring to study engineering were subjected to an extremely severe weeding-out process. While this process has been highly effective in establishing the prestige of the engineering profession and degree in Spain, it has also widened the social gap between the graduates of the Escuelas Técnicas Superiores and the people trained by the Escuelas Técnicas Medias. The vast majority of top management posts in Spanish firms are filled by graduates of the Escuelas Técnicas Superiores, leaving as a rule only the subordinate positions to the people with diplomas from the Escuelas Técnicas Medias, who not so long ago were still referred to as Peritos (technicians). Comparison of the earning levels of the two types of engineer, at least at the start of their careers, gives striking evidence of the extent to which the distinction is observed. This hierarchy among the people holding diplomas and degrees from the various technical education establishments, considered normal until now, will have to become less pronounced as the number of people awarded diplomas increases, so as to pave the way for industrial expansion, the effect of which is to increase the number and diversity of technical functions.

The Economic and Social Development Plan calls for 26,000 graduates of the Escuelas Técnicas Superiores and 53,000 graduates of the Escuelas Técnicas Medias by 1970; this objective demands a considerable increase in the capacity of the technical training establishments, and the opening of additional schools. At the same time, however, the Ministry of National Education desires not only to increase the number of engineers but also to adapt the education provided to the requirements of the Spanish economy.

The Acts of 1957 and 1964, concerning the reorganization of technical education, constitute clear-cut evidence of the Spanish Government's determination to carry out a far-teaching reform of the educational system and adapt it to the economic conditions of a country in an active phase of renewal.*

Essentially, the objective of these acts is twofold: in the first place, to modernise the educational system and train students for the economic function they will be called upon to fulfil; secondly, to shorten the time actually required to complete these studies so as to bring it into line with that required in other European countries.

The act of 20th July 1957 abolished the traditional system of competitive entrance examinations for the Escuelas Técnicas Superiores and Medias in favour of selective courses with final examinations; as a result, candidates with higher secondary school leaving certificates who have passed the examinations at the end of the pre-university course, in order to qualify for admission to one of the Escuelas Técnicas Superiores, must spend two successive years in selective courses, the "curso selectivo" and the "curso de iniciación". Similarly, candidates for admission to the Escuelas Técnicas Medias after obtaining the lower secondary school leaving certificate must complete a preparatory course and a "curso selectivo de iniciación", in that order. Students failing the final examination for any one of these one-year courses are allowed to sit for it once more.

The system brought into being by the act of 1957 has, however, failed to give the desired results; for one thing, a gifted student who passes one after the other the different levels of selection cannot hope to obtain his engineering degree before the age of 24; then again, the considerable number of candidates, combined with the limited capacity of the existing technical schools, has made the examinations increasingly difficult. As a result, many students are obliged to repeat the one-year selective courses, so that the time finally required to complete the course frequently means that a student is 26 or 27 before obtaining his engineering degree. In view of these facts, the Spanish Government has found it necessary to promulgate a new act abolishing the two years of selective courses and organizing the engineering school along similar lines to those of the faculties of sciences. The act of 29th April 1964, took effect on 1st October 1966; in addition to granting direct access to the Escuelas Técnicas Superiores, it calls for a fairly thorough reform of the education provided in such establishments, as regards the curriculum, the form and the teaching methods used. The 1964 reform is not therefore just an institutional one, but should at the same time make it possible to re-orient and modernize engineering studies, an undertaking for which the Spanish authorities desired the advice of the Organization's experts.

The first request made by the Spanish authorities concerned the organization and syllabus of the final three years at the Escuelas Técnicas Superiores. As stipulated by the act of 29th April 1964, the Minister was to issue, during the first half of 1965, a decree defining the syllabuses for the various fields of specialization**; he desired to have the advice of experts*** from other European countries which had already studied similar reforms. Thus, as early as December 1964 four experts took part in the first mission, carried out, in Madrid, on behalf of the Organization. In the course of this mission they conferred with the Minister of National Education, the people in charge of Technical Education and indus-

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* An annex to this report contains the the text of the Acts of 20th July 1957 and 29th April 1964.

** An annex to this report contains the section of the decree pertaining to the Escuelas Técnicas Superiores producing general engineers for industry.

*** The names of these experts are given in an annex.

trialists who gave them the employer's viewpoint on the value of the education offered under the existing system; they examined the syllabuses of the Escuelas Técnicas Superiores and the methods of teaching used. They were thus able to get an overall impression of technical education problems and arrive at a preliminary conclusion concerning the syllabuses for the final three years.

Clearly, however, the experts could not possibly, in such a short time, have worked out detailed syllabuses, a task which involves, a thorough study of the objectives of each type of education in relation to the needs of the country's economy, together with an appraisal of the structure of the educational system. Moreover, a syllabus, i.e. a simple enumeration of the subjects the students must take, does not mean a great deal on its own; it has to be supplemented with detailed information concerning the spirit which prevails and the teaching methods used. For this reason the experts were careful not to include specific recommendations in their report – they limited themselves to making a number of observations to the Spanish authorities concerning the proposed syllabuses and to indicating the broad lines of subsequent studies. However, this first mission enabled the experts and the Secretariat to form a general idea of the difficulties encountered by those in charge of technical education, to find out which aspects of technical training should be re-examined and to detect their weak spots. This mission was therefore an excellent starting point for subsequent studies conducted by the Organization.

In June 1965, a further request was made concerning the establishment of three new Escuelas Técnicas Superiores; quantitatively, the Economic and Social Development Plan calls for an increase in the capacity of the technical training establishments, and the Spanish Government has decided to set up a School of Civil Engineering at Santander, a School of Agriculture at Cordova, and a School to train industrial engineers at Seville. The Minister of National Education has requested the collaboration of experts from the Organization in establishing these schools.

The Seville School, for training industrial engineers, is doubtless most essential to the development of the Spanish economy, which depends mainly on industrial development. The School will also have to meet a very heavy demand for admissions, as most of the Escuelas Técnicas Superiores are concentrated in the Northern part of the country. In view of all this, the Minister of National Education has given top priority to the Seville School.

The Cordova School of Agriculture also meets a definite economic need: the migration of the active primary sector population towards the secondary sector must be compensated by an increase in agricultural productivity. Admittedly, the country already has a number of agricultural engineers, but most of these occupy administrative positions where they generally have no direct influence on the use of technology in farming. The need for more agricultural engineers has thus made itself felt. The choice of Cordova for the new school seems a particularly wise one; apart from the absence (mentioned above) of any Escuelas Técnicas Superiores in the Southern part of the country, Andalusia is a region which offers a combination of exceptionally favourable conditions and should lend itself to the development of a variety of crops. The Spanish authorities again requested whatever assistance the Organisation could give them, in preparing the establishment of this School; the requisite studies are currently being carried out, and coordinated by the Organization's Agriculture Directorate.

The economic justification for the School of Civil Engineering that the Spanish authorities contemplated establishing at Santander was much less obvious; moreover, civil engineers, like their colleagues in other fields of engineering, must nowadays have a sound all-round technical training: this being so, it is difficult to see the need for setting up an isolated school of civil engineering, with only limited laboratory facilities and teaching staff, especially in a non-university town. No definite decision seems to have been taken regarding this project, and the Organization, wishing to cencentrate on the Seville and Cordova establishments, has taken no action.

At Seville, the Spanish authorities hope to set up a school in which to test out a more up-to-date concept of engineering training; later on, this experiment may well be extended to the entire field of higher technical training, which is why the experts' recommendations in this report are so important: they have not simply to plan a school to meet the needs of the Spanish economy and which is properly adapted to its resources, they must constantly bear in mind that their recommendations have a much broader scope and must eventually be applicable to the Escuelas Técnicas Superiores as a whole. The Seville project is in fact the creation of a pilot establishment.

An industrial engineering school designed to provide training in such widely differing specializations as electricity, electronics, chemistry and mechanical engineering is exceptionally valuable from this point of view. As stated very clearly in the preamble to the Act of 20th July 1957, traditional schools which train students for specific professions no longer meet the needs of the economy; present day industry requires engineers with an adequate general background in science and technology, each specializing in a particular branc of technology. Establishments combining several specialized departments are particularly suitable for training students for functions of this type in both teaching and research; they allow the various technical disciplines to be influenced by each other and resources to be concentrated. Planning such a school is no easy task: it involves maintaining an exact balance in the value placed on the teaching of the various disciplines, and achieving flexible and effective organization.

The establishment of a pilot school, however, is bound to run into difficulties of another nature, to which the experts have already had to call the attention of the Spanish authorities: by definition, pilot establishments go beyond the scope of the existing legislation; the solutions advocated for the overall organization of such establishments are often in contradiction with the acts and decrees governing the organization of other schools. The Minister of National Education will therefore have to adopt a number of special measures in respect of the Seville school. This will prove all the more difficult, since a number of these measures may well encounter opposition from certain pressure groups, whose immediate interest is not necessarily that of the general public. It will therefore have to be made clear that the Seville School of Engineering is to be a pilot establishment designed to meet the actual needs of Spanish industry and that it will provide an example which might subsequently be extended to all Escuelas Técnicas Superiores, ultimately serving as a model for a number of countries at a more advanced phase in their development, or even for more highly industrialized countries facing similar problems.

The experts designated as a result of the request made by the Spanish authorities in June 1965, first met in October 1965*. The recommendations and findings contained in this report are the result of the work accomplished during the following six months**. They were to enable the Spanish Minister of National Education to adopt such measures as were necessary to open the school in October 1966. At the same time, the experts felt it would be useful to submit two interim reports to the Spanish authorities, not only to keep them abreast of the progress made, but to enable them to adopt at the earliest possible date the measures defining what the Seville School was to be. They emphasize that a number of their

* The names of these experts are contained in an annex.

** A draft report was submitted to the Spanish authorities in April 1966.

recommendations have not always been put into effect in their own countries, although several of the experts agreed to re-examine their own approach to teaching as a result of the exchange of views during the five plenary meetings.

The experts feel that the task entrusted to them involves more than the preparation of the present report; once the Minister of National Education has examined this report and taken such decisions as he may judge necessary, the experts are ready to propose their collaboration in starting the school and in studying specific questions such as the organization and objectives of research, which have not been dealt with up to now. After seeing how the school operates they will be in a better position to make recommendations concerning the reform of higher technical education as a whole.

This report, prepared at the request of the Spanish Minister of National Education, might then be communicated to all those concerned in the planning and operation of the Seville School, to give them an understanding of its methods and spirit. The report may also be of interest to authorities in other OECD Member Countries, many of which are currently re-examining their policy for training scientific and technical personnel.

The report comprises four parts: the first describes the objectives of the Seville School; part two sets forth the teaching principles required to attain them; part three contains the syllabuses; part four indicates the means required to carry out the foregoing recommendations.

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OBJECTIVES OF THE SEVILLE SCHOOL

The Act of 29th April 1964 fixes the period required to complete the course at the Escuelas Técnicas Superiores at five years and stipulates that holders of the upper secondary school leaving certificate who pass the pre-university course examination shall be eligible for admission to the first year of the Escuelas Técnicas Superiores or of the Science Faculties. The Act also states that students who pass the examination at the end of the first year in an Escuela Técnica Superior or a Faculty of Science, and who were preparing an engineering degree, shall be eligible for admission to the second year of any Escuela Técnica Superior.

In view of these two clauses, the experts first considered it impossible to make any recommendations concerning the organization, teaching methods and curricula for the first year. They considered it more important to maintain the orientation possibilities provided under the act of 1964 than to suggest improvements that would loose much of their effectiveness as a result of the considerable number of first year students. Otherwise, the recommendations made by the group of experts would have had to be applied to all the scientific and technical schools throughout Spain, which would certainly have been premature. Obviously, the ideal would have been to apply the principles set forth in this report to all engineering training, i.e. to the five year course provided for under the act of 1964; however, as is inevitably the case with pilot ventures, difficulties were encountered due to the superposing of two educational systems. Accordingly, the experts informed the Spanish authorities that their recommendations concern the last four years of study only.

Subsequently, while on mission in Spain, the experts were able to study the first effects of the act of 1964, and the temporary difficulties the Spanish authorities are having, particularly with the first-year syllabus. They therefore considered it useful to include in Part III of this report some fairly general indications of how at Seville the pre-university course might be linked up to the last four years of study.

In order to determine the organization and nature of the education to be provided during the four final years, the experts first turned their attention to the task of defining the objectives of the Seville School. These objectives are either quantitative or qualitative in nature and each will be dealt with in turn.

CHAPTER I

NUMBER OF GRADUATES

At the very outset, the experts raised the question of the number of students expected to enrol in the new engineering school in October 1966, the year in which the Seville School was scheduled to open its doors to first and possibly second-year students: the problem was therefore to predict the enrolment in these two years. It is difficult to estimate the number of young men who, having successfully completed the pre-university course, will apply for admission to the first year, and even more difficult to predict how many who, having passed the examination at the end of the first year at the Faculty of Sciences of Seville or at any of the other Science Faculties or Escuelas Técnicas Superiores throughout Spain, will apply for admission to the second year. Despite this difficulty, those who were to be in charge of the School arrived at the conclusion that approximately 450 students (1) would apply for admission to the first year, 1966, and that this number would increase considerably in the years to come. Although a sizeable fraction of the students in the Sciences Faculty of Seville choose to enter the preparatory year for the engineering schools, the officials felt it useless to try to estimate the number of second-year applicants, in view of the many different sources supplying such students: they do however expect the number of applications to be high. The experts found these forecasts all the more alarming, particularly as the number of graduates to be produced by the Seville School will in any case be a good deal smaller. They felt that further thought should be given to the question and that measures for ensuring the proper functioning of the School should be recommended to the Spanish authorities.

Determining the size of an engineering school is a fairly complex undertaking; various factors have to be taken into consideration and analysed in depth. The experts first attempted to predict, in relation to the current utilization of engineers, the effect of increasing the number of graduates; they then looked into the reasons for the growing demand for education, i.e., the reasons motivating an increasing number of young men to take engineering, and wondered whether this demand was abnormal; lastly, they considered the various limitations influencing educational efficiency.

1. THE NEEDS OF THE ECONOMY

The recent rapid expansion of the Spanish economy, particularly in the industrial sector, has made the Government aware of the need for a considerable increase in the number of engineers and technicians; it is generally recognized that the level of development attained by a country is directly dependent on the number of engineers and technicians at its disposal.

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(1) In actual fact, 380 students entered the first year in October 1966.

Forecasts made in connection with the work accomplished under [illegible] Mediterranean Regional Project indicate that the Faculties of Sciences and the Escue[illegible] Técnic[illegible]s will have to produce 100,000 new graduates between 1961 and 1975. These objec[illegible]s, amb[illegible]tious as they may seem, will doubtless be attained. In 1961, for example, the [illegible]ties of Sciences awarded 1,200 degrees, and the Escuelas Técnicas Superiores 800, whil[illegible] the Escuelas Técnicas Medias granted approximately 3,000 diplomas. Moreover, first-year enr[illegible]ment was steadily increasing, even before the Act of 1964 went into effec[illegible]

The new crop of graduates will bring about changes [illegible] th[illegible] current pattern of engineering employment. At present most engineers occupy managerial a[illegible] ad[illegible]istrative positions with very little direct responsibility in technical matters. This s[illegible]uation [illegible]s due to the relatively limited number of engineers available in Spain and the [illegible]t that such people choose the least exacting and best-paid jobs; agricultural engineers [illegible] a striking example of this state of affairs. People are nonetheless beginning to realize that the number of functions of the type attributed at present to engineers is not going to grow as fast as the number of engineers themselves, and a certain disparity is beginning to make itself felt between the status of engineers managing small firms and that of their colleagues employed by bigger concerns in positions involving more technical responsibility. [illegible] is therefore predictable that most of the young men now entering the Escuelas Técnicas S[illegible]periores, on graduating, will assume functions more similar to those performed by their count[illegible]parts in other European countries. The increased emphasis on the technical aspect of t[illegible] engineering function, leading as it is bound to do to an increase in the productivity of fi[illegible]s and a more rational organization of the industrial sector, will prove highly favourable to the development of the economy, provided that engineers are trained in consequence.

It is therefore safe to conclude that the needs of the economy do not justify sacrificing the quality of the training offered by the Escuelas Técnicas Superiores to an increase in enrolment: the rate at which technical education is developing suggests that the number of engineers available in 1970 will be sufficient. The trend in the functions assumed by these engineers, of the utmost importance for the future of the Spanish economy, depends, on the contrary, on the quality of their training.

2. THE DEMAND FOR EDUCATION

Engineering schools in Spain enjoy considerable prestige, due no doubt to the purpose for which they were originally founded; the same situation exists in France. At a time when Spain had not yet begun to emerge as an industrialized nation, the State realized the need for technically trained people able to carry out the necessary services; this is what gave rise to the corps of government engineers such as mining and civil engineers, who, because they occupied positions of great responsibility in the economic world, enjoyed considerable social status. At the same time, virtually the only possibility open to people graduating from the Faculties of Science was to teach in the secondary schools, at considerably lower salaries. Nowadays, although most engineers are employed in industry, they continue to enjoy the same prestige, and the Escuelas Técnicas Superiores continue to attract the brightest students.

The growth of the national income has made it possible for an increasing [illegible] of young men to continue their studies at university level; those interested in tak[illegible] science are therefore naturally led to apply to the Escuelas Técnicas Superiores, rather than to the Faculties of Science. There is, moreover, no other outlet for the young men reaching the level of the pre-university course, since the Escuelas Técnicas Medias have lower entrance requirements. As a result, the entire demand is concentrated on the Escuelas Técnicas Superiores.

The demand for admission to the Seville school will be even greater, since it will be the first Escuelas Téchnica Superior established in southern Spain. Here more than anywhere else, the engineering profession is synonomous with employment security and an assured future. And, as we have already seen, the act of 1964 abolishing the two-year preparatory course, allows all those eligible to enrol in the first-year course. It is clear that the administrative officers of the Seville school will experience considerable difficulty in keeping the enrolment down to a reasonable level, but this is precisely what will have to be done, if the school is to remain a pilot establishment, and if the educational standard is to be maintained or even improved.

The Seville school, like the other Escuelas Téchnicas Superiores, will probably be unable to meet the increase in demand for admission as a result of the Act of 1964; this, in fact, is a problem beyond the scope of the directors of an isolated school, and is due to shortcomings in the overall structure of scientific and technical education, which does not offer a sufficient number of possibilities to young people with an upper secondary school leaving certificate. Admittedly, the economy requires an increasing number of engineers; but at the same time, there will never be more than a limited number of openings for engineers with top qualifications; what the economy actually needs is a complete spectrum of people trained at various levels and in different specialties. It is very useful to build up the prestige of the engineering profession; certain countries, in which engineers are not so highly thought of, experience considerable difficulty in developing their industries. The ideal is therefore to maintain the quality and prestige of the Escuelas Técnicas Superiores while at the same time increasing those of the Escuelas Técnicas Medias, as the Act of 1964 tries to do.

3. LIMITATIONS ARISING FROM EDUCATIONAL CONSIDERATIONS

The foregoing considerations clearly show that the Spanish Minister of National Education should not allow quantitative policy considerations to have an adverse affect on the quality of the teaching in the Escuelas Técnicas Superiores or to yield to the pressure for admission, especially when a pilot establishment such as the Seville school is concerned; the preamble to the act of 29th April 1964 clearly expressed the Spanish Government's determination to safeguard and even improve the educational standard. This preoccupation implies that certain limitations arising from educational considerations should be taken into account.

As we shall be able to explain in greater detail later, the purpose of the Seville school is not so much one of imparting knowledge as of providing training; in other words the preparing of young men to assume their functions in the economic world is more effectively accomplished by giving them a constructive and practical turn of mind, working methods and a sense of professional discipline, than by requiring them to absorb an enormous amount of knowledge which they would rarely have the occasion to use. This trait is peculiar to engineering studies and sets them apart from the traditional university education This distinction is apparent in the way in which the students' work is organized: while students in Faculties are for the most part free to work on their own along individual lines, the work of engineering students must be organized and closely supervised.

This objective peculiar to engineering studies requires that teaching be organized efficiently, to make such supervision possible; this condition determines the size of the school i.e the maximum number of students admitted to the second year, once the permanent organization of the school has begun to function. Past experience has shown it to be inadvisable to group more than sixty students in any given specialty; a brief examination of the functioning of the school after applying the principles of organization gave the same results.

4. CONCLUSIONS

On the basis of these considerations, the experts came to the conclusion that enrolment at the Seville school should be limited and a recommendation was made to this effect. In this connection, the experts made a distinction between the normal working of the School once it has been established a few years and the transitional situation leading up to it; they examined the measures which the Spanish Minister of National Education might adopt to implement this recommendation.

A. The System under normal conditions

Efficient teaching should be the essential characteristic of the Seville School and the principal concern of the School's officials to see to it that all students are given adequate training. All students admitted to the second year should normally obtain their engineering degree four years later. Only a minimum percentage of students should be eliminated, and these should not be delayed after the end of the second year, so that those students who are unable to adapt themselves to the work of an Escuela Técnica Superior may transfer to another type of establishment; similarly, only exceptionally should students repeat a year's work. All this requires a large and well-trained teaching staff.

The experts consider that, once the school is working normally, it should not be expected to produce more than 180 graduates each year, corresponding to a total enrolment of approximately 800 in the final four years; at most 200 students should be admitted to the second year, from all sources. If the pressure for admission becomes so heavy that this figure is unacceptable, in view of the considerations mentioned above, the establishment of another school will have to be envisaged.

RECOMMENDATION I

The experts recommend that at most each year two hundred students be allowed to enter the second year of the Seville school; all these students should normally complete the course for the engineering diploma within four years.

For the reasons mentioned previously, the foregoing recommendation concerns only the final four years. The first year will continue to be a period of orientation, or of selection, and will mainly call on the students' memory and powers of assimilation, and their ability to work on their own. The first-year course will thus be radically different in conception from the final four years. It is to be hoped that this situation will be only temporary so that the five years for training engineers will be used to the best advantage and that those students incapable of following the course will not lose too much time.

B. Transitional conditions

During the first few years of the School's existence, the Principal will have to cope with such difficult problems as training and recruiting teaching staff and working out teaching methods. It is therefore inevitable that the early years will be a "breaking-in period" during which the School's officials will find it impossible to supervise and organize effectively the studies of two hundred students. Accordingly, the school will have to begin with a smaller number of students, and increase it each year until normal conditions are achieved.

Although it is difficult for the experts to evaluate current possibilities for recruiting professors, lecturers, and assistants, either qualitatively or quantitatively, since no official decision has been made on the basis of the interim reports and no appointments have been announced to date, they feel that only 90 second-year students should be accepted in 1966, i.e. in the first year of the school's existence*. A number of the experts have, in fact, already had the responsibility of setting up new engineering schools, generally under more favourable conditions, and have come to the conclusion that this figure should not be exceeded.

Similarly, it is difficult to predict the length of time needed to reach normal conditions. Although the first and second years, which must be in operation by October 1966, are now occupying the attention of the School's directors, the Principal will have to set up the third, fourth and fifth years successively, a task which involves recruiting an ever-increasing number of professors, lecturers and assistants and dealing with more and more complex organizational problems. At the same time the directors will have to see that enrolment is gradually increased. The experts, estimate that, under the most favourable conditions, this transitional period might last five years. In this case, enrolment in the School might be expected to develop as indicated in the following table:

Graduating Class	N° 1	N° 2	N° 3	N° 4	N° 5	N° 6
1st year	(450)	...	...	...	...	...
2nd year	90	110	130	150	170	200
3rd year	...	...	...	...	...	...
4th year	...	...	...	...	...	...
5th year	85	105	125	135	150	180

RECOMMENDATION IA

During the first few years of the School's existence, however, the number of second-year students accepted will have to be much smaller; this number will increase each year until it reaches two hundred. In 1966, it should not exceed ninety.*

C. Implementation of these recommendations

The Minister of National Education and the people in charge of the Seville School will doubtless have a hard time convincing public opinion, and particularly the students, that the number of applicants accepted for entrance to the second year should be so strictly limited, because of the considerable pressure created by demand, and the recent act granting access to the Escuelas Técnicas Superiores. Two arguments may, however, be advanced: material factors do, in fact, make it impossible to accept a large number of students in a newly established school; the Seville School will not be just another school designed along the lines of existing establishments to train general engineers for industry, but rather a pilot establishment for experimenting with new teaching and organizing methods.

* or in 1967, if only the first year course is opened in 1966.

It should be pointed out right away that the directors of the Seville school will doubtless find it impossible to go on indefinitely justifying this recruitment procedure, particularly the limiting of the number of second-year students, even by invoking the fact that the Seville school is a pilot establishment. In all likelihood, the demand will increase very considerably, without its being possible to accept more students. The Minister of National Education will have to take measures to bring the demand down to a more reasonable level by offering students a real choice of possibilities; this would make it possible to abandon the current policy of elimination which is a source of frustration to students and of considerable expense to the State.

In any case, as was said above, there should not be too large an increase in the number of graduates from the Escuelas Técnicas Superiores, if the risk of unemployment is to be avoided. Like many other countries, Spain has a much more urgent need for engineers who are not so highly qualified, and who could be supplied by the Escuelas Técnicas Medias. It is important not only to increase the number of such schools, but also to raise their prestige and make them the normal outlet for students with an upper secondary school leaving certificate.

In any event, the Minister of National Education will have to recognize that the fact of making admission to the Escuelas Técnicas Superiores open to all qualified students implies that the capacity of these establishments is sufficient to meet demand. As this condition is not, in fact, met, the matter must be considered as one of principle to be put into effect only in the more or less immediate future, and not as justifying the admission to the Seville school of so many students that their education would suffer, and whose number would in any case be limited by the capacity of the buildings.

CHAPTER II

FIXING EDUCATIONAL OBJECTIVES

The Spanish authorities hope to establish at Seville a school where a more up-to-date concept of engineering training can be tried out; this experiment may subsequently be extended to all the other Escuelas Técnicas Superiores. It is always necessary, when planning a new school, to specify what the education provided there is intended to achieve; this preliminary study is of the utmost importance when the school in question is to be a pilot establishment on which will be based all future higher technical education. For this reason, the experts paid a great deal of attention to defining the educational objectives, and this phase of their work, the results of which should be applicable not just to the Seville School but to all the Escuelas Técnicas Superiores, represented a vital aspect of the work accomplished by the international group.

The conclusions of this study obviously cannot be given in the form of recommendations. The present chapter describes the considerations which led the experts to formulate the objectives of the Seville School; and subsequently more specific recommendations arising from these considerations are given together with indications for their implementation. The method outlined below makes it easier to understand the meaning and the scope of the School's educational objectives.

1. QUALITATIVE REQUIREMENTS OF THE SPANISH ECONOMY

Usually, when referring to the needs of the Spanish economy, one thinks of quantitative requirements, of the forecasts made by the Planning Commission, of firms' demand for qualified personnel, of the number of young men interested in a technical education. In the preceding chapter we analysed the effect of these needs on the number of second-year students to be accepted at the Seville School. But the needs of the economy may also be expressed qualitatively, and the engineers graduating from the Seville School should correspond to the specific character of Spanish industry.

A. Educational Objectives

The various types of instruction making up an educational system are fixed by their objectives, whether their purpose be to stimulate certain aptitudes, to impart specific knowledge, or develop manual dexterity. For the sake of simplicity, these objectives may be grouped under the heading of two main goals: to provide students with an overall culture designed to help them take their place in an to organized society or to train them for a specific form of professional activity.

Whereas the objectives of education for cultural purposes are essentially the result of policy considerations, those of professionally oriented education result from a study of the needs of the economy. We have already emphasized the fact that the economy calls for a whole spectrum of qualifications and that the various categories of qualified personnel should be complementary to one another. In general, any attempt to define the objectives of professionally oriented education involves an analysis of the functions to be assumed by the various types of graduates and an evaluation of the output of the other types of education. In the case with which we are concerned, this analysis is simplified considerably by the fact that the regulations of the Seville School lay down a five-year course to train engineers at the highest level; the number of doctorates in engineering whose training is covered by the new act will not be large enough to have a great deal of influence on the use made of engineers.

To determine the type of engineer the Seville School should produce, an attempt was made to define their future functions. This may seem a complex undertaking, for it is difficult to forecast economic trends in Spain over the next fifteen years; in fact however, the Economic and Social Development Plan indicates the direction the Government intends the economy to take; and in addition, the recent development of the more highly industrialized countries which, not so very long ago, were in a position comparable to that of Spain today, provides an adequate guideline. This makes it possible to form a fairly exact idea as to the future structure of the Spanish economy; the task of the Seville School will be to train its students for the part they are to play in it. The objective of the Seville School, then, is not to produce engineers of the type trained several decades ago by the Escuelas Técnicas Superiores, nor to base itself on foreign establishments, conceived with another economy and another type of society in mind, but rather to determine the functions and responsibilities the engineer will have to assume in the course of his career, so as to give him the appropriate training and develop in him the qualities he will most need.

Clearly, in any country, the nature of the tasks perfomed by the engineer changes in the course of his career. Recent graduates are usually assigned functions of a technical nature; as time goes by, they assume increasing responsibilities and devote more and more of their time to management, organization and administration problems. The first objective of an engineering school is to give students a training that makes them adaptable; students cannot be expected to assimilate in five years all the technical knowhow they may need later on. Upon leaving school to go to work in a firm, they will have to familiarize themselves with the specific areas of technology in which they will be working; later on, they will be expected to acquire a knowledge of the organization or marketing techniques they will need. Clearly, though, an engineering school must do more than give its students a training that will make them adaptable; it must also impart a mentality compatible with the state of industry and the general level of development in the country, i.e. in the case of Spain, as will be seen later on, initiative, practical intuition, to provide them with the means and instil in them the desire to play an effective part in the economy and contribute to its progress.

B. The functions of the engineers

Engineers at the level of those produced by Spain's Escuelas Técnicas Superiores will be called upon to assume a wide range of functions requiring a variety of markedly different aptitudes. It would be excessively difficult to list these functions and to describe all the aspects of the engineering profession; at most a few of the functions usually entrusted to engineers can be given, it being understood that certain of these functions may be performed by people with a lower-level or even an altogether different type of diploma. The choice of a graduate engineer for a given post depends on a large number of factors: the availability of a sufficient number of engineers on the market, the wage level, confidence in the quality of their technical training and in their ability to cope with practical problems, the size of the firm, the complexity of the techniques used, the availability within the firm of technicians with previous experience and a sufficiently high level of competence. This means that the utilization of engineers, and accordingly the objectives of an engineering school, depend on many factors, very few of which are of a technical nature: the degree of industrialization of the country, the structure and average level of qualification of the work force, the mentality of contractors and top management, all play an important part. All these considerations were taken into account in the following attempt to classify the functions usually performed by engineers.

(i) Design functions

The nature of the sedign functions performed by the engineer varies considerably according to the size of the firm in which he is employed. In the design office of a large firm, team work on highly specialized studies, often of a fairly theoretical nature, is the rule; certain engineers are in charge of organizing, subdividing and supervising the work, and of liaison with the other services in the firm. In small and medium-sized firms, design work is to a much greater extent based on the engineer's practical intuition; such work is much less specialized and is entrusted to people who often also have other tasks to perform. Engineers in consultant firms must be highly versatile and well up in very widely differing branches of technology.

(ii) Research functions

Nowadays, major industrial firms have their own research programmes involving practical applications of the latest scientific developments, or even basic research. While research of this type requires a very special set of aptitudes and methods, past experience has shown that engineers of the level of those produced by the Escuelas Técnicas Superiores are capable of adapting themselves perfectly to such work.

(iii) Technical production functions

Factory production comprises two aspects which may correspond to distinctly different functions. These are: first, the technical aspect, which involves elaborating a manufacturing process, determining the tools, machinery and ancillary equipment to be used, acquiring, assembling and putting into operation the means of production, ensuring technical supervision of production, coping with handling and repair problems; and secondly, production planning, the distribution of labour, problems of organizing and giving orders. While these functions are distinct in big firms, they cannot be separated in small and medium-sized firms, and engineers in the latter must demonstrate not only technical knowhow and practical intuition, but also their ability to act in a managerial capacity.

(iv) Commercial functions

A common misconception has it that commercial functions should be left to the graduates of specialized schools or, indeed, that one does not have to have a diploma to know how to sell. In the modern firm, distribution is an increasingly complex function; market research nowadays requires the collaboration of engineers to spot what the public needs, find a way to meet this potential demand, determine the characteristics of the market, launch the product and ensure after-sales service. The purchasing of raw materials, machinery and ancillary equipment also requires a good, all-round technical training. Clearly, engineers employed in smaller firms cannot afford to be ignorant of these fundamental aspects of running a business, even if they are not fully responsible for them.

(v) Managerial and administrative functions

Engineers perform an extremely wide variety of managerial and administrative functions; in production they act as heads of section or division; they are found in commercial and administrative directorates, and also in top-level posts combining these different functions, and where they must deal with co-ordination and management problems; they may also be employed in any of the departments in the firm (personnel, finance, public relations, etc.). To carry out these functions the engineer will find his overall background, his ability to tackle and analyze problems, more useful than his technical training; nonetheless he must acquire specific qualifications for each of the functions he performs. While these functions are distinct in big firms, they cannot be separated in small firms, and engineers therefore must be highly versatile to be able to carry out a variety of tasks without specializing in any.

(vi) Other functions

Engineers may themselves be heads of enterprises, and called on to perform a wide range of functions often having little or no technical content, but where their training is nonetheless a vital element of success.

At the level of higher technical education, it is out of the question for special instruction to be offered corresponding to each of these functions. An analysis of the structure of Spanish industry should, however, make it possible to determine which functions are the most frequently encountered and the most vital. Care should be taken, for example, to avoid the error, fairly frequently found Europe, of producing mainly design engineers, despite the very limited number of openings for such people. In Spain, as in most European countries, the principle task of engineers, and particularly of industrial engineers, is to organize production; emphasis should therefore be placed on encouraging an "enterprise" attitude, a taste for practical achievement, a productivity consciousness. The engineering schools, particularly the Seville School, should choose the direction most favourable to the development of the economy. This does not mean that the School's graduates will be unable to adapt themselves to other types of work such as research or design; in fact, the engineers produced by the Seville School will be very highly qualified, and their training should enable them to succeed in any of the many branches of engineering.

C. The structure of Spanish industry

To find out the type of functions graduates of the new school will carry out, the experts collected a certain amount of statistical information supplemented by information from industrialists concerning the present use made of engineers. On the basis of these data, the experts attempted to forecast the structure of Spanish industry some fifteen years hence and from this to decide on the School's orientation.

The data gathered by the experts concerned the Spanish economy as a whole, and also the region of Andalusia. The data for Andalusia were mainly useful for estimating how much the University of Seville, the Escuelas Técnicas Medias and local industry might be expected to contribute to the functioning of the School.

A thorough study of the probable breakdown by social class of future enrolment would, of course, have been desirable; the results of this would have been two-fold. In the first place, the behaviour of students is definitely influenced by their origin, and an attempt should be made, at least during the first few years, to adapt teaching methods to the character of the pupils to be trained; in fact, as will be seen later in this report, the methods advocated represent a basic change in traditional Spanish education; it would have been difficult, in the absence of previous experience to foresee the reactions of the students. The experts therefore asked that the methods they proposed be applied exactly as laid down for the first few years; subsequently, the professors will be able to adapt their teaching methods to the specific conditions in which they find themselves. The second advantage of such a study would be to give the experts an idea of the way in which future graduates will fit into the Spanish economy. Those whose family or friends are able to provide them with the necessary capital will be more inclined, and be in a better position, to establish new firms; students from less affluent families will be more dependent on existing firms or nationalized industries. Similarly, the mobility of the graduates can be forecast from their social background; but such a forecast, although of interest to the local officials in charge of implementing the Economic and Social Development Plan, should not be allowed to influence the orientation of the School.

The experience of other countries has been that it is useless to expect an engineering school to have any direct influence on the development of industry in the surrounding region. While not to be underestimated, the influence of such a school is felt only after a long period of time as a factor of economic and social development, and only if the setting up of the school is part of a broader development plan calling for the establishment of new firms, the development of the necessary infrastructure, etc. Should this condition fail to be met, as soon as they graduate, students would leave the region to find jobs where their training can be used, i.e. in regions which are already industrialized. The training of the Seville School graduates should therefore be in line with the needs of the entire country. Although the organization and methods of firms in the still sparsely industrialized region of Andalusia differ from those in Nothern Spain, such differences should become less pronounced in the near future and the industries in the South are expected to pattern themselves on those in the North. Even for small firms it is now no longer possible to imagine the existence of regional operating conditions. This is why, when determining the educational goals, the experts used data for the Spanish economy as a whole. One of the objectives of the Seville School should be, in fact to set in motion a mechanism tending to diminish the differences and imbalances between Andalusia and the more industrialized regions of Spain.

In this chapter only the statistical data necessary for an understanding of the approach adopted by the experts have been retained.*

The present structure of Spanish industry is illustrated by two tables: the first gives a breakdown of firms by number of employees, for each branch of industry and for the branches as a whole; while the second, which supplements the first, gives a breakdown of the labour force by size of firm, for each type of industry. A table concerning the metalworking industries taken from the Industrial Production Statistics has been included to give an example of the productivity of the different-sized firms.

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* An annex to the present report contains additional data on the Andalusian region and the qualified manpower available in Spain.

TABLE I

BREAKDOWN OF FIRMS BY SIZE AND BRANCH OF ACTIVITY

INDUSTRY	TOTAL	FIRMS EMPLOYING			
		fewer than 50	from 50 to 99	from 100 to 499	more than 500
National total	536,323	529,176	3.496	3,209	442
Coal mining	666	389	116	121	40
Extraction of metal-bearing ores	852	685	59	94	14
Crude petroleum and natural gas	3	–	–	3	–
Extraction of stone, clay and sand	5,757	5,729	17	11	–
Extraction of other minerals	4,904	4,858	23	18	5
Food products	102,270	101,584	393	248	45
Beverages	24,103	23,999	63	39	2
Tobacco	169	140	12	11	6
Textiles	21,707	20,277	631	743	56
Shoes and clothing	138,174	137,910	160	98	6
Wood and cork	40,407	40,268	91	47	1
Furniture	15,210	15,114	60	36	–
Paper and assimilated	1,715	1,568	60	82	5
Graphic Arts	5,204	5,058	88	54	4
Leather and assimilated	7,218	7,173	30	13	2
Rubber goods	839	760	28	45	6
Chemicals and chemical products	6,768	6,407	160	181	20

INDUSTRY	TOTAL	FIRMS EMPLOYING fewer than 50	from 50 to 99	from 100 to 499	more than 500
Petroleum and coal derivatives	288	261	12	12	3
Mineral products	19,830	19,433	216	171	10
Metal industries	1,508	1,351	117	1[illegible]7	33
Manufacture and repair of engineering products	35,189	34,787	19[illegible]	[illegible]	10
Manufacture and repair of non-electrical goods	[illegible]06	8,378	167	[illegible]	14
Manufacture and repair of electrical machinery	7,233	7,055	72	[illegible]	24
Manufacture and repair of equipment for transport industry	25,214	24,806	163	18[illegible]	56
Other processing industries	12,630	12,491	87	47	5
Building industry	45,463	44,632	423	357	51
Gas and electricity	4,196	4,063	53	65	15

Source: Industrial Census, 1958

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TABLE [illegible]I

BREAKDOWN OF LABOUR FORCE BY SIZE OF FIRM AND BRANCH OF ACTIVITY

INDUSTRY	TOTAL	FIRMS EMPLOYING			
		fewer than 50	from 50 to 99	from 100 to 499	more than 500
National total	3,140,876	1,739,337	238,340	666,140	497,059
Coal mining	97,929	6,334	8,299	27,569	55,727
Extraction of metal-bearing ores	42,329	8,508	4,06[illegible]	18,154	11,598
Crude petroleum and natural gas	1,064	-	-	1,064	-
Extraction of stone, clay and sand	26,870	23,981	1,112	1,777	-
Extraction of other minerals	25,938	15,918	1,617	3,718	4,685
Food products	406,881	299,163	26,401	50,351	30,966
Beverages	100,785	88,560	4,220	6,651	1,354
Tobacco	9,836	1,108	852	3,313	4,563
Textiles	343,183	96,628	44,357	155,972	46,226
Shoes and clothing	328,476	293,722	10,471	18,165	6,118
Wood and cork	138,729	124,058	5,893	8,015	763
Furniture	65,161	54,291	4,179	6,691	-
Paper and assimilated	35,930	12,853	4,146	15,384	3,547
Graphic Arts	50,623	32,122	6,030	9,236	3,235
Leather and assimilated	25,171	19,645	1,975	2,324	1,227
Rubber goods	23,206	4,353	1,994	11,249	5,610

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INDUSTRY	TOTAL	FIRMS EMPLOYING fewer than 50	from 50 to 99	from 100 to 499	more than 500
Chemicals and chemical products	109,547	39,011	10,827	38,225	21,484
Petroleum and coal derivatives	10,734	1,313	850	2,683	5,888
Mineral products	162,711	102,012	14,333	38,446	7,920
Metal industries	97,740	16,157	8,007	22,118	51,458
Manufacture and repair of engineering products	171,352	102,760	13,154	37,484	17,954
Manufacture and repair of non-electrical goods	100,904	50,059	10,964	28,654	11,227
Manufacture and repair of electrical machinery	83,552	25,132	5,130	18,622	34,668
Manufacture and repair of equipment for transport industry	236,872	91,693	11,159	43,664	90,356
Other processing industries	61,813	42,417	5,988	9,833	3,575
Building industry	336,554	170,535	28,437	73,190	64,392
Gas and electricity	46,986	17,004	3,876	13,588	12,518

Source: Industrial Census, 1958

TABLE III

PRODUCTIVITY AND SIZE OF FIRM

METALWORKING INDUSTRIES

Size of firm (number of employees)	Number of firms	Labour force employed by these firms	Status within the firm			
			Unsalaried %	Salaried (1)	Salaried (2)	Productivity (3)
1 to 5	4,094	9,814	43.0	4.9	52.1	23.8
6 to 25	2,529	30,467	7.0	6.2	86.8	26.4
26 to 50	969	33,425	1.8	10.9	87.3	32.4
51 to 100	556	37,599	1.0	11.5	87.5	35.8
101 to 250	300	52,554	0.1	14.6	85.3	37.2
251 to 500	109	39,456	0.0	16.8	83.2	48.6
more than 500	70	93,352	-	21.6	78.4	60.2
Total	8,627	296,667	2.5	15.1	82.4	42.9

(1) Management, technical and administrative personnel

(2) Workers and clerical staff

(3) Productivity = Pesetas per hour worked (gross value added)

<u>Source</u>: Industrial Production Statistics, 1963.

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These tables show that Spanish industry, which in 1962 represented 32% of the gross national product, is characterized by its many small and medium-sized firms. The vast majority of the manpower is to be found in firms employing fewer than fifty people, with a relatively limited managerial staff and very low productivity. For this reason, the Spanish Government, which has committed itself to a gradual lifting of restrictions on trade with foreign countries, is interested in seeing that mergers take place to enable private industry to meet foreign competition; to this end the Plan features a credit policy favouring mergers and associations of small and medium-sized firms.

An idea of the effects of this policy and of competition on the utilization of engineers in the next ten or fifteen years can be obtained by examining recent trends, or the present situation in other European countries. The big companies, in their wish to keep reducing their costs, will increase the technical side of the engineer's work, whether he is in charge of production or directing a unit or a department. Moreover, the mergers, which may reasonably be expected to take place, undoubtedly will not reduce the number of small and medium-size firms, which on the contrary, is likely to increase, but many of which will have to disappear. The creation of big companies gives rise to that of a number of small ones, whose directors must have a good flair for the possible application of scientific advance, and also be capable of starting up a firm, i.e. of evaluating the market potential of a product and organizing its production. This rapid review is sufficient to show the direction the work of engineers will take and to determine which aptitudes the Seville School should be designed to develop. However, not only the needs of the Spanish industrial structure should be taken into account; the rapid change in technology and the constant progress in science impose other considerations, which may affect educational objectives.

2. EFFECTS OF TECHNOLOGICAL CHANGE

Scientific progress and continuous industrial development have brought about a tremendous technical expansion with an increasingly rapid pace. At the beginning of the century, the techniques employed in industry were relatively simple, and all the engineer needed was a sound background in elementary science and practical common sense. Since then, industrial techniques have become increasingly complex and the number of specialized branches has grown considerably; it is no longer possible for an engineer to be universally qualified, or even to be familiar with all the different techniques employed in his own specialization. The task of engineering schools has therefore changed, and the education they provide must be adapted to this situation.

The evolution in the conception of what engineering schools should be gives a fairly good idea of the difficulties encountered by their directors. Certainly other factors of an economic or institutional nature have contributed to this change, as we have seen above in the case of Spain, but these factors were themselves conditioned by the development of industry and by technological progress. The first engineering schools taught their students all the techniques employed in a particular economic branch; graduates of these schools had to be familiar with every aspect of a profession. This professional specialization does not manage to limit the number of disciplines taught however, particularly as the various branches of industry now employ an increasingly wide range of techniques. The schools which still function along these lines therefore tend to provide an encyclopaedic i.e. an increasingly superficial education.

This evolution in the work of engineers then caused those in charge of higher technical education to turn to another type of specialization, by branch of technology. A number of schools were then set up along these lines, but isolated schools did not lend themselves very easily to specialized training. With a departmental system the students can begin with a common training, and then be provided with an ever higher degree of specialization; this system has been developed to the full in the United States. For various reasons, however, it is not considered fully satisfactory, and recent steps taken in the United States show that even there another solution is being sought.

In point of fact, an engineer's knowledge, especially when it is highly specialized, rapidly becomes obsolete; continuous scientific progress means engineers must be highly adaptable to technological change. Adaptability implies a judiciously balanced training in the basic sciences and in specific techniques; and of course, such a balance cannot be obtained in a highly specialized school. Engineers with this type of training have difficulty in adapting themselves to the progress made in their own field, not to mention their position when their speciality is superseded by another.

The role of engineering schools is nowadays considered essentially to be one of training. The term "training" is used to emphasize the fact that an advanced engineering school should influence the mentality of its students and their reactions to the situations in which they will find themselves, rather than simply provide them with a certain amount of technical knowledge. This does not mean that the school will provide them with a set of answers to all the problems they will have to cope with in management posts, rather that their attitude and their conception of the role they have to play will lead them to adopt that pattern of behaviour which has been found most rational and most effective in industry. Clearly, any training, any pattern of behaviour, must be based on a certain amount of knowledge; but such knowledge should be considered almost as a pretext for such training. In any event, even though the education provided by such schools should give students a solid foundation in the sciences and in basic engineering techniques, it should have no pretension towards teaching them the entire range of techniques involved in their specialization, and the practical experiments selected must be studied in depth sufficient to constitute an effective means of training.

This system is particularly suitable for Spain. Engineers in American Universities are certain to find - in the most industrialized country in the world - a job corresponding to their skills, no matter how specialized. This is not true of Spain, where on the contrary, the general technical education of engineers should be good enough to allow them to undertake responsibility for a production unit.

3. EDUCATIONAL OBJECTIVES

The foregoing considerations have lead the experts to the conclusion that the Seville School should train young men to assume, in firms that are often limited in size, technical production functions and also managerial and administrative functions, in order to meet the most urgent requirements of the Spanish economy. The creation of a category of executives having an exceptional degree of initiative and a market bent for practical achievement, and who are able then to cope with the various problems involved in running a firm would, in fact, make a very effective contribution to the development of the Spanish economy.

On the basis of the foregoing considerations, the objectives of the Seville School may be formulated as follows:

(a) Most of the engineers graduating from the Seville School will be assigned functions very closely concerned with production, for which they will be both technically and administratively responsible. They must therefore be able to use the knowledge they have acquired, have a practical turn of mind and a taste for concrete achievement. They must at the same time remain alive to scientific progress, in order to make use of the new possibilities it affords and derive applications therefrom.

(b) The engineers from the Seville School will have to adapt themselves to the specialized techniques characteristic of modern industry, either to assume new functions or to keep up with constant scientific progress. They must therefore have an adequate general technical background; furthermore, the three suggested fields of specialization - mechanical, chemical and electrical engineering - should not lead to a degree of specialization which necessarily determines the subsequent career of graduates.

(c) Most of the Seville School graduates will have the responsibility of running workshops or firms. Accordingly they must have the spirit of an entrepreneur or director, and be familiar with the basic techniques of management and organization. In addition, to make the most of a variety of personal interests, the education provided should enable those having a special bent for these subjects to study them in greater depth, without, however, neglecting the technical side of running a firm, which must still be the main purpose of the School's training.

PART TWO

TEACHING METHODS

The objectives of the Seville School having been determined on the basis of the needs of the Spanish economy, it is now essential to specify how these objectives are to be attained. The quality of the training provided for engineering students necessarily depends on the teaching principles applied in the School; the syllabuses will be effective only to the extent that students are taught how to make use of the knowledge they have acquired. Accordingly, the teaching methods recommended by the experts constitute a vital part of this report; they should make it possible to train students to participate effectively in the development of Spanish industry.

The definition of these principles depends on the educational expression of the objectives determined above. The problem at Seville is not to set up a school on the same lines as the other Escuelas Técnicas Superiores, or simply to transplant a foreign establishment in Andalusia but to define the form of education most likely to produce the desired results.

The recommendations included in Part II apply to the final four years only, for the reasons already stated. The experts wish to call the attention of the Spanish authorities to the fact that there will certainly be some difficulty in implementing these recommendations during the first few years of the School's existence, hence an earlier recommendation that, for a time, only a very limited number of second-year students be accepted. This trial period will enable staff to adapt themselves to unfamiliar working methods.

CHAPTER III

ANALYSIS OF THE OBJECTIVES

The three objectives given in Part I bring out general teaching principles from which will derive specific recommendations concerning the graduation of subjects, the organization and supervision of students' work, the practical training periods, and academic administration. These principles concern the ability of engineers to use the knowledge they have acquired, the degree of their specialization and their managerial training.

1. ABILITY OF ENGINEERS TO USE THE KNOWLEDGE THEY HAVE ACQUIRED

Engineers at the Escuela Técnica Superior graduate level are often disconcerted by the practical difficulties they encounter on the job, and experience difficulty in applying the knowledge they acquired in school, or subsequently, to practical problems, so that their intensive theoretical training is not used as it should be. Engineering graduates from the Seville School should be ready to take over production responsibility. This requires a type of education which combines practical application and theory so that they alternate with each other and continuously bring together abstract theories and concrete facts. This alternation should apply to both the educational process and the organization of the students' practical training.

A. The training process

The characteristics of engineering graduates are the result of a method of training based on an educational gradation. The training of an engineer requires the teaching of theory and the imparting of practical knowledge. Normally, first the basic subjects are taught - mathematics, physics, chemistry - then the engineering sciences such as thermodynamics and strength of materials, and finally the engineering techniques leading directly to practical applications.

The experts felt that this procedure should be retained, but should not be applied as rigidly as usual*. In point of fact, traditional education does not usually provide students with the opportunity of applying their knowledge to concrete problems; only when they start work in a firm are they called upon so to do. According to a number of Spanish industrialists, graduates require several years to adapt their theoretical knowledge to actual

* The procedure finally adopted might have to be modified, if it were decided to allow certificate-holders from lower-level establishments (e.g. Escuelas Técnicas Medias) to enter the Escuelas Técnicas Superiores, not as first-year students, but into one of the following years, e.g. the third year, to acquire a specific training.

working conditions. To avoid this sudden change over, theory and practice should be combined during the whole academic career of the students. As from the second year, the teaching staff should always try to give students examples of simple practical applications; as the students advance, the examples might become more complex and less immediate. For the same reason, the basic subjects, particularly mathematics and the physical sciences, should not be dropped after the first years, as is too often done, with the result that students have forgotten much of their theoretical backg ind by the time they get to the final years, which are meant to show them how theory is applied. The teaching of technical subjects in the final years should, on the contrary, rely heavily on, and make constant use of, these subjects, and use them as indispensable tools. The effective use of the scientific and technical knowledge acquired at school is conditional on this.

B. Practical work in engineering training

Although maintaining the same quality of theoretical training as in the other Escuelas Técnicas Superiores, the experts consider that the students of the Seville School should receive a much more intensive practical training; considerable room will therefore be given, in their syllabus, to practical shop and laboratory work and to training periods in industry. However, if this practical training is to be useful and effective, it must be closely integrated with the theoretical subjects: the idea is not produce technicians, but to train engineers capable of appraising the feasibility of a project, of deciding on the means to implement it and of giving orders to technicians. The training periods will therefore be part of the academic year; the practical work will form part of the course and of the theoretical instruction they are designed to illustrate. The principle of alternating theory and practice should apply to the organization of both the academic year and the day.

2. DEGREE OF SPECIALIZATION

We have seen that the specialization of engineers trained at the Seville school should be fairly limited, and that the specialties studied should serv as means to attain the educational objectives. The first aim will therefore be to produce engineers with a sound general knowledge of the various areas of technology: this led the experts to allocate the first three years to this training, which will be complete in itself, specialization starting only in the fourth year, contrary to the Ministry of National Education's project. The final two years will be devoted mainly to specialized work, allowing the student to go more thoroughly into a particular branch of technology, for training purposes. This would still be sufficent to provide students with a good basis for the specialization they have chosen and with sufficient skill in this branch to start their professional career without difficulty.

Obviously, students cannot be expected to acquire at school more than a very small part of the knowledge proper to their specialization. So that there is no point in trying to teach them a vast store of knowledge they will have plenty of time to acquire later on; on the contrary, only a minimum amount of indispensable knowledge should be required, to allow them to study very thoroughly a few examples of applications chosen for their training value, and often using techniques other than those of their specialization. In particular the final projects in a given specialization should require the use of the techniques belonging to another specialization.

3. TRAINING FOR MANAGERIAL AND ADMINISTRATIVE POSTS

Most of the engineers graduating from the Seville School will be called on to manage firms or take part in their administration, so that all should, therefore be prepared to do so. Obviously, business administration cannot be taught in an engineering school, so that this preparation will consist of an introduction to administrative, organizational and marketing problems and an explanation of how firms are run.

Training periods spent in firms will be an important part of this training. A considerable part of the curriculum will be reserved for economics and the social sciences; the proposals in this report consider this should represent 17% of the time spent at the School.* The objective would be: to make students familiar with such elementary administrative techniques as business accountancy and budget and quality control; and to show the importance of human factors in production by teaching the rudiments of industrial psychology and sociology. These courses should not be purely theoretical, though; wherever possible students should be given concrete cases to work on, and the training periods should be so organized that students come into contact with the difficulties they are likely to encounter later.

It is hoped that students who have a particular interest in organizational, administrative and commercial matters will have an opportunity, during their final year, for more-intensive training in this field, as it affects their specialization. The technical training period which the experts advocate including in the final year would offer them such an opportunity.

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* Including the first year.

CHAPTER IV

ORGANIZATION OF STUDIES

The general teaching principles given in the preceding chapter determine the various aspects of the organization of the School, and from these can be drawn up detailed recommendations for the use of those responsible for technical education. In this chapter, we shall study what effect the application of these principles has on the organization of the courses : that is, we shall give a general description of the education provided by the Seville School. The organization of studies represents a synthesis of the work accomplished by the group of experts, and the recommendations in this chapter are a consequence of those given later in this report. It was necessary, however, first to describe the general framework into which other aspects of education will be incorporated.

1. ORGANIZATION AND LENGTH OF THE ACADEMIC YEAR

The organization of the academic year depends not only on the syllabus for each year but also on the scheduling of the training periods in industry, to which the experts, as well as the Spanish authorities questioned, advocated devoting a fair amount of time.

A. Time table of training periods spent in firms

The fixing of the time for the training periods in firms depends primarily on the progress made in the students' socio-economic training, which includes the human sciences in the school and experience during these training periods. As shown later in this report, it was decided that students should spend three periods of training in industry, each lasting seven weeks. It was felt that the three training periods should be spread over the three terms of the academic year to even out the load for the firms and make the most of the School's facilities.

Further limitations were also imposed for educational reasons. The experts were first in favour of placing the final training period, which is technical, at the beginning of the fifth year, so as to leave students plenty of time to prepare their final project thoroughly and, at the same time, ensure that they were ready for certain courses requiring a certain amount of industrial experience. It was also felt that the fourth year should be spent entirely at the School to allow the students sufficient time to assimilate the basic knowledge required in their specialization. Lastly, school officials hope that students will have at least one week in the School after they return from the summer holidays. These are the considerations which governed the fixing of the training periods for the year 1966-67, as shown in the following Table.

B. Length of the academic year

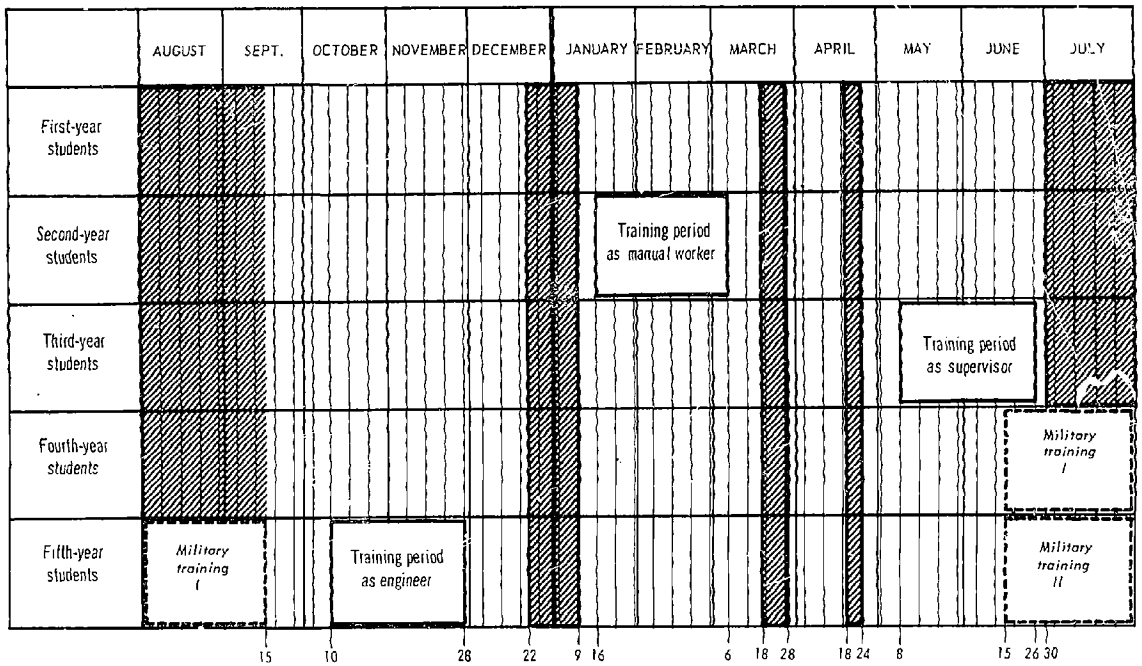
During the academic year, students at the Seville school will spend training periods in industry totalling 21 weeks; they must also acquire technical training equal if not superior to that of students at the other Escuelas Técnicas Superiores. This means that the academic year must be as long as possible, to compensate for the shorter time devoted to formal teaching at the School. After considering the various arguments against this, the experts concluded that the second- and third-year courses should be extended to the end of June; the academic year should begin on the 15th of September. The amount of time thus gained is not very considerable, and teachers will have to put it to the best use. But, as we shall see later, in general there are no final examinations, so that the entire month of June can effectively be devoted to teaching.

The second- and third-year courses would therefore last $36\frac{1}{2}$ weeks, minus approximately one week in odd days for bank holidays. In actual fact, however, if training periods and their preparation at the school are allowed for, only $27\frac{1}{2}$ weeks will be left for formal coursework. The fourth year would last 33 weeks, and the 5th year, 25 weeks.

Table IV

TIME TABLE

EXAMPLE OF THE ACADEMIC CALENDAR FOR 1966-1967



Nota : 1. In this schedule, each training period lasts 7 weeks, corresponding to the time actually spent by the students in the firm.
2. The schedule does not show add days corresponding bank holidays, which account for approximately one week per year.

2. SCHOOL TIME TABLE

The general time table worked out by the experts for the four final years is given in the following pages. Responsibility for teaching the different subjects is shared by five departments, the departments of Mathematics, Chemical Engineering, Electrical Engineering, Mechanical Engineering, and Economics and Social Sciences. The tables also show the importance attributed to each subject.

Specialization is put off until the fourth year, contrary to the plan drawn up recently by the Ministry of National Education for the other Escuelas Técnicas Superiores. In this respect the experts stress that the aim of the curriculum for the first three years, common to all students, is to provide a basic engineering training and should constitute a whole. We have already seen that specializations are a form of backing for a more thorough training. Care will therefore be taken to prevent this common curriculum from becoming the first stage of specialization.

RECOMMENDATION 2

As the aim of the Seville School is to train engineers who are expected to have to adapt themselves to the many functions allotted to them, the experts recommend that specialization be deferred until the fourth year. The common curriculum for the first three years is intended to provide a sound basic technical training and should not be considered as a preliminary phase of specialization.

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Table V

Second Year

Subject	Department responsible*	1st term	2nd term
Economics and Social Sciences	Economics and Social Sciences	–	1
Mathematics	Mathematics	2	1
Science of Materials I	Chemical Engineering	2	–
Design for Manufacture	Mechanical Engineering	2	–
Electricity I	Electrical Engineering	–	2
Thermodynamics	Chemical Engineering (Mechanical Engineering)	–	2
Period of training as manual worker	Economics and Social Sciences	7 weeks	

Third Year

Subject	Department responsible*	1st term	2nd term
Economics and Social Sciences	Economics and Social Sciences	1	1
Mathematics	Mathematics	1	1
Science of Materials II	Chemical Engineering (Mechanical Engineering)	2	–
Mechanics of Machines	Mechanical Engineering	2	–
Electricity II	Electrical Engineering	–	2
Fluid Mechanics and Heat Transfer	Mechanical Engineering (Chemical Engineering)	–	2
Training periods as supervisor	Economics and Social Sciences	7 weeks	

* This column gives the department in charge of each subject; the name of any other department(s) which the one in charge may have to consult, whether for specific sections of the course or practical work sessions, appears underneath in brackets.

Fourth Year

Subject	Department responsible*	1st term	2nd term
Economics and Social Sciences	Economics and Social Sciences	1	1
Control Systems I	Electrical Engineering**	1	1
Transmission and Application of Power	Mechanical Engineering (Electrical Engineering, Chemical Engineering)	2	–
Transmission and Application of Power II	Electrical Engineering (Mechanical Engineering)	–	2
Specialization course	Chemical Engineering,		
– Subject I	Electrical Engineering or	2	–
– Subject II	Mechanical Engineering.	–	2

Fifth Year

Subject	Department responsible*	1st term	2nd term
Economics and Social Sciences	Economics and Social Sciences	1	3
Specialization course	Chemical Engineering,		
– Subject I	Electrical Engineering or	1	–
– Subject II	Mechanical Engineering	1	–
– Option I	d°	1	–
– Option II		1	–
Final Project	Economics and Social Sciences; Chemical, Electrical or Mechanical Engineering	1	3
Training Period as Engineer	Economics and Social Sciences; Chemical, Electrical or Mechanical Engineering	7 weeks	

* Same remark as for the sec d and third years.

** This is an interdisciplinary subject given by the Departments of Mathematics and of Chemical, Mechanical and Electrical Engineering, which must work in close collaboration, despite the difference in their fields of interest. The Department of Electrical Engineering will be in charge of this course and responsible for co-ordination with the other Departments.

CHAPTER V

TEACHING METHODS

The teaching methods described in this chapter will enable the staff to prepare their lessons in line with the objectives established and to provide their students with a proper engineering training. Teaching principles apply not only to the organization of the academic year, but also to that of the students' daily work, both at school and during the training periods spent in firms. The methods advocated by the experts differ considerably from those adopted by the other Escuelas Técnicas Superiores; the staff will doubtless require some time to adapt themselves to the new methods. The experts also stress that the facilities required to implement these methods are more extensive than those generally accepted in Spain. This is not a result of the methods proposed here but is due to the need to provide engineers with proper training and working methods - not simply to expect them to assimilate a large volume of knowledge on their own.

1. ORGANIZATION OF STUDENTS' WORK

Teaching at the school should not be intended simply to impart knowledge, but should also, and even more particularly, train students to use it. Students' work should be planned in line with this objective, and will require the active participation of the student, which is impossible under the traditional system of formal lectures. Moreover, the assimilation of knowledge requires students to spend long hours of patient work before reaching the point where they have mastered this knowledge and acquired the ability to manipulate it with ease. Students must therefore be allowed sufficient time to go deeply into their subjects and their attention should not be distracted by requiring them to absorb too many subjects in small quantities. Lastly, engineers are called on to work as one of a team, with subordinates or with other engineers; at school, group work should accustom them to this aspect of professional life.

These considerations led the experts to recommend that only one subject be studied each day, so that the students would realize the close relationship between theoretical knowledge and its practical application. This arrangement makes it possible to link, by means of alternating, the teaching of theory and practical applications, so that a unit of instruction is created on which the students' work is based. It will be noted, especially in the timetables given in the preceding chapter, that there are invariably six subjects per term; there will also be six teaching units per week.

The teaching unit, which may vary in length from four to five hours, consists of a number of parts. First, the professor* gives a short lesson to the entire class, explaining

* As used in the present report, the terms "professor" and "assistant" refer to functions rather than to specific grades in the Spanish university system.

the main points of the subject under study and then questions the students to make sure they have grasped the main points of this talk and to prepare them for the ensuing work. The class is then split up into small groups, each of which is assigned to an assistant* who is responsible for guiding it in carrying out exercises and practical work directly connected with the questions covered by the professor, and who gives all the necessary explanations to each student. Lastly, the professor talks to the whole class and the assistants to go over the day's work and take up the main points of the [illegible].

This scheme of organization is given for the sake of illustration. Obviously, the unit may, for certain subjects or within a given subject, include only one or two of the foregoing activities. For example, a mathematics session would comprise a lecture and supervised work; a lesson on the strength of materials might be entirely devoted to practical work. The lenght of the teaching session would depend on the subject treated or on the professor, and may be curtailed to allow students to work on a project requiring several days.

The professor should be available during the entire session to help the students and assistants and to make sure the lesson has been understood. Such a system is much more effective if the students are given suitable literature on the previous day to study in preparation for the lesson. This naturally presupposes that they be supplied with suitable texts written in Spanish; this, the experts feel, should be the first task assigned to the teaching staff.

A. Lectures

The lecture is an important part of traditional teaching methods; its importance tends to grow as the number of students increases, without there being a corresponding increase in the number of professors or lecturers. In view of the current nature of the engineer's job, however, the lecture is becoming a far less efficient form of teaching and should no longer be used as a means of providing students with all the knowledge they must acquire. Lectures should be supplemented by the study of reading matter, which could consist of a course written by the lecturer or of any other works he may recommend. The experts desire that lectures be used very sparingly at the Seville School; it is well known that the students still listening to the lecturer at the end of 45 minutes are very rare indeed. The task of the lecturer will therefore be to explain briefly the basic concepts of the subject being studied and to go more deeply into the more difficult points.

B. Tutorials

For tutorials, the class is split up into small groups of approximately 15, each being assigned a small classroom, where it meets under the guidance of an assistant, acting as discussion leader. During these classes, students learn to put into practice the concepts covered in the day's lesson; they put into application the subject matter of the coursework in the form of exercises and problems, and study problems which have actually occurred in firms. The subject matter for this work may be provided by either the professor or by his assistants. It is hoped that engineers working as part-time assistants will bring the problems they have come across in the firms where they are employed; this is the best way to compile a repertory of subjects within a few years' time.

The role of the discussion leader is not to deal with the problems while students look on, but rather to help the students do the work themselves; the students work together, with

* As used in the present report, the terms "professor" and "assistant" refer to functions rather than to specific grades in the Spanish university system.

e access to any reference material they may need; as a rule, they break up into sub-ups of three or four and the leader goes from one sub-group to another answering ques-ns, helping students to cope with the difficulties they encounter and raising questions t the students themselves might fail to ask. The leader should leave students enough time study the problem and seek a solution; the group should advance as a result of its own work, : because it is being pushed too quickly by the leader whose role is essentially advisory. e atmosphere of these classes should be that of an industrial research department, where ople discuss, raise questions and consult reference works, rather than that of a lecture examination room.

For a particular subject the same leader meets with the same group of students every time, that all concerned soon get to know each other. The professor, however, goes from one oup to another to see whether the students have properly understood the subject matter; he -ordinates the work of the several groups, and answers questions put by students when their ader is unable to do so.

Obviously, if these classes are to be effective, the students must have done the ne-ssary preparatory work, but it is easy for the leader to detect which students are not rking and, in any case, those who come without doing the necessary preparation and are e only ones doing nothing in the midst of a busy group find themselves in a very awkward tuation.

Practical work

The Decree of 26th May 1965* shows the importance attached by the Ministry of National ucation to practical work in the Escuelas Técnicas Superiores. The experts are in whole-arted agreement with the wish expressed in this Decree, which should enable students to quire good practical training if the sessions are effectively organized and supervised.

The practical courses given in the engineering schools have several objectives. First, e teachers are able to let students observe, and thus more easily understand phenomena that uld be difficult to explain theoretically; practical courses have much the same illustra-ve value as the experiment_ performed in secondary schools. Visual experience is not enough, wever, for engineering students, who later on will have to control actual phenomena.

Gradually the student must acquire the mentality of an engineer: he will have to inter-et measured data; have a feeling of the order of magnitude of the results he is looking r and acquire a certain amount of experience in using equipment, i.e. acquire a practical rn of mind.

Practical work is also considered useful in helping students to get to know the prin-pal types of equipment they will later have to use. Obviously an engineering school cannot equipped with plant comparable to that found in certain industries; under these conditions, me teachers feel it preferable to have equipment which is simple but adequate for the pur-se. If the equipment is simple it is easier for the student to understand how it works; it so encourages the students to be pr..ctical by obliging them to find ways and means of taining the desired results; it also prepares them to cope with situations arising in in-stry, where they may have to manufacture new products with inadequate machinery. This gument was opposed by some on the grounds that, if industries, whether in Spain or else-ere, are to meet competition and increase productivity, they must use up-to-date.

The text of this Decree is contained in one of the annexes.

techniques. This means that young engineers must have had an opportunity to get to know these techniques, even if they are to become obsolete within a very short time. In point of fact, they argue, it is much easier to teach such techniques to students of the Escuelas Técnicas Superiores than to engineers who already have heavy responsibilities in industry and are perhaps less receptive; the providing of young engineers with a knowledge of modern techniques is a means to ensure industrial progress. These considerations led the experts to recommend that simplified plant be used at the beginning, and ultra-modern equipment for the later years.

The practical work carried out by engineering students is not intended to develop the same manual dexterity as for skilled workers; this is not the objective of their training. They should, however, know how to use the more usual types of machines, for this will give them a feeling of familiarity with machinery that will be very useful to them later on. They should know what the machine can do and its characteristics so as to be able, later on, to organize production and judge the work they will expect of their subordinates. This is why the experts have included shopwork in the syllabus as from the second year*, which will prepare the students for the training period they are to spend as workers. Some experts have even suggested that simple work for outside firms be carried out at the School; this, of course, implies that close ties be established between the School and industries in Andalusia. This suggestion should be considered as soon as possible; it would give students practice in actual application, for which they would be held responsible.

The practical work will also be carried out in small groups; throughout, the size of these groups will be such that the assistant is able to control the work of each student. For the supervised group work we have seen that each group should consist of approximately fifteen students; for the practical work these groups should be sub-divided into teams of two or three students each, depending on the type of work and the equipment being used, so that each student can learn how to use the apparatus, understand the method employed and the extent of its precision. On a reduced scale, practical work should anticipate that of engineers in an actual firm and train students to work as part of a team whose objectives each member must know and be able to realise, even though his own part in this is limited. A report of the work must be made on the spot, under the permanent supervision of the assistant, as soon as the results have been obtained.

RECOMMENDATION 3

The experts recommend that at the Seville School only one subject be covered each day, so as to allow students to grasp the close connection between theory and practice. Most of this unit of instruction will consist of supervized exercises and practical work carried out in small groups under the supervision of assistants; the time occupied by formal lectures should be considerably less than is currently the practice elsewhere.

This recommendation will require each department to make efficient use of the facilities available. Whereas a teaching unit may normally begin at 8:00 a.m. with a talk given to the entire class, the tutorials and practical laboratory work are necessarily intended for a smaller number of pupils, commensurate with: the size of the buildings, the equipment at the disposal of the School, the number of assistants the department is able to recruit, and the number of groups a professor can actually supervise. Permutation must therefore be arranged, which should be facilitated by the gradual increase in enrolment.

* In Part III some indications are given on first year practical work.

Each phase of the unit of instruction is part of a process at the end of which the student should be able to put his knowledge into practice. Students are expected to acquire this knowledge prior to the unit of instruction by studying the course written by the professor and any reference material he may recommend so that, instead of having to cover the entire subject matter, he can concentrate on making it clear. Within these groups, the assistants must make sure the subject has been thoroughly understood, and give any necessary explanations. Direct-application problems which are more complete and more complex, and practical laboratory work make students increasingly familiar with the concepts concerned. Practical work in the shop and laboratory constitute the most effective means of incorporating new concepts with those already acquired and of making them usable, at the same time memory is brought into play and the process continues automatically throughout the rest of the course by virtue of the frequent revisions that are required.

2. TRAINING PERIODS IN FIRMS

The training periods spent in industry are designed to fami. . . . students with the environment in which they will work one day and to acquaint them w... the practical problems encountered in an actual firm. This training, which lasts several weeks, is on a full-time basis, and is spent in an industrial firm, where the student is assigned a definite task agreed on by the officials of the School and of the firm; these training periods are compulsory, for they constitute an integral part of the training.

As students at the other Escuelas Técnicas Superiores do not have any training in industry, it may be useful to recall the educational value of these training periods. First, they help build the character of future engineers, who must adapt themselves to different social environments, and deal with problems which are much more complex than these arising in the exact sciences; they give students an opportunity to become acquainted with the professional surroundings in which and the people (workers, foremen) with whom they will one day live and work, to understand their attitudes and personal interests and to get to know their problems, before the title Engineer inevitably raises a barrier between them. Training periods develop a taste for practical achievement, without which their education is devoid of meaning. They also make it possible to include in the School curriculum such subjects as organization, economics and the social sciences, for these are useful only if the student has had some small experience in an actual firm; conversely, thes subjects enable the students to derive the greatest possible benefit from their training periods.

Training periods are equally profitable from the technical standpoint. They oblige students to grasp new techniques rapidly and thus prepare them for the subsequent adaptation to technological change. They show students the technological solution applied to a specific theoretical problem and why other possible solutions were rejected. Lastly, they provide guidance and help the student to choose his specialization in the light of experence.

The experts consider that students should have three training periods in industry during their academic career. Each period should last seven weeks; approximately one week would be spent at the School in preparing and rounding off the training. The first period would be as a manual worker, the second at foreman level and the third as an engineer.

A. Training as a worker

The main objectives of this training period are, first, to build up the students' character as a result of the change in environment, of the effort to ...., observe and understand, of the hard physical work, and secondly to make the student ... of the problems and attitudes of workers, both on the job and outside the firm. The trainee is one of a team: he is assigned the place of a worker and is subject to the same discipline, the same standards and hours of work. He is provided with board and lodging in a working-class family whenever possible, or else in a workers' canteen.

To oblige the trainee to be observant and to think, despite his fatigue, he is required to write a report on the attitude of the workers rather than on the technical aspects of his training. The training period is prepared by a series of briefings at the School and followed up by a seminar during which all the students meet for a few days to exchange experiences, discuss their impressions and think things over. The seminar is conducted by engineers (one for every twelve to fifteen students).

B. Training as a foreman

This training period is intended to familiarize students with the working of a small production unit (organization, structure, chain of command, information, checking and control) that is, in this context, with the functions, means and attitudes of foremen. To this end the trainee is assigned to one or perhaps two foremen during the entire period, spending for example three weeks with the charge hand, who has 10 to 25 workers under him, and four weeks with the foreman, the charge hand's immediate superior, who has 30 to 80 worker nder his orders. When possible, he shares some of the foreman's responsibilities. It is not necessary, or even desirable, that this training be spent in a "model plant", as the aim is to stimulate the trainee to think about what he sees and to familiarize him with the problems he will encounter later. Naturally, the trainee is subject to the same discipline and hours of work as the foremen.

The report written during this training concerns questions of organization, supervision and foremen's duties. Briefing sessions are held before the training, and a seminar immediately afterwards and, as before, these are conducted by engineers.

C. Training as an engineer

This training period should provide the student with an opportunity of dealing with a problem which actually exists in the firm, similar to those he will have to tackle subsequently as an engineer. The project, on which the student works full time during his seven-week course, may be purely technical or concern organization or management; for example, the working of certain equipment and ways to improve it, or a critical analysis of the organization, efficiency and costs of a department such as maintenance, supplies or dispatching.

The project is intended to teach the student to formulate clearly a concrete, and therefore complex problem and then go into it thoroughly, using the theory acquired at the School, observation, experiments and information obtained in the firm. It is therefore desirable for preliminary and follow-up work to be done on the project, under the guidance of a teacher at the School. The subject for each student's project will be chosen in relation to his specialization.

RECOMMENDATION 4

The experts recommend that students at the Seville School spend, in the course of their academic career, three seven-week training periods in industry, as worker, foreman and engineer. These periods, which ar part of the engineer's training, are compulsory, and imply close cooperation between the School and the firms accepting the students.

This training should not consist of relatively slack periods for the students. Its organization will require a considerable amount of preparatory work on the part of the School staff. A member of the staff responsible for this training must pay a prior visit to the firm to prepare the way for the trainee and explain to the engineers who are to work with him the principles on which the training must be based. He must decide with them the post the student will occupy, the job he will do, and how all his time is to be spent. He will visit the student during his training. The acceptance of a trainee also requires an effort on the part of the firm and its engineering staff; while in the firm, the student will receive guidance and help from an engineer, who should give him a few hours of his time each week. The effectiveness of this type of training depends on the link between the School, the students and the firm.

The three training periods should be closely co-ordinated with the Economics and Social Science courses of which the first two training periods form an integral part; the fifth-year training period may be purely technical or, for those students who are particularly interested in the organization or economic side, concern these subjects. It was therefore felt that responsibility for organizing these training periods should be entrusted to the Department of Economics and Social Sciences, which thus becomes, at operational level, the link between the School - i.e. the other departments - and industry. Such an arrangement may eventually prove of considerable value as a means of technical assistance to firms in the Andalusian region.

3. SUPERVISION OF STUDENTS' WORK

The purpose of the School is to train men for the functions they will be assigned; the teaching staff must ensure that the student to whom they award a degree actually has the requisite aptitudes and standard. This means that students' efficiency and work must be tested throughout their school life. Oral or written examinations are usually held at the end of the year or on completing a course; many teachers consider, these examinations have a harmful effect on the students' work.

All teachers, in fact, like their students to work at a steady pace throughout the year and keep up with the course. The traditional type of examination has the opposite effect: knowing he will be judged on the basis of an examination, the student concentrates all his efforts on preparing for it. Usually, the student is required to know far too much, so he crams for the examination and then forgets as quickly as he learned, and so has wasted his time. The experts, therefore, wish the Seville School to have a more effective system of testing the students which the teaching methods they advocate should make possible.

The system is intended to show which students are not up to standard, and also those who are particularly gifted, and the subjects to which this applies. The system of teaching recommended by the experts allows the assistants to keep a very close check on the work of each student: the assistant in charge of a group of fifteen students for a given subject can keep a continuous check on the work of each without having to question him individually. It is enough, therefore, that in each subject the students' term work be graded at the end of the course. Only three different marks will be given: "excellent" (10 to 20% of the students), "satisfactory" (70 to 90%), "unsatisfactory" (less than 10% if teaching is up to standard).

If during term an assistant considers any of his students below standard, he immediately refers him to the professor; the professor subjects the student to an oral designed to oblige him to catch up with his class mates. Any backward student is thus tested before the end of term and made to catch up on his studies.

It is useful, however, for students to have a written test periodically, to be completed in a set time. This gives the student a good idea of how much he has learned and can effectively use, and allows the staff to assess the efficiency of their teaching. A two-hour test is recommended, once every sixth or seventh lesson in a subject, with reference to books allowed. Marking should be the same as above: excellent, satisfactory, unsatisfactory. This mark is only one of the factors used by the assistant when allocating his final marks.

Students with an "insufficient" mark at the end of a course are required to take a more conventional type of examination at the end of the school year or after the summer holidays. Ordinarily, these should be very few in number; if this were not so it would mean that the teaching was poor. The student who fails to pass this examination is summoned before the Faculty Council, which may decide to:

(a) allow him to continue the following year if he has had good marks in the other subjects, for it is perfectly conceivable that an engineering student may be weak in one of the subjects in his curriculum;

(b) require him to spend a year's training in industry; a student who lacks the incentive to work properly is generally immature or unaware of the importance of his academic work for his professional career. A year in industry, in a position commensurate with his qualifications, i.e. a very subordinate one, will help him to acquire the required maturity;

(c) send him down if he is judged incapable of completing university level studies. In principle this should happen only at the end of the second year, when it may sometimes be necessary to modify the marking given on the basis of somewhat different criteria at the end of the first year; after the second year only exceptionally should a student be sent down.

(d) allow him to repeat a year, in exceptional cases, if this would help the student; this might apply to a student who has been off sick for some time.

Continuous supervision of the students' work should make these cases very rare indeed and encourage students to work steadily and more efficiently, and to reason better; it considerably reduces the time ordinarily spent by staff in questioning students, a factor of particular importance when there is a shortage of teachers. The fact that students are not given a position in the class at the end of term means they are freer to work as a team, i.e. under the same conditions as when they are engineers.

RECOMMENDATION 5

To encourage students at the Seville School to work steadily and efficiently, the experts recommend that the traditional system of examination be replaced by one of continuous supervision of their work. Professors, lecturers and assistants should draw attention at any time to students whose work is not up to standard; at the end of the year these students, and these only, will be required to take an examination. According to the results, they will either be allowed to continue normally at school or spend a year training in industry.

The abolition of traditional examinations should not mean that students are not required to work so hard. On the contrary, working discipline at the Seville School will have to be very strict. In particular, attendance at all classes should be compulsory, any unjustified absence being severely punished; the timetable, which is heavy, should correspond to the hours worked in industry; students are required to take an active part in all the different forms of teaching used.

PART THREE

SYLLABUSES

The syllabuses given in Part III were worked out in accordance with the educational objectives of the Seville School; considerable importance has been attached to the problems encountered by engineers when implementing theoretical projects, or when using the equipment put at their disposal. This does not mean that such practical training conflicts with the theoretical training which engineers from the Escuelas Técnicas Superiores must have. On the contrary, this theoretical training will frequently be more intensive and at a higher level than at present.

The fact of keeping education in line with the objectives laid down, has led the experts to group the various parts of the syllabus in a different way from that in which Spanish teachers are accustomed to have them. It would therefore be useless to compare the syllabuses proposed in this report with, for example, those in the Decree of 29th May 1965 for the other Escuelas Técnicas Superiores; although the titles of some of the courses are similar to each other, their content is not necessarily the same. In point of fact, the content of the complete syllabus is not very different from that taught in the other Escuelas Técnicas Superiores, although all the subjects not strictly needed by industrial engineers have been taken out. This explains why reinforced concrete techniques, topography and astronomy are not in the syllabuses given in this report.

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CHAPTER VI

DESCRIPTION OF SYLLABUSES

A syllabus consists simply of a list of selected curricula and subjects, and, as such, can not be expected to give a very exact idea of the authors' intentions. The syllabuses given in this report therefore have only a very relative value; the staff of the Seville School will have to interpret them in the light of the School's aims and try to understand the spirit in which they should be taught. This report does of course give them some indications, and the experts are prepared to provide every assistance in applying the syllabus.

Time will certainly show where these syllabuses can be improved. But they were prepared to provide a specific type of training. They constitute a whole, and if one part had to be altered it would be difficult not to alter the rest. The experts would therefore like these syllabuses to be maintained for a period of five or six years, to allow an objective appraisal to be made of them.

1. ECONOMICS AND SOCIAL SCIENCES

The syllabus for Economics and Social Sciences, which is new compared to that for the other Escuelas Técnicas Superiores, is designed to train engineering students for the managerial responsibilities they will be called on to assume. The syllabus covers the whole five years and was designed in such a way as to provide a progressive training for the student and constitutes an introduction to the different aspects of running a firm.

This syllabus was drafted with not only the Spanish authorities in mind, but also the professors and assistants, so as to give them a better understanding of its aims, its general content and the spirit and methods to be employed. Its contents will provide them with a basis for the detailed planning of the timetable, for procuring the required textbooks, writing up their courses, planning their classroom work and training their assistants.

Accordingly it was felt neccessary to reiterate, in a more general fashion, some of the considerations already dealt with in this report, to show how the principles defined in the foregoing chapters may be applied to the teaching of Economics and Social Sciences.

As stated earlier in this report, those students who are particularly interested in management and business administration should be given an opportunity to study these subjects thoroughly regardless of their specialization. They will be able to opt for this in the fifth year, and to spend their training period studying an organization or business problem in an industry relevant to their specialization. They might use this training period as the basis for their thesis project, and should be allowed to complete their paper during the year.

2. FIRST-YEAR COURSE

Under the Act of 1964, the first year should be an orientation course, at the end of which students would be in a better position to decide whether they should pursue their studies in a science faculty or at an Escuela Técnica Superior, and, in the latter case, to choose their field of specialization; clearly, this implies that the level and syllabus of these first year courses should be very similar, if students are to transfer from one type of establishment to another without too much difficulty. It was to safeguard this possibility for students to make their choice that the experts were reluctant at the outset to make recommendations concerning the organization, methods and syllabus for the first-year course at the Seville School.

But the 1964 Act also stipulates that holders of upper secondary school leaving certificates who have passed the examinations for the pre-university course may enrol directly in the first year of the Escuelas Técnicas Superiores. The abolition of the entrance examination has attracted to these schools, which are very highly thought of, a considerable number of students, most of whom are unable to complete a course of study at this level. The experts felt it would have been too expensive to apply the teaching methods described in the foregoing chapters to the first-year course. It would also have been pointless, since the first-year is no longer intended to be the beginning of an engineering course, but a means of selecting those capable of advanced engineering studies and who would be admitted to the second year*.

While on mission in Spain, however, the experts realized that the teachers responsible for applying the 1964 Act were having considerable difficulty in working out first-year curricula, at both Seville and the other Escuelas Técnicas Superiores. The 1964 Act, which was put into effect in 1966, abolished the two preparatory courses, the "curso selectivo" and the "curso de iniciación", whose syllabuses were already far too heavily loaded, as the members of the December 1964 mission had already pointed out. The subjects that used to be taught in these preparatory courses now have to be incorporated in the syllabus for the Escuelas Técnicas Superiores. No way has as yet been found to do this, and in most cases the first-year course is obtained by combining the syllabuses for the preparatory courses. The Spanish authorities have therefore requested the experts to give them some indications on how this syllabus might be worked out and a link made between the pre-university course and the final four years as defined in this report.

Advice on the first-year syllabus to be applied at the Seville School is therefore given, and will doubtless be widely used as a model for the other Escuelas Técnicas Superiores. This syllabus is in line with the official one defined by the Decree of 20th August, 1964, the only change being the addition of a series of lectures organized by the Department of Economics and Social Sciences, to explain the function of the engineer and his role in the modern firm and the business world; these orientation lectures are in line with the

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* The Spanish authorities have, in fact, decided to apply to the first year the recommendations applicable to the following years, so as to acquire some experience before inaugurating the second-year course in October 1967, and to train young teachers in the new methods.

spirit of the 1964 Act. The syllabus will also give non-Spanish readers an overall idea of what is involved in an engineer's diploma; an Annex describing the level of the students entering the first-year has been included for the information of such readers.

Students entering the first-year on completing the pre-university course will not have had any practical training. The education most of them have received in secondary school is very general and very theoretical; this conception of secondary education is not peculiar to Spain. But most of these students have lived in regions where there is little industry, i.e. where technology is of secondary importance, where life moves at a leisurely pace, where, since early childhood, they have not been used to machines and their functioning. This would not be very important for future scientists, but does make the training of engineers more difficult. The main objective of the first-year will therefore be to make up to some extent for this lack of practical experience. Students should be made aware that the "deductive reasoning" type of thinking based on the Aristotelian tradition is not the only one, and that the inductive method is much more useful, and is even indispensable, to the engineer. They should be initiated to the experimental method through simple tasks to be carried out in the workshop or laboratory, where they will be brought into contact for the first time with the world of observable phenomena. Any of the subjects included in the syllabus may be used for this purpose: the nature of the phenomenon to be observed or measured is less important than the fact that students are being taught scientific observation and the concept of measurement.

Here, useful reference might be made to the teaching of mathematics, on which the Organization has recently published several works*. Engineers are, in fact considered primarily as mathematicians in most European countries; the first part of their training consists mainly of mathematics, treated very theoretically, without any attention being paid to its application. It would be much more useful to train engineering students to express laboratory phenomena in mathematical terms than to make them solve abstract problems which are now usually solved using computers. A first-year programme based on the idea that mathematics is a means and not an end would, moreover, make it possible to select students according to their aptitude for the engineering profession, rather than their skill in solving problems which they will encounter only rarely in the course of their career.

The second objective of the first-year is to familiarize students with the basic laws of physics and with elementary mathematical tools, so that they can derive full benefit from their subsequent years at school. This will be achieved by giving them a limited syllabus they can thoroughly understand, rather than a general description of the various sciences of interest to the engineer; this is particularly advisable in Spain, where the pre-university course already provides such a description. It will therefore be necessary to exclude from the first-year syllabus those subjects which students are to study later in more detail; subjects which are too theoretical or specialized, such as descriptive geometry or topography, and which are not of direct use in training industrial engineers should also be eliminated. There is apparently no reason to fear, if this is done at the Seville School in the transition period, during which the first-year course is likely to differ from those elsewhere, that students who are not admitted to the second-year at the Seville School will be refused elsewhere. They may have learned less, but will have retained more.

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* Applied Mathematics for Engineers:

- Mathematical education of engineers;
- Mathematics and Engineering Applications.

The Decree of 20th August, 1964, stipulates that there will be five subjects in the first-year as opposed to six in each of the following. In view of the particular aims in the first year, the experts felt this arrangement should be retained and that there should be only five days of teaching per week. The guidance lectures at the beginning of the year will be replaced by technical drawing later in the year. The timetable is as follows:

	First term	Second term
- Linear Algebra	1	1
- Differential and Integral Calculus .	1	1
- Physics	1	1
- Chemistry	1	1
- Technical Drawing	–	1
- Economics and Social Sciences	1	–

The amount of technical drawing is smaller, this corresponds to the reduction for this subject in the syllabus as compared with that previously taught.

The foregoing remarks, together with the syllabuses given in Chapter VIII, included at the request of the Spanish authorities, indicate how a transition might be made between the pre-university course and the second year; they do not, in the eyes of the experts, constitute a solution to the first-year problem resulting from the Act of 1964. It has already been shown that students completing the pre-university course and, a fortiori, the first-year course, have not really any choice between the Escuelas Técnicas Superiores and the Escuelas Técnicas Medias. The result is that the first year constitutes a selective course which is expensive for the State, of little use to the students who complete it successfully, and of none to those who fail, i.e. the majority. The experts earnestly hope that these remarks be taken into consideration and that the Spanish authorities reconsider the structure of technical education, and pay more attention to how the resources at their disposal are used.

3. SCIENTIFIC AND TECHNICAL SUBJECTS

The first three years at the Seville School should give students a basic, all-round engineering training; specialization, which we have already seen will not begin until the fourth year, will give them further training through more intensive study in the field that interests them most particularly. The reasons for which a special chapter has been devoted to the first year have already been stated. The syllabuses for the four following years are set out in two separate chapters, to emphasize their diversity. The first of these contains the second and third year curricula, and the second those for the fourth and fifth years.

The specialization of the fourth and fifth years should essentially be the backbone of the engineer's training, i.e. the study of a particular field should provide the graduate engineer with the type of intellectual approach and working methods that can subsequently be applied to any sort of problem whether in or outside his specialized field. The aim is to train engineers to solve the wide variety of problems they will encounter in their various functions. Their training is therefore much more important than the specialized knowledge acquired in a particular field, for once they begin work in a firm they will rapidly be able to acquire or improve this knowledge. Graduate engineers from the Seville School should be able to make a career outside their specialization if necessary. These considerations led the experts to formulate the following recommendation:

RECOMMENDATION 2 A

The experts further recommend that the engineering degree awarded by the Seville School make no mention of the student's specialization.

As the second and third-year syllabuses contain only subjects required by all engineers, the scope of the subject matter in the third year is limited in electrical, and particularly in chemical engineering. In the fourth year, students therefore have to acquire the bases for their specialization and this is one of the reasons why the experts consider there should be no outside training period at this time. In any case, the syllabuses have been so designed that those students who have the right type of temperament and aptitude will acquire an overall approach to all engineering problems, and the others will acquire sufficient knowledge in their specialization to deal with any problems in this field as soon as they leave school.

Educationally speaking, this method of organizing the courses gives favourable results, for the students will already have acquired a good general background in science and technology and so will be better equipped to begin specializing than those in other Escuelas Técnicas Superiores. The fact of specializing will act as a challenge, i.e., by allowing them to apply what they have learned to actual problems in specific fields; they will even find that their own knowledge is not far behind what is known in their specialization.

This is why provision was made for students with the same specialization to opt for more advanced study in one or more subjects. Most of the fourth- and fifth-year courses should, in fact, be common to all students with the same specialization, and this option should therefore be reserved for the fifth year. The thesis project required of students during the fifth year should preferably concern an application of their optional subject. The thesis project will therefore be at an advanced technical level, but of limited scope and ambition, so that the engineering student will be aware of the various practical problems resulting from its application.

The approved second and third year syllabuses are given here in their definitive version, together with the indications requested by the Spanish authorities concerning the corresponding practical work and facilities. The fourth and fifth-year syllabuses are given mainly by way of illustration, to give a better idea of what the experts mean by specialization; clearly, these syllabuses will, in fact, depend on the qualifications and special interests of the professors appointed; it was therefore pointless to go into details. Similarly, the first-year syllabuses are no more than fairly general indications, based on the specific objectives which, it is felt, should be set for this course.

CHAPTER VII

ECONOMICS AND SOCIAL SCIENCES

1. TRAINING THE ENGINEER

The engineer is faced with increasingly complex problems as a result of scientific and technical progress. His basic training must therefore enable him to tackle these problems. One of the most important of them is certainly to learn how to get teams of workers doing vastly different jobs to cooperate so as to achieve a common end as smoothly and effectively as possible.

A very common misconception is that training is synonymous with the accumulation of knowledge. However necessary learning may be, knowing how to use the knowledge acquired is even more indispensable. The engineering student must learn to formulate his problems clearly and precisely, then analyse them, identify the factors involved and their relationship to each other and determine their parameters, define his objectives and, last of all, find a way to attain them. The same approach is used, whether the problem is technical, economic or social.

The engineering student must also learn how to find reference material and to collect the information he needs to solve the problem. This is where he must experiment and learn to "observe". Schools in the Latin countries neglect observation and inductive reasoning because of the long tradition of a deductive approach to the study of exact sciences.

The importance, indeed the almost mystical respect surrounding the study of mathematics in the best traditional engineering schools may cause the student to confuse what should be no more than the means for rationally linking up experimental and observational data with the actual end to be attained. Finally, there is even a possibility that the student ends up by believing that the laws of nature exist solely to demonstrate the power of mathematical and logical abstraction. Every means should be sought to develop the students' faculty for observation.

After the collecting of observational data comes the "synthesis", or, "interpreting the results" stage; the data are then classified, the importance of the various factors decided and also those which may be discarded. The engineer should learn how to assess the order of magnitude of phenomena.

Another indispensable part of the process of making use of one's knowledge is the ability to communicate with others. The different stages of the process described above are meaningless if the engineer is incapable of communicating his know-how, ideas and decisions to his superiors, subordinates or equals, i.e. to those with whom he lives and works. Communication, however, is more important than just the simple transmission of results, and facilitates rapid, clear-cut and concise decision making.

In addition to making use of one's knowledge, a third objective exists: the developing of the imagination, a basic element for invention, or at the least for innovation. Imagination enables a man to use the solution of one problem to help solve an entirely different one. It is developed by multiplying the number of analogies drawn. The acquisition of new knowledge, bringing together phenomena, ideas, principles and concepts, helps to develop the imagination. Changes in cultural, social and geographical environment are known to stimulate this faculty by inspiring comparisons and analogies. Although , of course, imagination depends on inherited characteristics, like intelligence, it can be encouraged. Creativeness and ability to innovate are essential characteristics of entrepreneurs and managers.

The last and perhaps most important aspect of training engineering students for management responsibilities is character-building. In practice, the task of a leader is to use his resources to attain a certain goal, these resources consisting mainly of the strength, energy and determination of his men. These qualities are not governed by invariable principles, rules and laws. The way in which he makes use of them, leads them to the desired goal, depends on his attitude, and this will determine his reaction to the constantly changing situations and circumstances.

The underlying principles of the teaching at the Seville School may be summarized as follows:

(a) To attain the objectives it is necessary:

- not only to impart knowledge but to teach students how to use it and to employ the appropriate intellectual and working methods;
- to develop the ability to communicate, to train, to strengthen personality, to develop independence and availability;
- to build character, develop a sense of responsibility, and the ability to make decisions;

(b) to achieve the most effective use of resources steps must be taken to:

- combine subject matter by abolishing the present division breaking up of subjects into far too many specializations.
- considerably reduce formal lecture time and encourage students to take an active part in classwork by work in small groups;
- see that the syllabus is properly organized and that units of instruction are carefully prepared;
- abolish examinations more or less completely, on condition that the staff agree to take the majority of the students (90 - 95%) through to the final diploma, and are able to report on their work objectively at any moment.

These principles apply to all subjects taught at the Seville School, whether technical or socio-economic (the latter term is used to designate those human sciences which are particularly concerned with production).

It should also be made clear that these principles, although seemingly peculiar to economics and the social sciences, should also be applied to the teaching of technical subjects. Here too, professors and assistants should give examples of actual applications or case studies during lectures and practical work, so that students are able to link up the objectives using with the methods described above.

2. THE TEACHING OF ECONOMICS AND SOCIAL SCIENCES

The scientific and technical subjects covering the transformation of raw materials and natural energy into goods and services should be combined, at the Seville School, with economics and the social sciences, so as to complete and orient the students' technical training.

The main points with which engineering students must be familiar are:

- the production of raw materials;
- processes for transforming raw materials into products;
- production and utilization of the various forms of natural energy;
- communication of information;
- the best techniques for an optimum use of human resources.

The last two points bring us more specifically to economics and social sciences, and should take into account the fact that:

- the transforming of raw materials and natural energy into goods and services for society relies on human energy or manpower, which must be organized, co-ordinated and channelled towards a fixed goal;
- production is never an isolated activity; the goods produced must also be distributed. The various elements employed - men, raw materials, energy, financial resources - must be brought together and any outside economic, social or political factors influencing production must be known.

To meet these requirements, right from the beginning the student should be given a comprehensive and exact picture of the role played by engineers in modern society to help him decide which are the most suitable sectors for his particular talents, and what his choice involves for him.

Students must also get to know the main features of the firms in which they will take part, and learn to realize that whether a private firm or a public enterprise is concerned, whether it be large or small, or whether it produces goods or services, it is an integral part of the national economy. Some background information on the mechanism of economic growth and its repercussions on the development of each individual firm will therefore be useful. The description of the firm should stress not only the technical or production aspect and the related organisational problems, but also the administrative and commercial problems involved in distributing the goods and services produced. The necessity of coping with organizational problems is brought out by the co-ordination required between production, sales and administrative problems, and those of finance. Students should be informed of the existence of a specific branch of sociology, known as business management, which helps put the science of management on a rational basis. The principles of sociology and psychology, which are the basis for human contacts in industrial firms, should be taught as an approach to the study of business organization. Students should also have a knowledge of certain statistical, accountancy, tax, legal and trade union problems which intervene in the purely technical activities of a firm and considerably affect the directors' actions.

As a result of this information, plus that acquired while the student is on his training-in-industry period, it will finally be possible to hold a course on business management, and so allow those students who so wish, to choose an economic or social subject for their theses.

All socio-economic courses and the training in a firm should be arranged so that they form a whole and are centralized under the responsibility of a special Department; the Head of this Department will be responsible for the syllabus and for co-ordinating objectives, methods and teaching resources with those of other departments. The experts have already agreed to the general lines of certain principles and objectives; the following methods and elements will be used:

- method for organizing education to be the "unit of instruction";
- method for follow up of training periods in industry;
- general breakdown, for the five years of the course, of time allocated to each department and for training in a firm: timetable and syllabus.

The suggested timetables should not to be taken as final, however, and, in the light of experience and local or other requirements, the School may make any necessary changes, provided the basic principles are retained.

A. Units of Instruction

For the teaching of Economics and Social Sciences the professor's talk should be followed by work in groups, i.e. practical work, essays and group studies.

- the practical work will deal with specific applications of general concepts; in Economics and Social Sciences it might consist of: time studies, making charts of a given operation or phase of a job, fixing costs, budget analysis, case studies, etc.; all the students take part in this work;
- papers, on the other hand, are to be given by individual students, or, in exceptional cases, by assistants, on the "unit of instruction" subject for the day; the student prepares his paper with the aid of books, articles, papers or journals recommended by the assistant; the talk, which lasts 10 to 15 minutes is followed by a general discussion with either the assistant or the student giving the paper as leader.
- for group study a set topic is introduced by the assistant, who then asks questions to which the students, working in teams of four or five, must give suitable answers; these are then discussed by the entire group.

A whole series of schemes may be conceived along the same lines; a particularly effective system for the last year or so might be for the assistant to divide each "study group" into subgroups to undertake more complex topics necessitating diversified but integrated work requiring elaboration and research; this will have to be worked out beforehand by the assistants in charge of each group and will require a division of labour, a comparison, and a final collective synthesis achieved at a session attended by all the different groups.

In university institutes, usually the only occasion on which students can exchange ideas with their teachers is at examinations. At the Seville School, however, frequent contact will be maintained between professors, assistants and students allowing the teachers to get to know the qualities, aptitudes and character of the students. An analytical judgment can then be made, step by step and based on a much better foundation than that provided by an oral, not only about the amount of knowledge acquired by the student, but also his level of intelligence and ability to use it, his willpower and perseverence, the scope and depth of his cultural interests. Final examinations thus become superfluous, as students are continuously tested from the first to the last day of the course. Consequently, the psychologically erroneous idea students have that passing an examination is equivalent to assimilating the subject matter concerned, should be abolished. In any case, examinations will still have to be taken by those students whose work leaves some doubt in the minds of the teaching staff.

Comprehensive training should encourage the student to communicate, to acquire method in his study and work, to be able to put theory into practice. For this, the "unit of instruction" and particularly group study, should be used as a means to check:

- during the first and second years, the student's aptitude for expression and communication;
- during the third year, the best approach for a research project;
- during the fourth year, the ability to assume supervisory and management functions.
- during the first and second years, when doing practical work or papers on set subjects, the assistants must make sure that students learn to explain clearly and logically, whether in written or oral form, the subject matter of the professor's talk or of the suggested reading material and to make a résumé of the subjects discussed. The students must also learn to link up different arguments and to analyse rationally and systematically the subject under discussion. At the same time, assistants should use these occasions to improve the oral exchange of information and ideas; they should thus ensure that students speak correctly, that their gestures and attitude are correct, and that they choose the right words, so as to enhance the value of what they have to say;
- from the third year on, in addition to this basic orientation, the student should be taught research methodology. Research, carried out in groups of two to four students, should be on a subject in the field under study, and might concern some aspect of the economic, social or cultural life of the region; such research should, as mentioned above, help students to acquire a specific working method (definition of parameters, library research, possible field study, synthesis, etc.);
- as from the fourth year, students should learn to organize, take part in, an lead work meetings similar to those which take place in factories or firms; they must make arrangements for these meetings, chair them, get the opinion of all those present, work out decisions, etc. and even have recourse to "business game" and "role playing" techniques, etc.

B. Training periods

The training periods spent by the student in firms during his course at the Seville School are an integral part of his education; they are not optional or left to his choice, or do they, if he so desires, take place during the summer holidays. On the contrary, each period will be decided on and organized well in advance. This means that teachers from the School will make preliminary visits to the firms concerned, whose top and middle management must be fully informed of the objectives sought, and so that they can help organize the training period effectively; very precise agreements can thus be made between those responsible in the School and in the firms accepting the trainees. The professors and assistants will visit the trainees during their stay in the firm to see that everything is running smoothly or to take any remedial steps that may be necessary.

The trainee will thus become part of the firm, with a definite task for which he is responsible which, even though small and subordinate, will ensure his taking an active part instead of passively watching other people work.

The most important factor to be considered in arranging these training periods is the range of opportunities offered the trainee to have contact with men from all walks of life, to live among them, to understand their needs and difficulties, both in and outside the firm. During his training as a worker, for example, it would be preferable for the trainee to leave home for a while, board with a working-class family so as to break away from his social environment and avoid trying to be with his classmates; all this would help him to fit into the new environment. This is why responsibility for planning training periods should preferably be with the Department of Economics and Social Sciences, in close collaboration with the Departments responsible for the technical side.

This training, unlike apprenticeship, is not intended to provide manual dexterity through executing specific operations; but rather to accustom the trainee to the environment in which he is to work, and give him some experience, even if brief and by way of example, of some of the functions he may have to assume in the course of his career.

The "units of instruction", and particularly the work done in groups, will serve to prepare the student for his training in industry, to ensure that the training does not appear to be independent of the school course. On his return to the School, his period of training will be analysed and discussed during the work in groups. The "units of instruction", the preparation for, and the final discussions on the training period, together make a comprehensive whole which the Department responsible - that of Economics and Social Sciences, in this case - must make as coherent and as uniform as possible.

We shall now examine each of these three training periods and attempt to define their specific functions and requirements.

(i) Training as a worker

The first period, scheduled to take in the second year, is as an operative. The trainee will live and work for seven weeks in a working-class environment, and be subject to the same hours and discipline as the workers.

Main objectives:

- character building through his effort to fit in, to understand and to observe under conditions which are completely foreign to him;
- to help the student get to know the workers' problems, their attitudes and their way of thinking and looking at life, both on and off the job.

During his period in the firm the trainee will be required to write a report on a subject of his choice, giving his impressions of the environment in which he finds himself.

Three days before starting in the firm, the students will attend preparatory group sessions at school covering: a definition of their proposed objectives, preparation for the social problems they will have to face, practical information, etc...

At the end of the training period, the students will meet for three days under the guidance of the Department of Economics and Social Sciences to exchange, analyse and comment on their experiences, so as to be able to recognize to come to decide any change of opinion, new conceptions or attitudes resulting from industrial training.

This training, which is scheduled for the second year, follows the course on the "Organization of work in the factory", covering the organization of production, including practical work on time and motion studies. Every effort should be made for each trainee to have actual experience, during his training period, of time study, incentives and piece-work. The time actually spent in the firm amounts to only seven weeks (the same holds true for all the other stages).

(ii) Training as foreman

The third year ends with a training period designed to give students practical experience of the general ideas and concepts taught during the second and third years. This training period will benefit from the experience acquired during the preceding one as a worker; the standpoint from which the student will consider production problems is no longer that of the worker; he will see them in a different setting, learn of different attitudes and conceptions. Time and motion studies, work cycles and work simplification, analysis of the work place and functions, will be studied from the point of view of the lower management staff responsible for putting them into practice. This will give the trainee an opportunity to observe how a small production unit works within a larger organization and, thus, to realize the functions, resources and attitudes of the man in charge of a section. The trainee must work in close contact with this officer, assuming some of his tasks and responsibility, and acting as what is called an "assistant to", in English and American usage, i.e. as an aide with full responsibility for certain specific, though limited tasks. The trainee is required to write a report which, when making his observations, should help him to gather and arrange data on the organization of the section, department, work-site, etc. to which he has been sent; the trainee will be expected to make a critical examination of the organizational structure, the communication channels, the influence and authority of the manager, and of his quality as a leader, and of the criteria for selecting and training the manager himself.

A three-day meeting of the trainees and the Department lecturers and assistants will take place immediately after the training period. In the discussion of their experiences, more general problems and ideas will be discovered and should be analysed and fitted into a broader frame.

(iii) Training period as engineer

The final training period takes place at the beginning of the fifth year, and the student will be able to examine on the spot, in a firm, either a purely technical problem or one concerning the economics or organization of the firm, as mentioned in the foregoing chapters. The student should prepare a paper dealing with a concrete problem suggested by the management of the firm in agreement with the staff member in charge of outside training, i.e. from the Department of Economics and Social Sciences or the appropriate specialized technical Departments.

Students preparing their theses on questions of organization should collect as much literature as possible while in the firm and subsequently combine it with other bibliographical material to build up their thesis. Here again, the student must define the problem clearly, determine its limits and find a suitable working method; this will enable him to link up theory with practical application, and give him practice in coping with industrial problems. In this way, the transition from school to industry is prepared gradually, with the fewest possible jolts or unforeseen complications.

On returning to the school, a three-day seminar is held on problems in personnel administration and the functioning of the firm. Lectures on such subjects as staff training, selection criteria, business programming, etc., followed by debates, will be held with the participation of management, heads of personnel, union leaders and economists.

3. CURRICULA AND SYLLABUSES

The curricula for Economics and Social Sciences show the number of lessons in these subjects over the five-year period and for each year. The general syllabus showing the subjects for which each department is responsible must be respected; the daily timetable can be based on that for the scientific and technical subjects (see below). The syllabus, (with dates) for the socio-economic sciences should be given, but without repeating such parts as are common to other Departments.

The curriculum for each of the Economics and Social Sciences courses is given. These are not intended to be followed to the letter; the possible contents of a course are given as an example of what the syllabus might cover. Wherever possible books have been indicated as a guide to each course, but teachers are given considerable latitude within purposely vague limits to allow for the differences in the type of training and cultural background of the various lecturers. Once the Head of Department has been named, it would be advisable for more precise curricula and syllabuses to be set up with him, and possibly even for the contants of this report to be re-examined. After that he will be able to staff his Department. The newly appointed teachers will in turn meet with the experts to draugh a more carefully thought out and detailed timetable. A subsequent survey might be held however, which might also prove useful in helping teachers prepare their classwork, by the teaching staff in outside universities and firms before classes begin; this would allow further adjustments or possible modifications.

Improvements can thus be made progressively, and in any case should continue into the future.

<u>Daily timetable</u>

- Unit of instruction

8:00 - 8:30 a.m.	lecture
8:40 - 10:00	group work
10:00 - 10:20	break
10:20 - 12:30	supervised practical work in groups

- Private study and work in groups or sub-groups

14:30 - 16:00	writing up notes on work done during the morning
16:00 - 17:30	preparation of following day's lesson
18:00 - 19:00	foreign language

An explanation of the curricula for the Department of Economics and Social Sciences now seems opportune.

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	COURSE
1st year	The function and role of the engineer in modern society.
	The industrial firm in a modern economy
2nd year	Organization of work in the plant
3rd year	Basic activities of the firm
	Industrial psychology
4th year	Statistics in industrial research and production control.
	Economics, finance and auditing in business administration.
5th year	Sociology of Organization.

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A. A modern productive economy

Students enrolling in the Seville School should get to know as soon as possible the implications of their choice and the fields of action open to them. It would no doubt be preferable for this orientation to take place before students decide whether they will enter an engineering school or a science faculty; such a course might be envisaged between the end of secondary school and enrolment in an establishment of higher education, but this would require a thorough revision of education policy.

The first course is divided into two parts:

- the function of the engineer will first be examined, his relations with the firm in which he is employed, and the environment in which the firm itself develops. The fundamental role played by the engineer in the firm's development on both technical and organizational sides will be brought out.
- a brief description will then be given of the firm: one of the basic units of modern economy in which most of the students will take their place after leaving the School or with which they will certainly come into contact.

The talks on these two parts should be illustrated by films showing either a wide range of technical applications or the working environment, i.e. the firm, in which the students will one day work. The problems encountered by engineers, management and administrators in their daily work should also be shown. A rapid survey of the engineering profession should clearly emphasize the engineer's contacts with the outside world, and show the importance of economic, social and organizational problems to him.

Group work should dispel any doubts or preoccupations students may have concerning the engineer's functions. As these functions are extensive and have historical, economic, social and even philosophical implications, and can be linked to questions which have, or should have been dealt with in secondary school, advantage should be taken of these working groups to improve the students' facility of expression and communication.

These group exercises are particularly suitable for the use of examples clearly illustrating the nature of the engineer's relations with the outside world, and giving students a preliminary idea of the meaning of the terms "economy" and "organization" in actual practice. This introduction is necessary if students are later to understand the general theoretical and more abstract aspects of the subjects concerned.

The first part of course concerns the relationship of the engineer to society and second his relationship to the firm. The importance and nature of the relationships between technical, commercial, administrative, financial and production problems will be explained. The capital importance of the human factor will be emphasized as will and the problems due to the utilization of men in firms.

Students taking science and technology may sometimes get the impression that technology is more important than the other functions of an engineer and should be given priority. They should therefore be made to appreciate the relationships and reciprocal influence existing between scientific research, design and sales, between technology and production, and between financial and administrative problems, and to place these factors in their proper perspective as part of unified view of the firm.

Considerable use should be made of the "case-study" method, the only one showing how relative are the solutions to problems in the firm, and how importance it is that the students assume their responsibilities, know how to delegate them, and take rapid decisions.

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The course should be elementary and provide a wide range of examples covering all technical specializations. It will be fairly short, and should encourage students to ask questions: it will be used as a basis for the syllabus to be taught later.

SYLLABUS

Part 1 - FUNCTION AND ROLE OF THE ENGINEER IN MODERN SOCIETY

(i) The role of the engineer in society's effort to survive and develop in natural surroundings

- Environmental acclimatization. Improvement of man's means of existence in the midst of hostile nature; from the discovery of fire to air conditioning, from cave dwelling to modern homes.

- Food. More extensive and productive farming through mechanical, chemical and biological techniques. Development of methods for storing and distributing food resources.

- Water supply, irrigation, conditions of hygiene, etc. Methods for collecting and storing water; purifying and distribution. Effluents and effluent treatment. Preventing and eliminating diseases causing epidemics.

- Miscellaneous problems: weather control, fire prevention, protection against earthquakes, pollution of environment due to increasing population, etc.

(ii) The engineering profession: definition and boundaries, the engineer and technology, the engineer and science.

N.B. Emphasize the importance of creative imagination in the transition from scientific discovery to technological development.

(iii) The use of machines.

- Simple machines (lever, wedge, wheel, winch). Their effects on the conditions of existence and on the development of society (instruments and armament). The principle of the amplification of muscular effort.

- Motive power (steam and internal combustible engin[illegible] ic motors). Sources of natural energy their use (fossil fuels, solar [illegible] rgy). Modification and adaptation of nature (building of canals, dams and ports, refrigeration, air conditioning of dwellings). Mass production, means of locomotion, transport, distribution of goods. The first industrial revolution: rationalized expenditure of human muscular effort.

- Control and guidance systems (automatic pilots, photo-cell, radar installations). Computers. Amplification of signals, feed-back. Automation (use of computers to receive, transmit and manipulate data). Cybernetics. Second industrial revolution: rationalized use of human intellectual effort.

(iv) Role of the engineer in changing natural environment. The organization of human society. Specialization and technology. The new order created by technology. Modification of the environment and/or changing its state of disorder (reafforestation and deafforestation, crop raising, the use of insecticides, recovery of radioactive wastes), purification and pollution of the atmosphere.

(v) The engineer as a creator of order in human society. Town planning, motorways, airports, traffic control. Aid to developing countries. Information media and mass leisure activities. Industrial design. Diversification and/or standardization of patterns of living.

(vi) The engineer and the future of technology. The role of the engineer in decision making. Development of nuclear weapons, satellites travel in outer space and general problems: automation, work and leisure activities.

(vii) Study of the situation in Spain. Nature and development of the role played by the engineer.

BIBLIOGRAPHY

L. Urwick : Management's debt to the engineer
F.W. Taylor: Scientific Management
C. Barnard : The functions of the executive
C. Hegel : Appraising executive performance

Part 2 - THE INDUSTRIAL FIRM IN A MODERN ECONOMY

(i) The Firm: what is the firm? Its objectives and relationship to society. Public and private enterprises. Basic characteristics of capitalist society; competition and its effects. Other economic systems.

(ii) Economic factors. Technological progress and its effects; investments. Prices and profits. The social environment in which the firm operates. Capital and its origins. Banks and saving.

(iii) The mutual dependency of firms; the basic enterprises. Trends in industrial development; organization and speciali tion; mass production. Services. General background of the Spanish economy and development.

(iv) The labour force. Its classification. Vocational training: specialization, acquisition of new skills; problems of mobility. Vocational schools. Employment and underemployment. Productivity. Effects of competition on the employment situation and the mobility of workers. Labour legislation. Unions. Employment contracts; accident prevention.

(v) Scientific research and technological progress as factors of economic development. Government interventions and stimuli. Influence on the development of firms.

(vi) The market. Market research and forecasting. Various ways of distributing goods and services. Selling prices. The money and financial markets.

(vii) The management of the firm and organization problems. Historical development of the organization of the firm.

BIBLIOGRAPHY

Lyman A. Keith - Carlo Gubellini: Introduction to business enterprise.
Brown: The social psychology of industry.
Villers: The dynamics of industrial management.

B. Organization of the work in the plant

Preparation should be started as early as possible for the in-firm training as manual worker to take place in the month of January. This preparatory course is therefore intended to help future engineers to realize the problems raised by the setting up of practical processes and the use of tools for indus' ial production. From the very outset of their careers, young engineers are required to study designs, drawings, equipment and production cycles; they must cope with problems of check control, of the choice of machine tools, of the layout of work benches. Engineering schools do not regard these questions as beign very important, and if they do consider them, it is only theoretically and not very deeply, with the result that young graduates are a loss when faced by their first contact with industry and require several months, if not years, to adapt themselves. The experts want students at the Seville School to acquire more than just a passing acquaintance with the basic aspects of production. The syllabus was therefore set up to give students an idea of the meaning of these terms, before they meet them during their training as manual workers. They will then be ready to tackle the course on "Organization of the work in the plant", for which they should already have felt the need.

The course should make students familiar with such matters as:

- establishment of work cycles and charts;
- time study and stop-watch techniques;
- methods for increasing workers' output;
- estimating the production cost of a part.

In this connection, it is recommended that during their group work under supervision, students be given a number of problems of the same type as those they will meet in their in-firm training. There is no question of making them into experts or skilled operators in the use of these techniques, but to see that they are not completely lost and that they themselves are capable of suggesting the introduction of such techniques in firms which are still at an early stage.

This course is particularly important since it is the basis for the work most engineers will be doing throughout their career.

SYLLABUS

(i) Projects. How production projects get started. Inventions, discoveries, pure and applied scientific research. Prototypes. How market requirements are made known. Patents, licences, knowhow. Industrial projects. Simplification of design and transfer to an industrial scale. Problems of standardization. National and international rules. Drawings. Draughting tolerances.

(ii) Production planning and control. Working methods. Time studies. Use of work cycles and charts. Studies of specific tools, gauges, machinery and installations. Tool manufacture. Plant and its standardization. Stores. Ancillary departments. Stocking. Production planning. Issue of production orders. Progression and orders. Gantt charts. PERT. Machine loading and work stations. Erection and assembly. Packaging. Dispatching.

(iii) How to procure the means of production. Raw materials and semi-finished products. Consumption goods. Inspection of materials on arrival at plant. Waste recovery. Purchasing policies. Purchasing of installations, machines, tools and gauges.

(iv) Time recording and stop-watch techniques. Time studies; various MTM recording techniques - Work factor, etc. Motion studies. Workplace layout. Job analysis.

(v) Wages: piecework; job rates. Incentive schemes. Job evaluation. Assembly-line wages. Collective production bonuses for indirect labour.

(vi) Inspection and testing. Quality control. Elements of statistical quality control. Gauges and inspection equipment. Inspection costs.

(vii) Cost fixing. Cost of material, labour and energy. Waste, overheads, depreciation and amortization. Standard costs. Cost accounting. Tool and measuring instrument costs.

(viii) The factory. Design. Lay-out. Services. Specific services and ancillary technical facilities. Criteria for position of equipment. Criteria for the renewal of machinery and equipment. Production flowline. Maintenance. Preventive maintenance.

(ix) Elements of the organizational structure of the factory. Organigrams; line and staff management. Line and staff relationships.

BIBLIOGRAPHY

Maynard	: Industrial engineering handbook
Taylor	: Scientific management
Barnes	: Motion and time study
Maynard	: Methods Time-measurement
Scheele, Westermann and Wimmert	: Principles and design of production control system
G. Farauds	: Criteria economica del progetto meccanico
P. Saraceno	: La produzione industriale
Abruzzi	: La misura del lavoro humano
Cyert and March	: A behavioural theory of the firm
Holt, Modigliani, Muth and Simon	: Planning Production, inventories [illegible]

C. Basic activities of the firm

At the beginning of the third year, students will add to their knowledge of the firm by studying its basic activities, i.e.:

(a) distribution of goods and market research;

(b) the organization of production, previously described from the standpoint of its relationship to other functions;

(c) auditing, administrative and financial activities;

(d) study of resources, stock control, personnel administration and recruitment;

(e) programming;

(f) policy of the firm.

It is assumed that students were not taught anything about accountancy while in secondary school, so that, without overemphasizing the strictly "book-keeping" aspect, this should be made good by an explanation of business accounting, production cost estimates, the breakdown of their various components; next, general accounting and the drawing up of the budget will be dealt with; the latter, however, will be taken up in greater detail in the fourth year subject "Economics, Finance and Auditing".

In view of the importance the Seville School must attribute to the small and medium-sized firms which will provide an outlet for the majority of its graduates, teachers should constantly refer to the problems such firms have to deal with and take care to adapt the practical work in consequence.

SYLLABUS

(i) Distribution. Various schemes of distribution. Market research and motivation studies. Market research techniques. Sales organization. Sales staff. Expansion of sales, advertising. Relationship to design projects and production. Distribution costs. Supervision of sales. Transport, warehousing, dispatch, deliveries. Pricing.

(ii) Purchasing. Purchasing policy. Organization and control of stocks. Purchasing programmes and stock control. Purchasing tech[illegible]ques a[illegible] stu[illegible]s"

(iii) Human re[illegible] .. Human relations. Personnel policy. Hiring, selection. Methods of selection. Incorporating staff into the firm. Courses, training, supervision, further training, information and advancement. Redundancy evaluation of merit, salaries, aid to personnel and related problems. Labour [illegible], social charges. Labour relations.

(iv) Labour legislation.

(v) Financial activities. Investment. The firm's capital. Banks and av[illegible]ng. Working capital. Banks and credit. Schemes of financing. Business administ[illegible]ion. Costs, budgets and balance sheets. Administrative control.

(vi) Programming and control of the firm. Specialization and diversif[illegible]ion of production.

BIBLIOGRAPHY

[illegible]. Pieraccioni : Corso per analisti di mercato
[illegible]. Ippolito : I costi di produzione e di distrib[illegible]zione
Pfiffner and Sherwood : Administrative Organization
Holt, Modiglia[illegible], Muth and Simon: Planning Production, Inventories and Work Force.

D. Industrial psychology

This subject is the basis for a study of human relations; both inside the firm among colleagues, as a basic element of organization; and outside, wherever the firm's activities and development are concerned.

SYLLABUS

(i) Technological progress and human relations. Role of the human factor in industrial management. Job security. The human factor as a problem in business administration.

(ii) Education and the reasons behind it. The nature of human needs. Frustration, the mutual dependency and conflict between the different needs. Priority and development of needs. Organization of environment and modification of individual attitudes.

(iii) Leadership, supervision and giving orders. Relationship of superiors to subordinates. The work of subordinates. Management techniques.

(iv) Communications and information. Communications systems, techniques and flows. Communication and organization of the environment. Communication and motivations. The influence of information flows on individual and collective attitudes.

(v) Education, instruction and practice. The superior as an educator. Training in industry. On-the-job practice and training. Role of experts acting as instructors. Selection and training. Training techniques.

(vi) Productivity and incentives. Salaries related to productivity. Incentive bonuses and profit - sharing plans. Productivity and workers' morale. Professional and personal satisfaction.

(vii) The psychological attitude of the individual towards work. Factors modifying the psychological attitude of other people. Resistance to change. Roles in human relations.

(viii) Psychological problems related to the size, structure and role of an industrial organization.

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C.S. Myers : "Industrial Psychology"
J.A.C. Brown: "The Social Psychology of Industry"
M. Haire : "Psychology in Management"
H.E. Burst : "Applied Psychology"
" " : "Psychology and industrial efficiency"

E. Statistics in industrial research and production control

Statistics is a complicated subject covering a vast field. The engineer should be familiar with certain of its uses, without needing too deep a theoretical knowledge; he should be in constant contact with actual cases. As a general rule, the firm's activities (production, purchasing, sales, inspection, stocking, transport, financing) are not continuous, but composed of isolated, discrete elements. To be able to keep track of all these activities, a knowledge of the basic principles of statistical method is necessary, at least enough to be able to understand its use and how it applies to engineering problems; the engineer would then himself be able to "state the problems", put the right questions to the experts and interpret the results.

Widespread use should be made of the inductive method of teaching; a large number of examples drawn from current practice in the firm should be used to show students how more general rules and principles are formulated.

The constant use of statistical data and information in every phase of the activity of modern firms gives the teacher an opportunity to show students the many interesting aspects of the structure of firms and how they operate, based on examples taken from the various sectors (technical, production, commercial, administrative, testing and research).

SYLLABUS

(i) Use of statistics in industry, limitations. Statistics, science and practical activities. Observations and measurements. Cases of statistical applications in industry: examples.

(ii) Analytical recording of data. Series of observations. Terminology and symbols. Review of probability theory. Natural tolerances and draughting tolerances. Confidence intervals.

(iii) Comparison of two or more series of observations.

(iv) Relationship between two series of observations; calculation of correlation and linear regression.

(v) Statistical quality control (characteristics expressed as variables). Control slips.

(vi) Sampling and statistical testing by characteristics.

(vii) Interpretation of series of observations expressed as essential characteristics. Binomial distribution. Poisson distribution. Comparison of frequencies.

(viii) Statistical quality control essential characteristics. Control slips. Methods of testing on the basis of essential characteristics. Spanish regulations.

(ix) Quick methods of statistical observation.

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A. Palazzi : Metodi Statistici

P. Gennaro : Introduzione alla statistica

Boldrini : Statistica

F. <u>Economics, finance and auditing in business administration</u>

This subject deals in greater depth with a number of points referred to in the second and fourth courses. Emphasis is once again placed on the need for, and importance of, teaching future entrepreneurs and managers of small or medium-sized firms how to cope with basic management problems; the solution to these problems is also a determining factor in the policy adopted, i.e. the degree of expansion of production, sales, the size of the firm, etc. In studying administrative techniques, a detailed review will be made of the draughting and critical analysis of the budget, and the budgetary forecast method will be dealt with as a tool of business administration.

SYLLABUS

(i) Economics of industrial production. Risks in the firm. Relationship between market demand and industrial production. Framework in which the firm acts.

(ii) Ownership, control and management of the firm. Public enterprises, their role and objectives. Industrial and financial groups. Problems of administration and top management, in major public and private enterprises.

(iii) Financing of the firm. Relationship between the economic aim and the financing of the firm. Fixed capital and working capital. Tied-up capital and investment. Self-financing. Bank credit; medium long- and short-term credit. Special financing schemes: sales on the instalment plan. Assisted exports. Share issues. Optimum finance structure.

(iv) Criteria for the economic usefulness of industrial investment. Demand analysis. Structure of the market. Fixing the optimum size of the firm. Renewal of plant. Expansion of firm.

(v) The industrial firm. Installations. Sectionalization of the firm. Siting installations, selection criteria. Value and depreciation of plant.

(vi) Budgetary control. Basic principles of budgetary control. Different stages. The break-even point. Attaining objectives. From budgetary control to variable budgets. Application of budgetary control. Identification of differences and corrective measures. Budgetary control and organizational responsibility.

BIBLIOGRAPHY

H. Hoggland	: Corporation finance
J. Clark	: Social control of business
E. Spingler	: Introduction to business
E. Donaldson	: Business organization and Procedure
W. Mitchall	: Organization and Management of Production
Freck T'Jeffries	: Business' ideals, principles and policies
Berle and Means	: The modern corporation and private property
P. Saraceno	: La produzione industriale
Emerson	: Twelve principles of efficiency
W. Rauttestrauch and R. Viller	: The Economics of industrial management
" " " " "	: Budgetary control

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G. Sociology of organisation

This course will be based partly on the ideas presented in earlier courses and discussed following the periods of training in a firm, and partly on the theoretical examination of the general rules and principles carried out in the courses on "Industrial Psychology", "Statistics" and "Economics, Finance and Auditing". The subjects already examined are revised here, elaborated on and studied more thoroughly to produce a systematic and theoretical coverage. Again theory and practice are used alternatively, with emphasis on the inductive rather than the deductive approach. A general statement of principles is thus achieved by first providing a description which is then compared with factual experience in in-firm training.

The course makes no claim to transform the student immediately into a fully fledged industrial executive. When he eventually finds himself in a position of authority, however, he will have the benefit of understanding certain requirements, of being familiar with a specific category of problems, and of knowing how to tackle them. This is particularly important for the sons of those who own small and medium-sized firms and who, having started out on a small scale, continue to manage the firm on the basis of their experience. Any sons or relatives coming into the firm with a sound background in methodology would give family firms a good opportunity to consolidate and expand.

This course, like some of those preceding it, may seem difficult to some students, even if it is taught at a fairly elementary level. The student, accustomed to what are known as exact scientific and technical subjects now finds he must use the same type of "philosophical" reasoning he learned at secondary school: a study of fairly abstract concepts based on empirical observation rather than experimentation, and which is also the method used in economics, sociology and psychology.

The teaching of these subjects lends itself less easily to the use of mathematical symbols and graphs, the logical guide provided by the methods used for scientific and technical subjects. The student, who often feels he has a solid grasp of certain concepts, has in fact only scratched the surface and neglected the substance for the form. An understanding of man, needed in psychology and organizational sociology, must be acquired through the maturity and experience which only age will bring and which can be substituted only in part by the various in-firm training periods, a suitable syllabus and special teaching methods. Hence his difficulty in assimilating this type of subject and particularly in creating and transforming the principles learned in books into effective tools for implementing practical and concrete projects.

SYLLABUS

This course deals with the scientific management of an industrial firm from three different points of view; these are not contradictory but, on the contrary, merge to form a whole. A separate part of the course is devoted to each.

(i) Part 1: classical theory of management.

The basic characteristic of management is to consider its members as passive instruments, i.e., as factors of production to be used by the firm to attain its objectives. This concept should be developed along two lines:

(a) consider the elementary physical activities of the production process, according to Taylor's theory;

(b) put the emphasis on macroscopic management questions such as the division of labour, responsibility, authority and its delegation, the amount of control, etc. using the approach defined by Fayol and Urwick.

In connection with the foregoing, the course will follow the outline given below and the ideas developed in "The Industrial Firm" and "the Role of the Engineer" will be re-examined, this time more thoroughly and in greater detail; this will now be possible as a result of the direct, if limited, experience the student has acquired concerning the firm:

- basic management functions: forecasting, programming, organization, co-ordination, giving orders, and inspection;
- staff structure and line organization;
- fundamental requirements of business administration: definition of objectives, allocation of functions (de-centralization and centralization), definition of responsibilities, delegation of authority, scope and limits of control;
- basic sectors of the firm: design and scientific research, "engineering", production and production departments, quality control, personnel administration, market research, administrative control and financial matters.

(ii) Part 2: Sociological Theory of management.

This theory considers that the members of any social group bring their own aptitudes, systems of values, personal interests and aims to the firm. When personal ambitions fail to coincide with the aims of the firm, tensions and conflicts arise; these may be partly eliminated or allayed if the attitudes, scales of value, and the aims of the members of the group are known. This approach to the study of management is a follow-up of the research done by Roethlisberger and the disciples of Elton Mayo and the experiments carried out in Western Electric's Hawthorne Plant. The following should therefore be examined:

- the firm in relation to the motivations of associates and subordinates;
- communications inside the firm;
- human relations in view of the technical structures of the modern firm.

(iii) Part 3: Study of the activities of a group organized according to behavioural characteristics, whether rational or not, of its members, with special reference to those in positions of responsibility. This method, which implies a study of the decision-making mechanism used by management, paves the way for the use of operational research as an aid to decision making and the ensuing mechanized techniques, e.g. the use of electronic computers, etc.

During the second term, the professor and assistants choose the method to be used in the "units of instruction", with two requirements in mind:

- the comments made by all the students on the report written by each one of them during his in-firm training and a comparison with the contents of the course.
- the choice of a thesis subject with the aid of the professors and assistants by students opting for a socio-economic subject.

BIBLIOGRAPHY

Taylor	: Scientific management
Fayol	: Administration industrielle et générale
Urwick	: The elements of administration. Notes on the theory of organization
Davies Roethlisberger	: Management and the worker
Simon	: Decision making

4. FOREIGN LANGUAGES

No mention has as yet been made of the teaching of foreign languages; students are required to study at least one language, English, taught by the Department of Economics and Social Sciences.

The student should be able to understand, speak and write fluently by the end of his course. It is not considered necessary to provide him with an idea of the literature or to overload the course with grammar and syntax which should have been acquired in secondary school. A simple review of the grammar during practical exercises will suffice. For this, a properly equipped laboratory, under the supervision of a specially trained instructor will be necessary. This post should be filled by a technically trained person born in the country of the language concerned rather than by a university teacher. The instructor should speak only in his native language and see that no other language is used by the students during the practical lessons. These are designed for small groups of 12 to 15 students (two hours per week, plus two hours with the machines in the laboratory). These sessions might include:

- conversation on a specific topic, e.g. an article from a foreign review, which students will have read before the instruction period; the subject will be one on which students have already formulated their ideas.
- correction of the translation of a newspaper article from Spanish into the foreign language; here, the student will try to use the exact word and observe the rules of grammar rather than try to perfect their style.

Students will thus learn to hold a conversation without using any Spanish and, during the last two years, will reach a point where they can read technical, economic or sociological texts written in the foreign language.

In school the student will spend three or four hours per for 23 weeks per year - a total of 350 to 400 or more hours - in acquiring a practical command of a foreign language; this is ample time for him to learn to understand and be understood in a foreign language.

ANNEX TO CHAPTER VII

A TYPICAL "UNIT OF INSTRUCTION" IN THE SECOND-YEAR COURSE:

"The Organization of the Work in the Plant"

8:00 a.m The lecturer begins with an "operation analysis", as a basic element in the study of a technical process, the recording and fixing of work times, the unit motions required, and, finally cost evaluation.

For the unit of instruction, however, the lecturer will limit himself to explaining the first point only (operation analysis) and will avoid dealing prematurely with its importance and relationship to the following points. The lecturer's task will be easier if students have previously read the relative manual or textbook. In this case, we refer to Prof. R.M. Barnes' book "Motion and Time Study", published by J. Wiley and Sons, New York, 1951.

The subject pf the lesson is dealt with in Chapter V, entitled "Process Analysis". To begin with, the lecturer points out that a complete production process can be studied only if its various elements have been isolated and analysed.

Starting with a brief historical outline of the subject, the lecturer first mentions Galbraith's work and his theory of symbols, and goes on to discuss the elementary criteria underlying such analyses, with a description of the stages involved in watering a garden, for example. He then analyses the process of re-coating the buffing wheels used for cleaning and polishing pieces of metal, wood, porcelain or stone by means of abrasives. While he is cn the subject, he will mention some of the principles governing the technical side of these operations.

The textbook provides a further example by showing how to analyse the process of distributing fodder to livestock on a small dairy farm. The lecturer uses this example to show how a flow chart, starting with the workers in the byre and finishing with the final food products, is made. He demonstrates how critical evaluation based on the simple analysis of such a process makes it easy to improve the working methods employed and, as a result, bring about savings.

The textbook then gives a number of charts and diagrams, slides of which the lecturer projects to illustrate his talk, giving the necessary explanations with each. Using examples drawn from a wide variety of technical operations - processing a file, baking biscuits, varnishing tin-cans, an elementary assembly operation - the lecturer demonstrates how the process chart represents a valuable aid for deciding the layout of the department or plant site in which the process is to be carried out. In discussing graphic processes, the lecturer has an opportunity to mention combinations of several simultaneous or successive - and, in any event - closely related processes, and refer to the theory of graphs. PERT* will be covered more thoroughly in the fifth year, but should be mentioned here to arouse the students' interest, and to show how a complex process can be synthesized by linking up simple elements. This in turn shows the need for a variety of different tools, including mathematical and computer methods. The lecturer may then go on to analyse a team effort and illustrate certain specific forms assumed by process charts and flow diagrams.

Thirty minutes should suffice for a fairly analytical and precise talk covering approximately 30 pages of the textbook including a number of models, charts and illustrations.

8:30 a.m. The lecturer should encourage students to put questions and ask for explanations; he should use this opportunity to show the limits within which such analyses are meaningful and valid. This also affords an opportunity for dealing with mass production and continuous or alternating processes.

8:45 Students split up into working groups.

9:00 Group work begins.

Each assistant reviews the lecturer's talk on process analyses and has the students work out charts on the blackboard for different examples or ordinary everyday activities, e.g., shaving, planning an excursion, preparation for studying a specific subject. These examples will be used to show how a fixed set of criteria apply to widely differing technical processes.

Even though the method is independent of the type of activity, the various aspects of the activity should be examined, and the fact emphasized that it is neither advisable nor possible to try to apply these methods without a thorough knowledge of the technical aspects of the problem, of the resources available, the quality standard to be attained, the result sought and the savings to be achieved. The examples which will be used and illustrated should stimulate critical analysis and an examination to suggest improvements and ways of achieving savings, while at the same time taking into account all of the factors mentioned above.

At the end of the first hour or so, there is a 15-minute break, following which the group splits up into four or five subgroups of three or four students each. Competition is encouraged by giving each subgroup the same problem - similar to those contained in the textbook - to be solved within an allotted time.

11:15 The assistant will go over the results obtained by the subgroups with the students; he will try to show how difficult it is in fact to say that one solution to a given problem is inherently better than another, in view of the need to reach a rapid conclusion after examining a situation involving a host of variables. The assistant should bring in the notion of time, of time saving and of motion saving, so as to lead up to subsequent lessons on timing, stop-watch measurement and elementary

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* Program Evaluation and Review Technique.

motion fixing; he may then begin discussing the planning and optimum layout of work places, and the use of ancillary facilities in the various types of industrial firms. The assistants should then help students to examine processes to determine the optimum result in view of the equipment employed, the transport required, the tools and specific machinery available, the type of worker entrusted with the task, and even the overall conditions of work; each of these elements, with its inherent vari ions, requires another thorough analysis of the various factors involved in the production process.

(11:45
(12:00
(12:30

The entire class meets once again in the [illegible] room, and the lecturer rapidly goes over the talk given earlier, which has [illegible] clearer and elaborated on by the work in groups. The lecturer goes on [illegible] of [illegible] importance of spreading the use made of these analytical methods in [illegible] of t contribution they should make, and of the need for them to become a b[illegible]flex [illegible]hind all a student's actions. This affords an opportunity to bring [illegible] man-machine relationship and refer to the psychological difficulties it may [illegible]nder, [illegible] discuss man's ability to adapt - as a worker or employee - to his work[illegible] or [illegible] the requirements of a selective process based on aptitudes, and thus re[illegible] to [illegible]oblems involving the human factor and the attitude of the engineer in respe[illegible] of these problems. These are problems which will be given more complete and d[illegible]iled treatment in other parts of the course offered by the Department of Econo[illegible]s and Social Sciences. This is the reason why the first of the unit of [illegible]struct[illegible]n tries to explain and to put certain problems, and the second part returns, in a sense, to the same subject, to show its significance, and the importance of its relationship both to the other subjects and to professional life.

CHAPTER VIII

SCIENTIFIC AND TECHNICAL SUBJECTS

First Year

A. Mathematics

B. Physics

C. Chemistry

D. Engineering drawing

FIRST YEAR - SUBJECT A

MATHEMATICS

The general remarks which are to be found in the next chapter apply to first year work just as forcefully as they do to that in the second and third years. Thus the courses in Algebra and Analysis in this first year must not be presented in the same abstract manner as would be appropriate for students intending to become mathematicians. Consequently, it is important that the exercise work is chosen so that the relation of mathematics and the other subjects being studied is made apparent. In particular, there is scope for this to be developed in a fruitful manner in the work in Physics and Applied Mechanics. The proportion of the time devoted to exercise work should be at least a half.

SYLLABUS

A. Algebra

1. Elementary structures of algebra. Field of real numbers. Field of complex numbers. Binomial theorem. Polynomials and rational functions.
2. Vector spaces, including normed vector spaces. Linear dependence. Vector algebra. Linear transformations. Matrices. Systems of linear equations. Eigen-values and eigen-vectors. Quadratic forms. Classification and reduction to diagonal form.
3. Cartesian and other co-ordinate systems. Geometry of line, conic, plane, quadric (by vector and matrix methods).
4. Introduction to the differential geometry of curves and surfaces.

B. Analysis

1. Functions of a single real variable: Limits. Continuity. Continuous functions. Monotonic functions. Concept of an inverse function. Differentiation, mean value and Taylor theorems, maxima, minima and variation of functions.
   Indeterminate forms.
   Elementary functions.
2. Integration. The concept of an integral as the limit of a sum. Relation between integration and differentiation. Methods of integration. Applications of integration (e.g. areas, volumes, first and second moments).
   Indefinite integrals. Tables of integrals.
3. Elementary differential equations of the first and second order.

4. Series. Elementary convergence tests. Power series, convergence range, [illegible]tegration and differentiation, Taylor series.

C. Appl[illegible]d Mechanics

(The teaching of Applied Mechanics should be co-ordinat[illegible] with the te[illegible]chi[illegible] [illegible] Analysis and it should include simple experimental work using [illegible]quipment to [illegible] pr[illegible] [illegible]ded in the Physics Laboratories).

1. Motion in a straight line; displacement, velocity and acceleration [illegible] pa[illegible]icles. Two and three dimensional motion, introduction to vector concepts. Syste[illegible] of co-ordinates, vector representation of rotational motion.
   Motion of rigid bodies, degrees of freedom, continued rotation and tran[illegible]tion, instantaneous centres.
   Relative motion, moving frames of reference.
2. Inertia of physical bodies, determination of centres of mass. Newton's laws of motion. Momentum, work, kinetic energy, power. Torque and angular motion, moment of inertia, radius of gyration.
3. Forces as vectors, force systems acting at a point. Coplanar force syste[illegible], reduction to single force or couple.
   Equilibrium of rigid bodies under the action of coplanar forces, reactio[illegible] at supports or pivots.
4. Principles of the conservation of linear and angular momentum and of energy.
   Friction, the laws of friction, energy loss.
   Impact, direct and oblique; energy dissipation.

FIRST YEAR - SUBJECT B

PHYSICS

Much of the academic work of the engineer may be described as applied physics. Therefore, it is essential that a good foundation in physics be provided for the young engineer. At the same time it must be remembered that one is concerned with training engineers, not physicists, and this must therefore be reflected in the details of the physics syllabus taught in the first year.

It is very important that the principles discussed in lectures are illustrated by practical work in the laboratory, not only to give students a better understanding of these principles, but also to indroduce them to the proper methods of carrying out the practical work, which will play such an important part in the later stages or the course.

SYLLABUS

A. General

1. System of units, application to derivation of equations by dimensional analysis.
2. Properties of materials. Elasticity, stress and strain. Yield point and Young's modulus.
3. Surface tension, angle of contact, excess pressure in a spherical bubble. Elementary treatment of viscous flow, Stokes' law.

B. Heat

Scales of temperature. Measurement of temperature. Elementary calorimetry. Units of heat, specific heat and latent heat.

C. Vibrations and Waves

1. General characteristics, amplitude, frequency, phase, wavelength, velocity. Progressive waves, longitudinal and transverse waves. Polarization of transverse waves. Doppler effect.
2. Propagation and wave characteristics of light. Velocity of light. Wave and corpuscular theories. Simple treatment of spectroscopy, emission and absorption spectra.
3. Optics. Reflection and refraction at plane and curved surfaces. Simple treatment of telescope and microscope.
4. Magnetism. Magnetic field, magnetic moment, magnetic flux. Magnetic properties of iron and steel and of special alloys.

5. Electric current, Magnetic effects of. Field at centre of a circular coil, force on conductor in a magnetic field. Conductance and resistance. Application to measuring devices.
6. Electromagnetic induction and alternating current. E.m.f. produced in a disc and a coil rotating in a magnetic field.
7. Simple treatment of alternating current. RMS values. LCR (series and parallel circuits). Cathode ray oscilloscope.

FIRST YEAR - SUBJECT C

CHEMISTRY

The study of Chemistry is an essential part of the training of the modern engineer. This is partly because of the size and importance of the chemical and process industries, but even more because a proper understanding of the behaviour of engineering materials demands a sound knowledge of chemistry. This is emphasized by the fact that the world production of polymeric materials now exceeds in tonnage the production of metals.

It is also essential to recognize that one is training engineers rather than pure scientists and hence the chemistry that is taught must be carefully selected so as to provide a basis for the understanding referred to above. The outline syllabus for first-year chemistry reflects this selection.

SYLLABUS

A. General

1. The Periodic Table. Bohr's theory of the atom.
2. Electronic structure of the atom. Types of valency and their significance. Oxidation/reduction and principles of reactions.
3. Spectra. Applications of X-rays to study of matter. The crystalline state.

B. Physical

1. Kinetic theory of Gases. Kinetic concepts of the evaporation of liquids and melting of solids. Effects of pressure and temperature.
2. Gas Laws. $PV = RT$. Van der Waal's equation of state. Compressibility and compressibility factors. Critical states.
3. Phase equilibria. Phase diagrams for binary and ternary mixtures for solid/liquid systems. Distribution of unassociated, associated and dissociated solute between immiscible solvents.
4. Metals in equilibrium with aqueous solutions of their ions. Electrochemical series and electrode potential. Comparison between electro-chemical series and Redox potential. Mobility of ions in solution in an electrical field. Faraday's Law. Reactions occuring at electrodes during electrolysis.
5. Properties of solutions related to concentration, e.g. vapou pressure, freezing point, boiling point, osmotic pressure.

6. Elementary thermochemistry including heats of reaction, formulation and neutralization.

7. Law of mass action. Reaction velocity and effects of temperature and concentration. Chemical equilibria and effects of temperature and pressure in reversible reaction. Le Chatelier's principle. Catalysis, homogeneous and heterogeneous.

C. Organic and Inorganic

1. Properties of the more common and industrially important elements and their compounds with particular reference to their place in the Periodic Table. (Hydrogen, Halogens, Oxygen, Sulphur, Nitrogen, Silicon and the Metals).

2. Classical structure theory in organic chemistry. Homologous series.

3. Organic Chemistry as the chemistry of characteristic groups. Characteristic reactions and chemical behaviour of more important groups.

4. Simple aliphatic compounds.

5. Simple aromatic compounds.

FIRST YEAR - SUBJECT D

ENGINEERING DRAWING

Education up to university entrance is focussed on an assimilation of fundamental facts and it is only natural that these tend to be presented in abstract form in order to simplify the learning process. Even at university this tendence often continues and the graduate from an Engineering school frequently undergoes a period of re-orientation when he first enters industry before he is able to think clearly in terms of engineering hardware.

The Seville course deliberately aims at the inculcation of a full appreciation of the fact that engineering is the process whereby abstractions are converted into real objects. The success of the three training periods of the Seville student in industry will depend on his ability to communicate in the language of engineering, which will later on convey his thoughts to all concerned in manufacture, assembly, inspection, testing and maintenance.

The first-year syllabus in "Engineering Drawing and Design" not only provides a rigorous training in the precise communication of ideas concerning objects, but also seeks to overcome the misconception that the values of quantities can be stated precisely. Furthermore, through this subject comes a realization that the design of objects which are to be produced cannot be satisfactorily undertaken without linking the problem of how the objects are to function with the problem of how they are to be made and assembled.

The basic technique of orthographic projection must still remain as the foundation of this subject, but the engineer trained today must be ready to employ any design aid or means of communication to supplement the expensive and time-consuming production of engineering drawings. The introduction of computer-controlled machine tools calls for alternative approaches to drawing and dimensioning.

Assembly exercises and the sketching of actual components, should be based on items which bring the student into contact with common items including gears, couplings, shafts, bearings including ball and roller bearings, distances pieces, location and locking devices, splines, keys and sals.

Besides dismantling assemblies to prepare sketches and schedules of parts, the students should engage in discussions on the function of each item and thereby develop a constructive approach to design right from the beginning of their engineering education.

SYLLABUS

1. Introduction

The Drawing Office function. Assembly and detail drawings.

Drawing C iids: use of models in design; use of photography, microfilm storage and reproduction of drawings, drawing office standards.

2. Projection

First and third angle orthographic projection of simple engineering components.

Isometric and pictorial projection.

Simple exercises in visualization sketches or orthographic projections drawn from isometric or pictorial dimensioned views and vice-versa.

Auxiliary projections as an aid to visualization.

3. Drawing conventions

Sectioning, dimensioning, tolerance and machining notations.

Screwed and bolted connections, other standard fastenings.

TEXT BOOKS

French T.E. and Svensen C.L., Mechanical Drawing, McGraw-Hill (supplemented by correlated text-film series).

Masonet A.*, Las tolerancias en la construcción de máquinas, Barcelona, Ariel 1955.

Schiffner R. y Tochtermann W.*, Dibujo de máquinas con iniciación en la construcción de máquinas. Trad. de M. Rodriguez. 3rd ed. 3rd reimp. Barcelona, Labor. 1961.

*Books in Spanish which have not been reviewed.

CHAPTER IX

SCIENTIFIC AND TECHNICAL SUBJECTS

Second and Third Years

I. SECOND YEAR

- A. Mathematics
- B. Science of Materials I
- C. Design for Manufacture
- D. Electricity I
- E. Thermodynamics

II. THIRD YEAR

- A. Mathematics
- B. Science of Materials II
- C. Mechanics of Machines
- D. Electricity II
- E. Fluid Mechanics and Heat Transfer

S4

SECOND YEAR - SUBJECT A

MATHEMATICS I

General remarks on the role of Mathematics in basic engineering education and its significance in the education and training of specialists

The following paragraphs consider this topic only very briefly. A more extensive consideration of the whole role and significance of mathematics in engineering education will be found in the OECD publication on this subject(1).

Mathematics is of fundamental importance in the training of engineers for the following reasons:

- It provides a training in rational thinking and justifies confidence in the value of such thinking.
- It is the principal tool for the derivation of quantitative information about natural systems.
- It is the "second language" of human discourse and parallels natural language by providing a means of communication for ideas, as evidenced by the contents of technical papers.
- It is important in facilitating the analysis of natural phenomena.
- It is important in assisting the engineer to generalize from experience.
- It trains the imagination and inquisitiveness of the student if properly taught.
- It is a training for adaption to the future.

As a consequence of these and other considerations, it is concluded that mathematical methods of wide applicability should be emphasized in the presentation of mathematics to engineers rather than methods of limited applicability.

In addition, to fulfil the above functions for engineers intending to study certain of the engineering options, further mathematical methods may be required. In this case, they will be provided within the courses, as for example, in the syllabuses for control systems.

The spirit in which mathematics should be taught to engineers

It is recommended most strongly that those teaching mathematics to engineers must be mathematicians who are sympathetic towards the needs of engineers. They should be aware of the engineering applications of the mathematics they teach and be prepared to give special

(1) Mathematical Education of Engineers. OECD 1965.

thought to how the subject may be presented in a way that the engineering students will find relevant and stimulating. While the treatment of the subject must be exact, excessive mathematical generality and abstraction should be avoided.

At the introduction of a new topic, the student should be provided with a motive for its study through a discussion of some of the applications of the subject which are likely to stimulate his comprehension as well as his interest. This should be followed by an inductive-intuitive development in which there is some discussion of examples of the physical significance of the method. Each topic should finally be established on a sound deduction basis of limited generality, but indications may be given of the possibility of further generalization or abstraction which may be introduced in later and more specialized courses.

The depth of the treatment in the presentation of mathematics to engineers is a vexed question. The student should have some appreciation of the mathematician's attitude to mathematics and must always be aware of the limits of applicability of the methods which he has presented to him.

The development of the ability to think analytically is a vital purpose in engineering courses. It is suggested that both mathematics staff and engineering staff have a responsibility to discuss the relationship between mathematical systems and physical systems with their students. This can be achieved effectively only by consultation and close co-operation between the mathematics and engineering lecturers in the detailed planning and implementation of the teaching programme.

It is considered possible that mathematics could be taught to engineers in such a way that it is not just a diluted form of pure mathematics; i.e. that it becomes a special branch of mathematics, with motivation and attitudes of its own that can be conveyed to the student.

As computation is a new subject, a few notes on its teaching are given below:

- Computer training of all undergraduate engineering students is required to anticipate future developments both in engineering applications and in the availability of computers to practising engineers.

- It is evident that the aims of teaching undergraduates computer programming will not be realized unless the computer is used by the engineering lecturers in connection with lectures, laboratory work and problems assigned for student solution. Further, there is evidence that when the computer is used in engineering courses this leads to an enrichment of these courses.

- Since this course is intended for students of the various branches of engineering, the emphasis should be on problem solving rather than on computer hardware or machine language. The best available procedure-oriented language should be taught.

- Besides being provided with training in programming, including the writing of subroutines for their own programmes, students should be shown the scope and use of library programmes.

- In order to stimulate and facilitate the introduction of the use of computers in engineering courses it is most valuable to have access to reports on work done in this field. One well documented example is the Ford Foundation supported project "The Use of Computers in Engineering Education" carried out at the College of Engineering, University of Michigan, Ann Arbor. The reports on this project indicate, in some detail, the variety of types of problems which may arise from engineering considerations and which can be discussed more economically and efficiently by using the computer.

The staff of the Mathematics department must clearly include teachers with an interest in statistics and mathematics for computation, and also specialists in the mathematical aspects of some of the engineering subjects and who could participate in the lecturing, supervision, tutorial or research work involved with these subjects.

The importance of exercises and laboratory work in the teaching of mathematics

It is recommended that a considerable proportion - not less than one third - of the time available for mathematics be utilized in exercises and laboratory work. As indicated alone, this work must be chosen so that the relation of mathematics to the other scientific and engineering subjects is made apparent to the students.

SYLLABUS

1. Differential equations

Linear equations and systems with constant coefficients.

Use of Laplace transform.

Existence and uniqueness of the solutions (Statement only).

Singular points. Isoclines.

Linear equations with variable coefficients.

Fundamental systems of solutions. Examples of special functions.

The classification of second order partial differential equations with constant coefficients. Solution by separation of variables.

Boundary value problems for linear differential equations.

Eigen-values and eigen-functions.

Orthogonality.

2. Functions

Functions of several variables. Continuity. Differentiation. Taylor's theorem. Maxima and Minima.

Fourier series. Convergence. Gibbs phenomenon.

Differentiation and integration of integrals. Multiple integrals, including the rule of change of variables. Line, surface and volume integrals.

Vector fields: gradient, divergence, and theorems of Gauss, Green and Stokes.

Functions of complex variable: differentiation, analytic functions and Cauchy-Riemann conditions.

Conformal mapping, definition and examples. Integration, Cauchy's theorem and formula. Power series in complex variable, Taylor and Laurent series. Poles and essential singularities.

Elementary functions. Examples of branch points and multi-valued functions.

Theory of residues and applications.

Calculus of variations. Extrema of an integral, in the case of fixed or variable limits. Conditional extrema of an integral. Lagrange's equations and applications to vibrational problems. Conditional extrema, Lagrange multipliers.

3. Introduction to Computers

(In addition to what was said above, one should also note that throughout that part of the course dealing with the digital computer, emphasis will be placed on its role as a general purpose device for storing, retrieving, processing and transmitting information in addition to that as an arithmetic calculator).

Functional organization of a digital computer. Hierarchy of computing languages; machine, symbolic assembly, procedure-oriented, problem-oriented.

Instructions and procedures; flow diagrams, concept of stored programme and instruction modification; iterative procedures; automatic programming languages, sufficient details of one language, such as FORTRAN IV, to enable simple examples to be programmed; numerical and non-numerical applications, data structure and list processing.

An introduction to analogue computers with demonstration of solution of differential equations describing some typical engineering problems.

BIBLIOGRAPHY AND EQUIPMENT

See Mathematics, Third Year, Subject A.

SECOND YEAR, SUBJECT B

SCIENCE OF MATERIALS

A large part of engineering consists of the manipulation of materials and it is important therefore that the engineer should have a basic understanding of all materials he is commonly going to use. At the same time he should have some appreciation of why various materials behave as they do. Modern work in inorganic chemistry and in solid state physics is leading to an even better understanding of the behaviour of materials and this subject is intended to provide a basic training for the engineer in material properties. It is also a link between the pure science subjects studied in the first year and the applied technology in later years.

SYLLABUS

1. Structure of Matter

(A qualitative treatment of modern theories of structure emphasising behaviour of substances rather than analysis).

Internal Structure of the atom. Electron, proton and neutron.

Electron energy levels and associated cloud patterns.

The periodic table of elements.

Excitation and ionization.

Molecule formation. Bonds. Rate processes.

2. Structure of Materials

(The main emphasis here is intended to be placed on the solid state and the relation between atomic or molecular structure and 'solid-state' structure. Again the treatment is qualitative rather then quantitative).

The gaseous, liquid and solid states. Changes of state.

The solid state. Classification of solids (metals, ceramics, polymers).

Strength properties.

Crystalline, amorphous and intermediate forms of order.

The crystal lattice. Unit cell, Miller indices. Experimental methods of study.

Defects in the crystal lattice. Point defects and dislocations.

Microstructure of solids. Solidification, grain formation, crystal-amorphous structures.

Phase equilibrium.

Non-equilibrium conditions. Diffusion.

3. <u>Electrical Properties of Materials</u>

(A review of the more important industrial materials from an electrical point of view).

Conductors, semi-conductors and dielectrics.

Magnetic materials.

4. <u>Thermal Properties</u>

(The relation between structure and conductivity (or non-conductivity) treated largely qualitatively or some quantitative rules may be introduced here).

Thermal conductivity of metals.

Thermal conductivity of non-metals, liquids and gases.

PRACTICAL WORK (24 classes of 3 hours each)

In the text:

L = experimental sheet available at Loughborough University of Technology.

V = Details in J.A. Vaughan; Experiments in Electricity and Magnetism (Leeds: Reynolds and Branson Ltd. 1965).

D = Details in D.E. Davies: Practical Experimental Metallurgy (London: Elsevier Publishing Co. Ltd. 1966).

<u>Structure of Materials</u>

L 1. Preparation of metallic specimens for micro-examinations, and of ceramic thin sections (demonstration).

L 2. Use of reflected-light and transmitted-light optical microscopes. Photographic techniques in metallography (demonstration).

L 3. Microstructures of pure metals.

L 4. Microstructures of carbon and alloy steels.

L 5. Microstructures of cast irons.

L 6. Microstructures of copper alloys and aluminium alloys.

L 7. Examination of ceramic thin section and comparison with bulk materials.

L 8. X-ray diffraction - powder method; indexing of diffraction pattern.

L 9. X-ray diffraction - back reflection method; measurement of strain.

<u>Phase Equilibria and Diffusion</u>

L 10. Determination of a phase equilibrium diagram (eg. Pb-Sn). Calibration of a thermocouple.

L 11. Diffusion of aluminium in steel. Surface diffusion of carbon into pure iron.

Strength ... ties

L 12. ...mination of stress-strain relationships in typical metals and alloys ...ometer).

L 13. ... ...rison of hardness scales. Determination of impact strength (Izod & Charpy).

L 14 ... of lead and of lead alloys (room temperature experiment).

Electric... ... Magnetic Properties

L 15. ... ...es in resistivity of metals as a result of cold working (bridge method).

V 16. ...ination of hysteresis loop for a ferromagnetic material.

V 17. ...mination of magnetic field intensity using a current balance.

18. ...ement of dielectric constants of selected materials (including polymers). ... of frequency.

Thermal P... ...rties

L 19. Thermal expansion of metals and alloys (dilatometry).

L 20. Thermal expansion of ceramics (BCRA method).

L 21. Differential thermal analysis of simple oxides.

L 22. Gravimetric thermal analysis of simple oxides.

General Phys...al Properties of Non-metallic Materials

L 23. Density of porous ceramic materials. Determination of specific gravity by Rees-Hugill method.

L 24. Apparent powder density, moulding density and bulk factor of plastics.

EQUIPMENT

See Science of Materials II (Third Year).

BIBLIOGRAPHY

(a) Specif...

Elements of Material Science, A.J. Dekker, Prentice-Hall.

Electrical Engineering Materials, L.H. Van Vlach, Addison-Wesley.

Physical Metallurgy for Engineers, A.G. Guy, Addison-Wesley.

(b) General and Reference

Engineering Materials Handbook, Mantell, McGraw-Hill.

Det...oration of Materials, Greathouse & Wessel, Reinhold.

... Han... ...k of Lattice Spacings and Structures, Pearson, Pergamon.

Semi-... ...ctors, Hanney, Reinhold.

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SECOND YEAR, SUBJECT C

DESIGN FOR MANUFACTURE

Many university engineering courses provide a thorough insight into the scientific and mathematical principles which are the basis of engineering science. The courses at Seville are so designed that graduates from Seville should be regarded as "doers and thinkers" rather than just "thinkers". By introducing the student at the outset of his engineering studies to the problems involved in actual manufacture, together with the modifications of design considerations which ensue, a positive attempt is made to give the student a broad perspective as he approaches the various theoretical studies. From the very beginning, the student is concerned with varying degrees of uncertainty rather than the precision of exact mathematical analysis which is unrelated to the actual engineering science. Equally important is the need to engender a strong awareness of the dependence of material properties on the sequence of processes to which they have been subjected.

This syllabus has been written in an attempt to achieve these objectives and also to widen the interest of the student during the various industrial stages.

SYLLABUS

1. The Design Process

Conceptual design, design for function, design for manufacture.

2. Fundamentals of Manufacture

Manufacture by casting, forming, generating and fabrication.

Secondary considerations of location and holding of workpiece, inspection, assembly, stripping for maintenance.

Secondary considerations of interaction of manufacturing processes on design for function-strain compatibility in relation to the creation of internal stresses and/or distortion by temperature gradients and clamping forces during manufacture.

3. Moulding and Casting

General moulding considerations, elimination of multiple mould joints and minimization of flash removal by simple redesign.

Methods of core location and core extraction in metal castings.

Particular moulding in compression or injection moulding of plastics. Influence of thermosetting or thermoplastic material, inserts.

Solidification of metal castings; gating, venting and shrinkage requirements.

Factors influencing dimensional accuracy, location and allowance for machining, residual stresses, material quality, surface hardness and stress concentration.

4. Forging

Open, stamp and press hot forging. Metal flow in closed dies, manipulation of metal flow in open forging.

5. Welding

Types of welding and distortion, use of manipulators. Reduction of edge preparation, distortion and manipulation by simple re-design.

Problems of metal degradation or welding sequence.

6. Machine finishing

Introductory treatment of problems of accuracy, cost and technical feasibility, e.g. re-chucking, blind drilling and tapping, drilling at an angle, use of form tools.

Influence of tolerances on cycle time and inspection, use of undercuts.

7. Inspection

Introduction to the principles of interchangeable manufacture. Comparison of measurement and limit gauging.

PRACTICAL WORK

During this second-year course students will become conversant with a wide range of manufacturing processes and should study both their potential attributes and their limitations. A proportion of this work can be carried out within the school facilities, the mechanical workshop, the foundry and the welding bay. The remainder will be effected through well-planned visits to local industries where besides studying individual processes, the students will have the opportunity of discussing the problems of such processes e.g. injection moulding, with the engineers responsible. Metrology plays an important part in the appreciation of this subject and some experiments will make full use of the metrology laboratory.

Equipment in the mechanical workshop which students may use will include:

Marking-off table.

8 or 10 inch centre lathe with copying and taper-turning attachment.

Universal milling machine with dividing head and gear-milling accessaries.

Small horizontal boring machine.

Shaft-grinding machine.

Spark-erosion machine.

Optical-form tool-grinding machine.

Small centreless grinder.

Capstan lathe.

A programmed machine tool for which data preparation can be completely undertaken by the students.

Metrology equipment should include:

Surface tables.

Length verniers.

Angle verniers.

Length comparators.

Slip gauges and optical flats.

Internal and external micrometers.

Talysurf.

Talyrond.

Straight edges (hardened precision) of various lengths.

Optical profile projector.

Thread measuring equipment.

Foundry equipment should include:

Sand processing plant.

Core baking oven.

Moulding boxes.

Annealing furnace.

Moulding machine.

Shell moulding equipment.

Oil fired reverbatory furnace and crucibles for small batch e.g. 75 Kg.

Welding equipment should include:

Oxy-acetylene torch welding kit.

Arc electric welding plant fitted with pilot arc.

Semi-automatic granular flux welder.

Argon-arc equipment.

Other equipment which can usefully be employed in the teaching of this syllabus:

Reichert projection microscope with micro-hardness testing attachment.

Vickers hardness testing machine.

8" Photo-elastic bench.

This syllabus is not conventional so that experiments and demonstrations will need to be developed.

e.g. Residual stress problems

The casting of small articles in glass and their subsequent examination by polarized light before and after annealing will provide a useful insight into the creation of residual stress by solidification and one method of overcoming this problem.

The significance of residual stress in engineering may then be shown by welding three or four pads on to a steel plate and then clamping the plate to the table of a milling machine and machining a flat surface across the pads. The plate is then taken to the metrology department and the face of the pads tested for straightness*.

A different group of students could repeat this experiment, the procedure being changed by annealing the plate after welding and prior to machining.

The next group of students could start with a hot-rolled plate and, using a single cut, disclose the presence of residual stress in merchant section material.

The last group of students could perhaps operate on fully machined plate annealed again; by noting the clamping points they could gain an insight into the significance of clamping stresses on manufacturing accuracy.

Other experiments might include:

Accelerated tool-life test to destruction.

Measurement of tool forces using a tool dynamometer.

Study of interference in gear milling.

Milling of mating components.

Study of crystal formation in castings.

Influence of section thickness and presence of chills on the hardness of cast metal.

BIBLIOGRAPHY

a) General

SCHALLER G.S., "Engineering Manufacturing Methods", 2nd Ed., McGraw-Hill, 1959.

SHIGLEY J.E., "Machine Design", McGraw-Hill.

b) Specific

HINMAN C.W., "Press working of Metals", McGraw-Hill, 1950.

CAMP and FRANCIS C.B. eds. "The Making, Shaping and Treating of Steel", 7th Ed. United States Steel Corporation, 1957.

COX L.L., "Advanced Patternmaking", Technical Press, 1958.

"A practical guide to the DESIGN OF GREY IRON CASTINGS for engineering purposes", The Council of Ironfoundry Associations.

DOEHLER H.H., "Die Casting", Mc Graw-Hill, 1951.

"Control of Welding Distortion", Institute of Welding, 1957.

CONWAY H.G., "Engineering Tolerances" 2nd Ed., Pitman, 1962.

* "Testing the straightness of a straight edge". Some experiments in Metrology. Bulletin Mech. Eng. Ed. No. 2, July 1952, p.7.

SECOND YEAR - SUBJECT D

ELECTRICITY I

This course is intended to provide an integrated treatment, using S.I. units, of the electrical phenomena of most value to the industrial engineer. It may be convenient to present the course as an introduction to electric circuit and network theory supported by excursions into physics to explain the various phenomena that are encountered. It is essential for the course to be supported by extensive laboratory work which might occupy half the available time. Each day's unit of instruction might comprise a short lecture followed by an hour's work on problems by students individually. At least three hours should be spent in the laboratory, preferably with students working in pairs. Sufficient staff should be available to provide adequate personal instruction to each pair of students. In exercise classes, the problems should be carefully chosen to introduce interesting and realistic applications which the student may find useful.

SYLLABUS

A. Circuits

Measurement: S.I. units (units of the système international d'unités). Measurement of current with moving-coil and moving-iron ammeters. Voltmeters. Wattmeters. Estimation of accuracy. Conduction in solids: electron drift velocity; current; law of conduction; potential difference; resistance, power, resistivity and temperature coefficient of resistance. Conduction in liquids, gases and semiconductors.

Electrical circuits as linear, lumped parameter systems. Current-voltage transient and steady state relationships in simple circuits following impulse, step, ramp and sinusodial input disturbances. Kirchhoff's laws and a study of more complex circuits by means of mesh and node equations. Electric circuits with steady currents as a special case of the general relationships. Simple network theorems, series and parallel branches, potentiometers, delta/star transformations, single-port active networks (Thevenin-Helmholtz) with equivalent voltage or current source: superposition, reciprocity, substitution, compensation and maximum power theorems.

Alternating currents: definitions of r.m.s. value, form and crest factors. Impedance and reactance.

Circuit analysis with alternating quantities of constant magnitude and frequency, as a special case of the general circuit relationships. Use of complex numbers. Power and power factor, vector diagrams. 106

Series and parallel circuits; resonance. Measurement of power. Two-port networks. Bridge networks for resistance, inductance and capacitance. Simple circuits with mutual inductance.

B. Fields

Static electric fields; law of force, the electrostatic force-constant, electric flux density and field strength, potential gradient and potential difference, capacitance, relative permittivity, stored energy.

The electric flux-integral law (Gauss). Capacitance and electric field strength with parallel plates and concentric and parallel cylinders. Insulating materials.

Static magnetic fields: law of force between currents, the electro-magnetic force-constant, magnetic flux density and magnetizing-force integral law, relative permeability. Inductance, stored energy; inductance of concentric and parallel cylinders. Self and mutual inductance of toroidal coils and solenoids; coupling and leakage co-efficients.

C. Devices

Electronic devices: diodes; half-wave and full-wave rectifiers, smoothing. Introduction to transistor and thermionic triode as switch and as simple amplifier. Electric and magnetic deflections of electron beam; cathode-ray oscilloscope.

Ferromagnetic materials; magnetic circuits; magnetic instruments: ammeters, voltmeters, galvanometers, fluxmeters.

BIBLIOGRAPHY

Fundamentos de Ingenieria Electrica y Electronica, Fitzgerald and Higginbottom, McGraw-Hill.

Introduction to Electromagnetic Fields, Seeley, McGraw-Hill.

Linear Circuits, Parts 1 and 2 (2 volumes), Scott, Addison-Wesley.

LABORATORY PROGRAMME

Introduction

This list of experiments is designed to enable students, who may suffer from a lack of previous experimental experience, to investigate some of the basic electrical relationships for themselves. At the same time it will allow them to become familiar with the use of a considerable range of instruments. In particular, students should be encouraged to use an oscilloscope wherever appropriate to examine waveforms in their test circuits.

EXPERIMENTS

1. Calibration of an indicating instrument by comparison with a standard instrument.
2. Connection of a simple d.c. potentiometer - its use to measure voltage and current.
3. 3-voltmeter method of power measurement, leading to the use of a wattmeter.

4. Conditions for maximum power output, using resistors.
5. Experimental verification of Thèvenin and superposition theorems.
6. 4-terminal resistors - measurement by bridge methods.
7. Charge and discharge of a capacitor.
8. Experimental study of voltage phasors in addition, subtraction and determination of an unknown.
9. Frequency comparison using C.R.O.
10. Power transfer in a.c. circuits.
11. Series and parallel resonance.
12. Simple a.c. potentiometer.
13. Harmonic response loci of two-terminal networks.
14. Connection of 4-Arm a.c. bridge such as De Sauty.
15. Flux measurement in magnetic circuit.
16. Investigation of Magnetic field of long solenoid.
17. Magnetic measurements - the hysteresis loop.
18. Field plotting using conducting sheet.
19. Rectifier circuits, smoothing effect of shunt capacitor, output waveforms.
20. Measurement of characteristics of triode - triode in a simple amplifier circuit.

EQUIPMENT

10 Cathode ray oscilloscopes of a relatively inexpensive type.

2 Cathode ray oscilloscopes - double beam type.

4 Valve voltmeters.

2 Commercial field-plotting units (using Teledeltos paper).

20 Universal meters (e.g., Avometers or Selectest).

4 Gaussmeters with probes.

4 Wattmeters.

2 Sub-standard ammeters.

2 Sub-standard voltmeters.

24 Indicating instruments consisting of a range of single-purpose ammeters, milliammeters, voltmeters and millivoltmeters, including shunted instruments.

12 Resistance boxes

8 Capacitance boxes

8 Inductance boxes (including two mutual).

12 Adjustable autotransformers

6 Audio-range oscillators.

24 3-terminal rheostats (variable resistance)
4 Robust centre-zero meters for use as d.c. detectors.
2 Detectors for a.c. bridges.
2 Meter slide-wires (made up by laboratory staff).
2 Long solenoids
1 Variable air-cap inductor (e.g., machine carcass)

Sundries: Selection of triode valves
A few rectifiers of different construction
Selection of transformers

Circuit elements: fixed resistors, capacitors and inductors in variety.

SECOND YEAR, SUBJECT E

THERMODYNAMICS

It is difficult to over-emphasize the importance of this subject for the modern engineer. Thermodynamics is perhaps the most important single scientific subject with which engineers must be not only familiar but in which they must be practised and competent. All engineering involves the application and transformation of energy and this subject is intended to provide the students with a sound understanding of the theoretical principles governing such energy changes.

SYLLABUS

1. Basic Concepts

(This should occupy about one fifth of the total course, so that only elementary relationships can be covered).

Conservation and transformation of energy.

Equations of state.

Ideal gas laws, kinetic theory of gases

Van der Waals equation. Compressibility factor. Theory of corresponding states.

Specific heats at constant pressure and constant volume.

2. First Law of Thermodynamics

(This should be roughly the same length as the preceding section and will therefore be confined largely to statements of laws. Elaborate proofs are neither necessary nor desirable at this stage).

Equivalent statements of the first law.

Non-flow and steady flow processes. The general energy equation and forms of energy.

Internal energy function reversible and irreversible processes.

Reversible work, adiabatic and isothermal processes.

3. Second Law of Thermodynamics

(In this section the interests of all three categories of engineer must be covered although the main emphasis will be on mechanical or chemical processes. It is important in this section to show the universal nature of thermodynamic relationships in all fields of engineering).

Equivalent statements of the second law.

Available energy and the Carnot principle.

Entropy changes in reversible and irreversible proces s.

Entropy changes of ideal gases and non-ideal gases.

Entropy of mixing, entropy and probability.

Maxwell relations.

4. Applications of Thermodynamics

(This section, which should occupy more than one quarter of the course, applies the basic laws to many different processes and is of obvious importance).

The production of mechanical power from thermal energy.

Practical restrictions on the use of reversible cycles.

Power cycles adopted in practice for internal combustion engines, gas turbines, steam plant.

Refrigeration and heat pump cycles including thermodynamic consideration of compression processes.

Thermodynamic analysis of heat exchange processes.

Thermodynamic analysis of simple complete processes (including evaporation).

PRACTICAL WORK (Total 45 hours)

Note: Because of the impracticability o devising meaningful experiments in the first three sections it is suggested that, for these sections, laboratory time be devoted to tutorial work and problem periods.

1. Determination of the specific heat of air at constant pressure and constant volume (3 hrs)
2. Measurement of compressibility of CO_2. Determination of compressibility factor and critical constants (3 hrs)
3. Measurement of temperature with a gas thermometer (2 hrs)
4. The use of a throttling calorimeter. Measurement of dryness fraction of steam. (3 hrs)
5. Conservation of energy in a water-jet pump (2 hrs)
6. Expansion of air through a nozzle (2 hrs)
7. Determination of electrical equivalents in an electro-chemical cell (3 hrs)
8. Performance cycle on
   a) Air compressor (3 hrs)
   b) Steam Engine (3 hrs)
   c) Internal combustion engine (6 hrs)
   d) Refrigerator (6 hrs)
9. Energy balances on
   a) Simple two-fluid heat exchange with no change of phase (3 hrs)
   b) Simple single-stage evaporator (6 hrs)

EQUIPMENT

There is no standard list of equipment for thermodynamics as the experiments tend either to be designed to fit the ideas and emphasis of particular professors or to use equipment from the heat engines laboratory.

The notes on practical work have taken into account both these trends, but especially the latter.

Most of the more important principles in the syllabus can be demonstrated using a suitably instrumented internal combustion engine. Similarly a compression-type refrigeration machine with good instrumentation for measuring flows, pressures, temperatures and power inputs would also be very useful.

The heat exchangers required in teaching the application of thermodynamics could well be built into either or both the i.c. engine and refrigerator test unit mentioned above.

For the "complete processes", equipment in the chemical engineering pilot plant laboratories might well be used. Some of the experiments would best be located in the same laboratory as the i.c. engine and compression refrigerator unit. A large size domestic refrigerator of the absorption type would suffice for this.

Other experimental set-ups arising out of his own experience will doubtless readily spring to the mind of the teacher of applied thermodynamics; many of these will be such that the University's workshop can manufacture them out of pipes and simple fittings.

BIBLIOGRAPHY

Thermodynamics, Lewis & Randall, McGraw-Hill.

Chemical-Thermodynamics, Klotz, Prentice-Hall.

Thermodynamics, Lee J.F. and Sears F.W., Addison-Wesley, 1963 (2nd Ed).

THIRD YEAR - SUBJECT A

MATHEMATICS

The introductory remarks apply to this year as they do to previous years. The teaching of Statistics and Operations Analysis, in addition to being in the spirit previous indicated, should be co-ordinated with the applications being considered by the Socio-Economic Sciences Department.

SYLLABUS

In this year, for about 50% of the total time available for Mathematics is to be devoted to each of the sections A and B.

A. The numerical solution of equations (including differential equations)

Basic ideas. Formulation, truncation and rounding errors. Simple error analysis. Least-square approximation. Economization of series. Orthogonal polynomials. Introduction to finite and divided differences. Interpolation, differentiation, integration. Lagrange formulae.

Linear simultaneous equations by direct and iterative methods. Matrix inversion. Systems of non-linear equations by the Newtom-Raphson method. Matrix eigen-value and eigen-vector determination. Ordinary differential equations including boundary-value problems. Runge-Kutta method; selected predictor-corrector method; deferred-correction method.

Partial differential equations.
Solution by Laplace transform.
Finite difference methods of solution.
Ideas of stability.
Application to examples of boundary value problems.

B. Statistics and Operations Analysis

Introduction to probability. Theorems including Bayes' theorem. Inherent variations in observed data. The normal distribution, its properties and estimation of its parameters. Simple tests of significance and confidence limits for samples from the normal distribution.

Basic principles of experimentation; statistical inference and testing. Initial steps in planning experiments; randomization, replication and other means of improving the quality of estimates. Simple analysis of variance. Sources of variation in data; the use of models to describe data. The regressional modes; estimation of parameters etc.

General curve fittings. Statistical distributions: uniform, binomial, Poisson. Goodness-of-fit tests. Introduction to methods of quality control. The critical-path technique and techniques for linear programming: transportation and stock-control problems.

BIBLIOGRAPHY FOR YEARS I, II, AND III

a) General Works which cover much of the Mathematics syllabus, though no one of them includes everything.

1. Mathematical Methods for Science Students, Stephenson.
2. Ancillary Mathematics, Massey and Kestelmann.
3. Mathematical Methods for Technologists, Strain et al.
4. A Course of Mathematics for Engineers and Scientists, Plumpton and Chirgwin.

This series of seven volumes is not yet complete but will probably cover the whole of the algebra and analysis syllabuses when it is.

5. Applied Mathematics for Engineers and Physicists, Pipes.
6. Advanced Engineering Mathematics. Kregswiz, Wiley.

b) Other Books which deal with selected parts of the syllabus.

7. Schaum's Outline Series particularly:
   Theory and Problems of Vector Analysis, Spiegel.
   Advanced Calculus, Spiegel.
   Differential Equations, Ayres.
8. Matrix Theory for Electrical Engineering Students, Tropper.
9. Matrix Algebra for Electrical Engineers, Braae.
10. Matrices-Their Meaning and Manipulation, Bowman.
11. Modern Mathematics for the Engineer, Beckenback, McGraw-Hill.
12. Certain sections of the OECD publication on 'Mathematics for Engineers' contains helpful bibliographies and exercises.
13. Modern Computing Methods, N.P.L.
    Notes on Applied Science No. 16. H.M.S.O.
14. Numerical Analysis, Khabaza.
15. Elementary Numerical Methods, Seraton.
16. An Introduction to Computational Methods, Redish.
17. Introduction to Numerical Methods, Butler and Kerr.
18. Numerical Analysis, Hartree.
19. Numerical Solution of Partial Differential Equations, G.D. Smith.
20. An Introduction to Digital Computing, Arden, Addison-Wesley.
21. A guide to Algol Programming, McCricken D.D., Wiley.

c) Statistics

22. Introduction to Probability and Statistics, Adler and Roessler.

23. Statistical Methods for Technologists, Paradine and Rivett.

24. Introduction to Statistical Inference, Keeping.

25. Introductory Engineering Statistics, Guttman and Wilks, Wiley (1965).

26. Elementary Statistics. P.G. Hoel, Wiley.

27. Introduction to Mathematical Statistics, P.G. Hoel, Wiley.

28. Standard Statistical Calculations, Moore and Edwards, Pitman.

EQUIPMENT

1. Computer Facilities

The type of Computer

The lessons learned from the introduction of computers into the educational system in other countries should not be overlooked in advising a country such as Spain. One of the major conclusions which arises from the experience of past years is the need for compatibility in languages between computers in different educational institutions. The need for a rational plan for all the universities in the country is well presented in the recently published Flowers Report on this subject in the United Kingdom. Thus, in considering the question of a suitable computer for the school at Seville, it is desirable to consider the information on other computer installations which are at present operational in Spanish educational institutions and on any new or replacement installations proposed for the next few years.

Bearing in mind the size of the proposed student body for the school at Seville, and also that there may be some use of the equipment by students in the faculty of Science in the University of Seville and by industry in Andalusia, it is possible to give some general observations on the criteria which the computer should satisfy.

1. Availability of the main procedure-oriented languages and a library of programmes.
2. Fast compiling of programmes written in these languages.
3. Floating point hardware.
4. Satisfactory backing-store facilities.
5. Multi-programming operation to allow experimental work on the most up-to-date teaching methods.
6. An adequate range of peripheral equipment.
7. A configuration which is expandable.

The computer laboratory will also need to be supported by an adequate technical staff of various kinds.

Note:

It should also be checked that a suitable analogue computer will be provided in the laboratories of the Electrical Engineering Department and that this is available for the basic work specified above.

2. Desk Calculators

Experience in other educational institutions has shown that, in addition to having a digital computer available, it is necessary to have one or more laboratories equipped with desk calculators in which exercise work associated with the work in statistics, operations analysis, numerical mathematics, and other miscellaneous work can be carried out.

In view of the proposed size of the student body, it is recommended that provision be made for the purchase of 50 calculators; these should preferably be electrical or electronic.

THIRD YEAR - SUBJECT B

SCIENCE OF MATERIALS II

As was said previously, engineers are very largely concerned with manipulating or processing matter. Part I of this subject dealt with the scientific and basic properties of matter and Part II, therefore follows on logically in developing these principles into engineering applications. The subject is of obvious importance dealing as it does with the behaviour of metals in engineering situations and also covering the more important aspects of chemical behaviour, particularly corrosion.

SYLLABUS

A. Engineering Properties of Materials

(Here it is the intention to develop ideas of structure from the previous year's work to engineering behaviour (showing imperfections as well as ideal behaviour). These can be modified in various ways (sections 3 and 4) and the important engineering design relationships are presented finally).

1. Elastic, highly elastic, visco-elastic and plastic deformation. Stress-strain characteristics.
2. Plasticity in crystalline materials. Dislocation theory of yield and work hardening.
3. Thermal processing of materials.
4. Strengthening processes. Alloying, age-hardening, two-phase systems, including alloys, fibre-reinforcement.
5. Extension, flexing and twisting. Moduli of elasticity and rigidity. Poisson's ratio. Elastic, plastic and compressive failure.

B. Chemical Properties of Materials

(The emphasis here is on section 1 (about $\frac{1}{4}$ of the course). Surface properties are treated in a qualitative way. It is important to avoid Section 3 becoming a mere catalogue and the professor in charge may wish to choose particular examples in each class. Over-emphasis on metallic materials, to the exclusion of non-metallic ones, should be avoided).

1. Electrochemical theory of corrosion. Electrode potentials. Overvoltage polarization. Passivation and sacrificial protection.
2. Surface properties of materials: reactivity, adsorptivity, solubility.
3. The chemical nature and behaviour of the principal non-metallic engineering materials including cements, ceramics, polymers, resins, and paints.

BIBLIOGRAPHY

Materials Handbook, Brady, McGraw-Hill.

Elements of Materials Science, Second Edition, Van Vlack, Addison-Wesley, 1964.

Corrosion and Corrosion Control, H.H. Uhlig, John Wiley.

The Chemistry and Physics of Rubber-Like Substances, Bateman, L., Ed. McLaren, 1960.

Chemistry of Engineering Materials, Leighon, McGraw-Hill.

Reactivity of Solids, de Boer. Elsevier.

Organic Protective Coating, Fisher and Babalek, Reinhold.

PRACTICAL WORK

Thermal Processes

L D 1. Preparation of small melts and casts. Macrostructure of ingots.

L 2. Extrusion of lead and of polymers.

L 3. Determination of minimum packing density. Sintering of powders.

L 4. Isothermal transformations of steels.

L 5. Hardening and tempering of mild steel.

L 6. Precipitation hardening of a heat-treatable aluminium alloy. Effect of temperature on tensile properties.

Strenghening Processes

L 7. Working of metals by rolling.

L 8. Determination of brittle-ductile transition temperature in steels.

L 9. The Jominy hardenability test.

L 10. Influence of temperature on the tensile properties of dispersion-strengthened materials (SAPO load).

L 11. Effect of annealing on cold-worked metals and alloys.

Corrosion and Surface Properties

D 12. Oxidation of copper; determination of rate law.

L 13. Measurement of half-cell potentials and calculation of single electrode potentials.

D 14. Inhibition of corrosion on mild steel.

D 15. Differential aeration and determination of anodic and cathodic regions (ferroxyl indicator).

D 16. Anodic oxidation of aluminium and its alloys.

D 17. Protective metal coatings by hot dipping and by electrodeposition.

D 18. Evolution of hydrogen on metal surfaces. Hydrogen diffusion in metals.

L 19. Effect of current density on the cathode current efficiency of the electropolishing process.

General Physical Properties of Materials

L 20. Condensation reactions in simple polymers (e.g., phenolformaldehyde resins).

L 21. Determination of network parameter of vulcanized rubber.

L 22. Hydration of gypsum plaster and of magnesia.

L 23. Non-destructive testing of metals and alloys: penetrant, magnetic particle and ultrasonic methods (demonstration).

L 24. Determination of the softening points of selected glasses.

EQUIPMENT (Science of Materials I and II)

Experiments

Structures	Metallurgical microscopes
Photography	35 mm camera attachment
	Polarizing microscopes
	Projection miscroscope
	Pre-grinders
	Polishing wheels
	Vibratory polishers
	Electropolishing unit
	Mounting presses
	625-line closed-circuit TV camera, for use with microscopes
	Low-power binocular microscopes
	Photographic enlarger and accessories
	Microspecimens (various sets in triplicate)
	Specimen cut-off machine
	Specimen hand-lapping plates
	Ceramic thin-section polishing machine
Mechanical and Thermal Experiments	Gas-fired furnace
	Muffle furnace
	Tube furnaces, $1\frac{1}{2}$ inch diameter

	Air ovens (0 - 500°)
	Salt-bath furnaces, vertical type
	Furnace for carbon-in-steel determination (small)
	Indicating pyrometers (0-1200°)
	Workshop potentiometers
	Chromel and alumel thermocouple wires (24 swg) and compensating lead
	Constant-resistance flectioned potentiometer
	Pt-Rh (13%) precious metal thermocouples (0.5 mm diameter)
	Potentiometer
	Extension attachment for tenameter
	Metallurgical dilatometer
Mechanical Properties	Tensometer and accessories
	Vickers hardness tester
	Rockwell hardness tester
	Brinell hardness tester
	Shore Sceleroscope
	Izod machine
	Charpy machine
	Jominy end-quench equipment
	High-temperature furnace and accessories
	2 high rolling mill 10 cm diam. x 18 cm wide hand rolls
	Drawbench
	Drawplates, 10-50 mm and 2-10 mm
Corrosion and Surface Properties	Galvanometer
	Calomel electrodes
	Slidewire potentiometer
	Resistance box
	Ammeter, 20A
	Ammeter, 5A
	Power pack, 20V, 20A DC

General Physical and Thermal Properties	Thermal expansion of ceramics Differential thermal analysis appts. Gravimetric thermal analysis appts. Density apparatus Vacuum pump Specific gravity bottles, Rees-Hugill type
X-ray Diffraction	X-ray generator Diffraction tubes Powder camera Flat plate camera Goniometer bend.
Phase diagrams	For Pb-Sn system: 200ml plumbago crucibles, potentiometer For NaF-NaCl system: Run on stage microscope, power pack, and hot thermocouple.
Elect. and Mag. Props	Magnetizing coils Ammeter, 0-12 A d.c. Voltmeter, 0-20 V d.c. Ammeter, 0-21 A d.c. Variable resistance, 85 ohm, 3.3A max Power supply, 0-16 V d.c. Weighing pan Wheatstone bridge Parallel plates, wax slab
Non-destructive Testing	Magnetic sorting bridge Fluorescent lamp Portable magnetic crack detector
Balances	Two-pan balance Unimatic balance
Optional Extra	75 kw electron microscope Reflector-diffractor attachment Specimen-coating unit and accessories

THIRD YEAR - SUBJECT C

MECHANICS OF MACHINES

Electrical, mechanical, and chemical engineering students study this subject during the first semester of the third year.

This syllabus relates the basic mechanics which the student has encountered in the first year of the course to the problems which arise in the machinery in everyday use in engineering. The syllabus attempts to cater for the differing interests of the mechanical, electrical, and chemical engineering students. Whilst this particular aim of the syllabus is ensured by some of the examples quoted, some sections, e.g. those on balancing and vibration are equally significant to the three categories of students.

It will be desirable in teaching this syllabus to widen the approach in order not only to provide strong stimulus to each of the student groups but also to contribute to the cross linking between subjects. In this way the students will be conscious of the need to avoid compartmentalization of their work, and will appreciate that the course has some entirely.

An example of this approach might be that of the balance of a geometrically perfect rotor which might lack uniform density or have directional magnetic or electrical properties arising from previous manufacturing history. The link back to the second-year subject "Design for Manufacture" would encourage the student to carry forward their awareness of third-year syllabuses to the subsequent year where "Dynamics of Machinery" follows naturally from this syllabus.

SYLLABUS

1. Statics

Three-dimensional force equilibrium. Problems of lifting equipment into position where a direct lift is impossible, e.g., chemical plant where crane access is obstructed or removal of heavy electrical rotors via the end of stators.

Distortion in three dimensions, strain compatibility problems of expansion due to temperature changes in large scale plant.

Use of frames of reference for analysing three dimensional problems.

2. Kinematics

Analysis of typical mechanical linkages, e.g., crank-driven process-stirrers; toggle-actuated switchgear mechanisms, electric typewriter actuating linkage.

Velocity and acceleration of linkage components, inertia forces in linkages.

Motion of rigid bodies.

3. Dynamics of rotating bodies

Nature of forces in rotating systems, strength of centrifuges, conductor retention in electrical machines.

Balancing - static and dynamic.

Balancing machines - methods of "field"-balancing operational machines.

4. Vibration

Energy storage and transfer in mechanical systems.

Energy input sources, mechanical, electrical, magnetic, process controllers.

Free and forced vibration of single-degree-of-freedom systems.

Sources of clamping, stick-slip motion.

Whirling of simple shaft systems.

BIBLIOGRAPHY

An Introduction to the Mechanics of Machines, Morrison, J.L.M., and Crossland, B., Longmans, Green, 1964.

Mechanisms and Motion, Hunt, K.H. English Universities Press, 1959.

Mechanical Vibrations, 4th Edition, Den Hartog, J.P., McGraw-Hill, 1956.

PRACTICAL EXPERIMENTS

1. The graphical differentiation and integration of space-time, acceleration-time curves.
2. The construction of velocity and acceleration diagrams, and coupler curves for linkages.
3. Construction of a turning moment diagram and a speed fluctuation curve for a single-cylinder reciprocating engine.
4. Graphical solution of problems involving inertia forces in linkages.
5. Graphical solution of balancing problems involving rotating and reciprocating masses.
6. Belt friction, verification of the relationship $\frac{T^1}{T^2} = e^{r\theta}$
7. Determination of the moment of inertia of rotors and other machine components by compound pendulum, bifilar and trifilar suspension methods.
8. Dynamic balancing of a rotor by measurement of vibration amplitude and phase.
9. Direct measurement of the coefficient of speed fluctuation of an engine.

10. Study of influence of damping on the amplitude and phase relationships of the forced vibration response of a simple spring-mass system.

11. Whirling of shafts - to demonstrate that for a light shaft carrying a single rotor:

$$(\text{critical speed})^2 = \frac{\text{acceleration due to gravity}}{\text{static deflection}}$$

Notes: Experiments 1 to 5 comprise graphical exercises to be carried out by the students in the drawing office. Experiment 3 should preferably link with experiment 5 and a practical laboratory exercise in obtaining engine indicator diagrams and inertias of engine components should be done if this linking of experiments is possible.

Experiment 6 Ambrosius, E.E., and Fellows, R.D., "Mechanical Engineering Laboratory Practice", Ronald Press N.Y., Exercise 6, p. 315.

Experiment 8 Johnson, K.L., Bulletin of Mechanical Engineering Education, No. 6, July 1964, p. 35.

Experiment 9 Downs, B., B.M.E.E., No. 8, July 1955, p. 25.

Experiment 10 Kelsey, A.R., B.M.E.E., No. 3, January 1953, p. 25.

Experiment 11 Bevan, T., "Theory of Machines", 2nd Edition, Longmans, p. 510.

Additional References

Tuve, G.L., Mechanical Engineering Experimentation, McGraw-Hill, 1961.

Doolittle, J.S. Mechanical Engineering Laboratory, McGraw-Hill, 1957.

EQUIPMENT

Planimeters (4)

Integraph (1)

Harmonic Analyser (2)

Electronic stop clocks (6)

Mechanisms

Double Hooke's Coupling (1)

Shaping-machine mechanism (1)

Slotted-link mechanism (1)

Crank and connecting rod (1)

Slow speed, single-cylinder diesel engine installation complete with instrumentation including dynamometer and indicating facility.

e.g. piston type indicator
Farnboro indicator

Dynamic balancing chine, mechanical (1)

" " " electrical (1)

Belt-friction apparatus (1)

Speed-fluctuation apparatus (1)

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Vibration measuring equipment	
Vibration meter	(1)
Absolute vibration pick-up	(1)
Relative vibration pick-up	(1)
Proximity vibration pick-up	(1)
Calibration unit	(1)
Angle marker	(1)
Oscilloscopes	(4)
Oscilloscope (twin beam)	(1)
<u>Vibration generating equipment</u>	
Audio frequency oscillator	(1)
Power amplifier	(1)
Vibration generator	(1)
Centrifugal force apparatus	(1)
Shaft-whirl apparatus	(1)

THIRD YEAR - SUBJECT D

ELECTRICITY II

Semiconductor devices are of great importance in many engineering activities and an understanding of their behaviour is essential. In the second-ye r subject "Science of Materials I" there is a basis of physical principles of semiconductor action. The development into amplifier circuits is based upon the use of valves as well as transistors, in order to bring out comparisons and to indicate fields of use. Measurements and transducers are also fundamental in engineering and, although shown as separate sections, should be related both to the work of the first four sections and also to the syllabus Electricity I, of the second year.

SYLLABUS

Semi-conductors

(A revision of the coverage of Science of Materials I extending into a description of devices. This section may be amplified by returning to it later for a discussion on some modern trends such as field effect transistors).

General properties. Intrinsic conduction in germanium and silicon. Extrinsic condution in semiconductors. Motion of current carriers in semiconductors.

Devices - the p-n junction: Zener diode. Variable capacitance diode. The Hall effect.

Valves and Transistors

(An introduction to the methods of applying valves and transistors).

Triode valve. Static characteristics and parameters operation in common-cathode, grounded-grid and common-anode type amplifier. Bias, clamping. Effect of inter-electrode capacitances.

Tetrode and Pentode valves. Characteristics, parameters and equivalent circuits, bottoming. Common-base, common-emitter, common-collector circuits.

Gas-filled devices, neon stabilisers, thyratron. Application to simple time-base circuits.

Small-Signal Amplifiers

(The use of valves and transistors in amplifier circuits could well be extended it time permits to give an introduction to d.c. amplifiers and power amplifiers).

Amplifier stages in cascade. Coupling methods. Difficulties in cascade amplifiers. Frequency and phase response.

Non-linearity: its effects and reduction by negative feedback. Noise and inherent limitations of amplification.

Measurements

(Although not specifically mentioned it is necessary as an introduction to discuss the philosophy of measurement. Electrical measurements refer to electrical methods of measurement of both electrical and non-electrical quantities).

Pulse and sine generators.

Oscilloscopes and electronic voltmeters.

Electronic integration and differentiation.

Counting and logical operations.

Measurements based on time delay and standing waves.

Analogue to digital-conversion and digital to analogue-conversion.

Information displays and information recording.

Transducers

(Transducers are related to measurement but should also be linked to instrumentation and control).

Thermocouples and thermosensitive resistors.

Photomultipliers and photodiodes.

Piezoelectric transducers.

Transducers of magnetic magnitudes.

Microphones and telephones.

Electrochemical transducers.

Radiation detectors.

Transducers for linear and angular velocity, acceleration and pressure.

Transformers and Machines

(Some basic principles of electrical machines follow from the consideration of magnetic fields in year II).

Transformers: magnetising current, equivalent circuit, efficiency. Electrical machines, excitation, induced voltage. Voltage, speed and torque relationships in d.c. machines, efficiency.

BIBLIOGRAPHY

Since Electricity I and Electricity II together provide the background of fundamentals necessary for the subsequent syllabuses of engineering applications, the textbook support recommended for Year II has been chosen to be adequate for much of Year III also with the possible addition of "Fundamentos de Electronica" Buckingham and Price (Editorial Tecnos S.A.).

LABORATORY PROGRAMME

Introduction

Some general familiarity with experimental procedures having been gained in Year II, it is appropriate that the emphasis in Year III should turn more towards the acquisition of a knowledge of devices and circuits; at the same time more attention should be given to measurement techniques, instrumentation and accuracy.

Experiments

GROUP 1 Investigation of characteristics of devices; valve, transistor, transducer. Control characteristics of thyratron.

GROUP 2 Connection of a simple amplifier and determination of its characteristics. This may be developed into a series of experiments on feedback; coupling circuits; amplifiers in cascade; simple oscillator.

GROUP 3 Illustrations of measurement techniques such as:
Phase comparison using the cathode-ray oscilloscope as in the measurement of inductance by comparison.
Location of a discontinuity by time delay of a reflected pulse. Exercises on simple logic circuits using one of the logic kits available for this kind of experimental purpose. Operational amplifiers and magnetic amplifiers.

GROUP 4 Open-circuit test and load test on transformer.
Magnetization curve of d.c. generator.
Load characteristic of separately-excited and shunt-connected d.c. generator.
Speed control of d.c. motor.
Load characteristics of shunt motor.
Relation between speed e.m.f. and frequency in a.c. generator.
A.c. & d.c. servo-systems. Remote position control; magslip. Tacho generator.

EQUIPMENT

The equipment detailed for the second year is a basis also for the third year, but needs extending by:

- further oscilloscopes including two or three of the more sophisticated types;
- logic equipment. The "standard logic laboratory" produced by the Digital Equipment Corporation of America merits consideration. It is designed to cover an experimental programme described in the associated manual;
- selection of machines and transformers; sizes of the order of $\frac{1}{2}$kVA or $\frac{1}{2}$ h.p. are adequate. Three single-phase transformers enable simple three-phase connections to be studied as well as transformer characteristics. Several manufacturers produce complete laboratory test benches for small machines with a range of interchangeable machines.

THIRD YEAR - SUBJECT E

FLUID MECHANICS AND HEAT TRANSFER

Materials and energy are often transported by fluid flow and the engineer is frequently called upon to design equipment or to analyse the performance of existing apparatus. Likewise one of the most common industrial methods of adding or removing energy when handling materials is by heat transfer or cooling. Particularly is this so when the substance to be heated (or cooled) is a fluid. Because of their frequent occurence together in industrial situations but also because of the close theoretical similarity, the two phenomena of fluid flow and heat transfer are treated together. This is a modern approach and helps the students to a better appreciation of the underlying principles.

SYLLABUS

1. Properties of Fluids

(A very brief review serving largely to define terms).

Basic definitions.

Shearing and viscosity, influence of temperature.

Newtonian and non-Newtonian fluids.

2. Flow of Fluids

(The basic engineering knowledge on problems in fluid flow are covered here. It is not intended that the treatment go beyond linear and one-dimensional problems. Compressible flow should only be mentioned).

Principle of continuity, energy and momentum equations for steady-state conditions.

Viscous and turbulent fluid flow, motion of a fluid element, introduction to stream function, descriptive treatment of flow at boundaries.

Application of the continuity energy and momentum equations.

Bernoulli's equation; vortex motion.

Flow measurement.

3. Introduction to Heat Transmission

(An introduction to the essential engineering heat transfer problem).

Mechanisms of heat flow.

The requirements for heat transfer (or non-transfer).

4. Conductive Heat Transfer

(A quantitative discussion of heat transfer in solids).

Thermal conductivity and conductive heat flow.

Continuity of heat flow in a solid in steady state in one dimension.

Conduction in solids in series.

5. Convective Heat Transfer

(The introduction of the concept of thermal films and a quantitative treatment of heat flow in fluids in forced convection. Natural convection relationships may be presented but no treatment in depth is needed).

Thermal films and convective heat transfer.

The heat transfer coefficient; individual and overall coefficients.

Heat transfer to fluids in motion, natural and forced convection.

6. Momentum and Heat Transfer

(The relationship between fluid flow and heat transfer and its applications in design and analysis should be developed quantitatively).

Heat transfer and skin friction. The Reynolds, Taylor-Prandtl and Martinelli analogies.

7. Radiative Heat Transfer

(A brief and elementary (but quantitative) introduction to applications of radiation heating including furnaces).

Application of Kirchhoff's law, Wien's law, the Stefan-Boltzmann law.

Radiation from surfaces and flames. Adsorptivity of gases.

BIBLIOGRAPHY

Specific

Fluid Dynamics and Heat Transfer, Knudsen and Katz, McGraw-Hill.

Momentum Heat and Mass transfer, Benett and Myers, McGraw-Hill.

Elements of Heat Transfer, Jakob and Hawkins, John Wiley.

General and Reference

Transport Phenomena, Bird, Stewart and Lightfoot, McGraw-Hill.

Chemical Engineering, Coulson and Richardson, Pergamon. Volume I.

PRACTICAL WORK

1. Measurement of the viscosity of:
   a) Kerosine
   b) Lubricating oil at three different temperatures
   c) Air (at two different temperatures).

2. Streamline and turbulent flow (demonstration).

3. Measurement of viscosity by streamline flow through a capillary.

4. Measurement of flow by:
   a) Orifice plate (with multiple pressure tappings)
   b) Venturi (with multiple pressure tappings)
   c) Rotameter
   d) Pitot tube.

Note: a) and b) should be done using a simple liquid, e.g., kerosine c) with both a liquid and a gas, and d) with a gas in a duct at least 6 ins. in diameter.

5. Flow of air through a nozzle.

6. Performance characteristics of:
   a) Centrifugal fan
   b) Centrifugal pump
   c) Jet pump, e.g. steam jet ejector.

7. Measurement of pressure drop in pipes and simple fittings.

8. Determination of temperature in a laboratory muffle-furnace using an optical pyrometer.

9. Measurement of thermal conductivity of cork, felt, and magnesia.

10. Measurement of heat transfer to a liquid in a single pipe heat exchanger:
    a) in viscous flow
    b) in turbulent flow

11. Measurement of heat transfer by steam condensing in a single pipe.

12. Measurement of heat transfer to a boiling liquid (electrically-heated-wire apparatus).

13. The Reynolds analogy demonstrated by the measurement of pressure drop and temperature rise when air is blown through a heated tube.

EQUIPMENT

Note: This should be read in conjunction with the paper on experiments in Fluid Mechanics and Heat Transfer.

1. Measurement of Viscosity

   Redwood Viscometers (2)

   Ostwald Viscometers (6)

   Thermostatically controlled water baths (2)

2. Streamline and Turbulent Flow

Demonstration apparatus by Q.V.F., Ltd., Stoke-on-Trant, England.

3. Measurement of viscosity by rate of flow through a capillary tube

This is a bench-top apparatus made up from a length of fine bore glass capillary tubing connected by rubber tubing to a constant level head tank. The rate of flow is found by using a measuring cylinder and stop-watch.

4. Measurement of flow

a) b) c) A continuous flow apparatus comprising a pump, pipes of different diameter, and different types of flow-measuring devices.

Suitable apparatus is made by several companies in England: e.g., Q.V.F., Ltd., Stoke-on-Trent; E. Reader, Ltd., Nottingham.

Note: This equipment will also be suitable for experiments in pressure drop through pipes and fittings.

d) Electrically driven centrifugal fan capable of delivering 2000 cfm against a head of 10 in w.g. connected to galvanized metal duct of at least 8 in. diameter and 20 ft. long.

Pitot tube.

Micromanometer.

5. Flow of air through a nozzle

Air compressor (100 p.s.i.g., 5 c.f.m.)

Suitable nozzle

Pressure gauges

Thermocouples

Pan balance to measure thrust of nozz.

6. Pump performance characteristics

a) Can be done using equipment under d) above with a variable-speed-drive gear-box fitted between the motor and the fan.

b) Can be done using equipment listed under 4, a) preferably with variable speed drive fitted to the pump.

c) A simple apparatus can be built up using Rotameters to measure rates of flow of working fluid and of entrained fluid into the engine. The smallest commercially available single-stage ejector should be used. This may be water-operated or steam-operated.

7. See 4 above

8. Measurement of high temperature

A laboratory muffle furnace, preferably gas fired, capable of reaching a temperature of 1000°C. A simple portable battery-operated optical pyrometer of the disappearing-filament type.

9. Measurement of thermal conductivity

A suitable apparatus comprises a rectangular metal box mounted on top of an electrical "hot plate". Slabs of the material to be tested are made so that they just fit into the box. Thermocouples are fitted on both sides of the slabs of material and, from the temperature differential at steady state, the rate of heat flow (hence thermal conductivity) can be determined.

10. Heat transfer to a liquid in a single-pipe heat exchanger

There is a commercially available apparatus for this by E. Reader and Sons Ltd., Nottingham.

11. Heat transfer by condensing steam

There is a commercially available apparatus for this by Heat Transfer, Ltd., Cheltenham.

12. Heat transfer to a boiling liquid

This is a very simple bench type experiment in which a platinum wire is immersed in a pure liquid in a container and a small portion of the liquid is boiled by passing an electric current through the wire.

The heat transfer can be calculated by measuring the electrical power input to the wire.

13. The Reynolds analogy

There is a simple apparatus which can be made for this experiment comprising a fan delivering air measured through a variable-area flowmeter (Rotameter) to a 3 cm diameter brass tube 2 m long, which is mounted co-axially inside a second tube which provides a steam jacket. The Reynolds analogy can be shown by measuring air temperature in and out of the heated tubes and the pressure drop at different rates of flow.

Miscellaneous

Several small centrifugal pumps up to 500 gph capacity.

Two centrifugal fans up to 300 cfm.

Brass or copper pipe with supply of standard sweat fittings, in sizes 1, 1.50, 2, 3, and 4 inches (equivalent metric), will enable many experiments to be devised.

Pressure gauges: dial type 0-50 p.s.i.g.; dial type 0-20 w.g.; manometer type 0-10 in w.g.

Flowmeters-standard Rotameter and test sets for air and water.

Multipoint temperature recorder (thermocouple type)

Several industrial-type galvanometers for temperature measurement.

CHAPTER X

SCIENTIFIC AND TECHNICAL SUBJECTS

FOURTH AND FIFTH YEARS

I. FOURTH YEAR

A. Control systems

B. Transmission and Application of Power I

C. Transmission and Application of Power II

Departmental Subjects

Chemical Engineering:

1. Chemical Engineering Principles

2. Unit Operations I

Electrical Engineering

1. Advanced Electrical Theory

2. Electrical Plant

Mechanical Engineering

1. Strength of Materials

2. Dynamics of Machinery

II. FIFTH YEAR

Departmental Subjects and Options

Chemical Engineering:

1. Unit Operations II (S)
2. Applied Thermodynamics (S)
3. Chemical Reaction Engineering (O)
4. Particle Technology (O)
5. Process Dynamics (O)
6. Separation Processes (O)
7. Materials Technology (O)

Electrical Engineering

1. Control Systems II (S)
2. Advanced Electrical Engineering (S)
3. Applied Electronics (O)
4. Communications Engineering (O)
5. High Voltage Transmission (O)
6. Traction (O)
7. Generalize Machine Theory (O)

Mechanical Engineering

1. Principle of Manufacture (S)
2. Control Systems II (S)
3. Refrigeration and Air-Conditioning (O)
4. Fluid Actuation Systems (O)
5. Metrology (O)
6. Lubrication Engineering (O)

FOURTH YEAR - SUBJECT A

CONTROL SYSTEMS I

The syllabus for this introductory study of control systems is built on the foundations of linear control theory. Control-system components are not included as a defined topic but should be introduced as illustrative examples and used as the basis of tutorial tasks and laboratory experiments. Examples should be chosen from mechanical, electrical and chemical engineering systems.

The course in Mathematics, already completed, provides an adequate basis for the study of systems in this syllabus and also for the fifth-year syllabus which appears as a subject in some of the specialized courses.

SYLLABUS

<u>General</u>

Basic discussion of open-load control-systems and their limitations.

Use of feedback - advantages and difficulties. Accuracy, stability, and the design dilemma. Differential equations as mathematical models of linear control systems - their solution by means of Laplace transforms.
Transfer functions and block diagrams - the feedback equation. The final value theorem - steady state errors and error constants. Definition of system stability based on the p-plane (or p-plane), relative stability - damping ratio, damping factor. Routh stability criterion.

<u>Frequency response methods of analysis</u>

Stability and the p-plane - the Nyquist criterion, inverse Nyquist, M & N circles, Nicholl's chart, Bode diagrams. Stability specifications and their interpretation on the above charts and diagrams.

<u>Root locus analysis</u>

Significance of root position in system stability. Rules applied to sketching the locus, steady state accuracy.
System transient response.

<u>The time domain</u>

The convolution integral and its graphical interpretation; the weighting function.

Analogue computation and system simulation

Linear computer elements and their organization in a general-purpose machine. Time scaling. Solution of sets of equations. System simulation. Non-linear elements: - multipliers, special- - and general - purpose function generators including diode switching circuits.

BIBLIOGRAPHY

See Control Systems II.

FOURTH YEAR - SUBJECTS B AND C

TRANSMISSION AND APPLICATION OF POWER I AND II

This syllabus, which is divided into two parts, is studied throughout by electrical, mechanical and chemical engineering students. The consumption of energy is basic to all engineering activity and the practising engineer is faced with the problem of selecting the best combination of power sources to meet particular industrial requirements effectively and economically. This syllabus is designed to provide the student with sufficient perspective and knowledge of the state of the art to enable him to review existing systems of power utilization or devise systems for new developments or extensions. Emphasis will be placed both on the efficiency of power processes and on the comparative costs of alternatives.

SYLLABUS - PART I

1. Sources of energy

   Quantitative comparison of wood, coal, oil, gas and nuclear fuels. Spanish, European and world resources.

   Hydro-power; comparison with wind, tidal and solar power.

   Secondary fuels, chemicals and oxidizing agents.

2. Engineering applications of energy

   Thermal processes; melting, drying, evaporation, welding, heat treatment, sintering; temperature considerations.

   Work processes; deformation and shear of materials, elevation and transport of materials, energy losses.

3. Conversion of energy from sources

   Release of thermal energy by combustion and fission, process and temperature limitations.

   Extraction of thermal energy by solar stills.

   Performance of hydraulic turbines and windmills.

4. Secondary conversions of energy

   Methods of extracting mechanical power from thermal energy.

Generation of electrical power; alternators, primary cells, fuel cells, magnetohydrodynamics.

Conversion of shaft power to fluid power; pumps and compressors.

Steam generation.

5. Transmission of power

Shaft systems, mechanical couplings, rope, belt and gear drives.

Fluid couplings, hydrostatic systems, torque convertors.

Pneumatic power systems.

Steam supply systems, efficient use of steam.

SYLLABUS - PART II

6. Electric power transmission

Single-phase and three-phase electric power supplies. Distribution networks, switchgear, transformers and regulators.

Direct current power supplies, process applications.

Simple commutation and d.c. windings. Forms of excitation e.m.f. and torque equations for d.c. generators and motors. Characteristics of series - shunt - and compound wound machines. Effects of armature reaction. Interpole and compensating windings.

Single phase transformer, transformation ratio and e.m.f. equation. Leakage reactance. Vector diagrams for no-load and full-load conditions. Referred quantities. Losses and efficiency. Open and short circuit tests. Regulation. Production of rotating field, principle of operation of polyphase induction motor. Types of rotor, squirrel [illegible] and wound type. Methods of starting.

[illegible] synchronous motor - effect of load and power factor.

Application of silicon-cont[illegible]d rectifiers to speed control.

Rectification of alternating current, inversion of direct current.

7. Storage of energy

Fuel stockpiles, degradation and safety problems.

Pumped storage in hydro-power systems.

Flywheels, hydraulic accumulators, compressed air receivers.

Heat storage, application of regenerative processes.

Electrical energy storage in capacitors, inductors and secondary cells.

8. Economics of power and selection of power systems

Elementary notions of energy availability and thermo-economics.

Comparative fuel costs and transport charges. Electricity tariffs - off-peak and peak demand factors, power factor improvement.

Combined thermal and electrical requirements - use of pass out and back pressure turbo-generators.

Restriction on electrical plant imposed by fire and explosion hazards.

DEPARTMENTAL SUBJECTS

FOURTH YEAR - CHEMICAL ENGINEERING - SUBJECT I

CHEMICAL ENGINEERING PRINCIPLES

This is one of the key subjects for chemical engineers, since the solution to the material and energy balance is nearly always the first step in the design or analysis of a process. It is largely a subject devoted to training in techniques of calculation, estimation and prediction based upon physical chemistry and thermodynamics. It is essential that potential chemical engineers should be well versed in these techniques.

SYLLABUS

1. Stoichiometry

(Application of the basic laws of chemical combination to industrial-scale operations. This should not occupy much time).

1. Use of molar quantities, composition relationships in chemical reactions.
2. Degree of completion of reaction. Excess reactants.

2. Material balances

(About one fifth of the course should be devoted to this with particular emphasis on sub-sections 2 and 3. Much practice in problem solving is usually necessary).

1. Material Balances - steady state without reaction.
   Selection of key component.
2. Steady state with reaction. Combustion calculations.
3. Recycle problems and unsteady-state balances.

3. Energy balances

(This follows easily provided the student has assimilated his basic chemistry and physics from the first year, and mastered the techniques in section 2).

1. Heat capacities of gases, liquids and solids.
2. Heat of fusion, transition and vaporization and methods of correlation and prediction.

3. Heats of reaction, formation and solution.

4. Heat and total energy balances.

4. Physico-chemical properties

(The emphasis here is on the correlation and prediction of data and their use in engineering situations. Thus stress should be laid on simple relationships and their application rather than on sophisticated and complex physico-chemical derivations.

1. Partial pressures, vapour pressure, composition of gas/vapour mixtures. Humidity charts.
2. Raoult's Law, Henry's Law, vapour/liquid equilibria. Non-ideal systems, fugacity and activity co-efficients.
3. Adsorption equilibria. Freundlich, Langmuir and B.E.T. isotherms.
4. Heats of reaction and the equilibrium constant.

5. Industrial Chemistry

(A descriptive treatment of the more important processes for producting a range of commoner chemicals likely to be encountered or used industrially).

Production processes for the following:

(a) Heavy inorganic chemicals
(b) Heavy organic chemicals
(c) Petrochemicals
(d) Polymers
(e) Pharmaceutical compounds.

BIBLIOGRAPHY

(a) Specific

Chemical Process Principles, Hougen, Watson, and Ragatz; (Vol. I) John Wiley.

Physico-Chemical Calculations in Science and Indus   Fromherz, Butterworth

Chemical Process Industries, Shreve, Mc

(b) General and Reference

Properties of Liquids and Gases, Sherwood and Reid, McGraw-Hill.

Material and Energy Balances, Schmidt and Lizt, Prentice-Hall.

Industrial Chemistry, Riegel, Reinhold.

FOURTH YEAR - CHEMICAL ENGINEERING - SUBJECT 2

UNIT OPERATIONS I

This subject introduces chemical engineering process ideas, and applies the basic material from previous years to some of the more important and frequently occurring chemical engineering operations. It is important to show the essential similarity between the three operations of momentum, heat and mass transfer. The material covered here will form the basis for much of the work in the fifth year.

SYLLABUS

1. Fluid/Solid Operations

(This is intended to be an introductory treatment following upon notions developed in Fluid Flow in the third year. However, quantitative relationships should be developed (although in sub-section 4 these will have to be semi-empirical). The time should be equally divided between the first two sub-sections and the rest.)

1. Introduction to boundary layer theory; relative flow of fluids past solids.
2. Motion of a single particle. Stokes' law and its limitations.
3. Sedimentation and elutriation in gases and liquids.
4. Single and two phase flow (co - and - counter-current) through porous media.
5. Fluidization in gases and liquids, bubble formation, limiting velocities.
6. Flow of mixtures of solids and fluids.
7. Filtration: constant pressure, constant volume, continuous filtration.
8. Dust collection by filtration and impaction.

2. Heat Transfer Operations

(This follows on naturally from third-year work and is the application of principles developed there to process equipment performance and design. Sub-sections 1 and 2 are introductory and define terms; and the main emphasis should be on the remaining sub-sections).

1. Liquid/liquid, gas/gas and liquid/gas heat exchangers.
2. Heat transfer with change of phase. Reboilers, forced and natural circulation. Condensers, horizontal and vertical.
3. Evaporation, single stage. Elevation of boiling point effect. Multistage evaporation. Thermo-compression.

4. Heat Transfer in packed beds and in fluidized systems.

5. Introduction to furnace design.

3. <u>Diffusional Operation</u>

(This introduces mass transfer for the first time and therefore the treatment is intended to be very largely theoretical. Particular emphasis should however be given to sub-section 5).

1. The mechanism of mass diffusion, Fick's law. Diffusivity in gases, liquids and solids.
2. Concentration boundary layer. Equations of mass diffusion in stationary media. Mass diffusion with convection.
3. Diffusion in turbulent flow. Eddy diffusivity.
4. Extension to mass transfer of the analogy between transfer of momentum and heat.
5. Interphase mass transport, rate equations and the mass transfer coefficient.

BIBLIOGRAPHY

See "Fifth Year - Chemical Engineering - Subject 1" Unit operations II.

FOURTH YEAR SUBJECT/ELECTRICAL ENGINEERING - SUBJECT I

ADVANCED ELECTRICAL THEORY

This subject is a continuation and extension of the basic electrical engineering theory introduced in the third year. This is necessary not only to consolidate the previous understanding but also to provide a sound basis for later specialist studies in the fifth year. Particular attention should be paid to the section dealing with the 'h' parameter, and practical work on the determination of this by the student for transistors working in various configurations is important.

SYLLABUS

Ampere's law of force on current carrying conductors. Magnetic induction in time-varying fields. Dimensional analysis. Magnetic circuits, including effects of remanence and saturation. Non-linear elements in circuits. Three terminal networks, active and passive. Four terminal networks, active and passive, introducing T, π, h, Z and Y parameters. Introduction to filter theory.

Mesh and nodal analysis.

Harmonic analysis. Fourier series. Complex waveforms applied to linear circuits. Harmonic resonance effects.

Power factor correction for single - and three-phase circuits. Unbalanced loads. Millman's theorem.

A.C. bridges including frequency-dependent bridges and high-voltage measurements.

Square-law devices and instruments.

Wattmeters. Power measurement in 3-phase 3-wire and 3-phase 4-wire systems.

BIBLIOGRAPHY

Linear Feedback Analysis, J.G. Thomason, Pergamon Press.

Electric Circuit Theory, Benson, Arnold.

Electronic Engineering, Alley and Atwood, Wiley.

Handbook of Line Communication, Royal Corps of Signals, H.M.S.O.

Electronics, Millman & Seeley, Wiley.

A.C. Bridge Measurements, Hague, Pitman.

Electrical Circuits, Including Machines, Draper, Longmans.

FOURTH YEAR - ELECTRICAL ENGINEERING - SUBJECT 2

ELECTRICAL PLANT - DESIGN AND PERFORMANCE OF A.C. MACHINES

In the fourth-year subject "Transmission and Application of Power", all groups study the production and conversion of electrical energy in fairly general and practical terms. It is clearly essential for the electrical engineering students to go into greater depth in this particular topic and this is the object of this syllabus.

These students will have to build upon the previous work in electrical theory and to study in detail the design, application, and utilization of electrical machines and plant to fit them for their specialty.

SYLLABUS

1. The mercury-arc rectifier, connections. Output voltage, transformer ratings, inverted operation. The ignitron. The silicon-controlled rectifiers.
2. Induction motors, pole changing, cascade operation. 3-phase variable speed a.c. commutator motor. The principles and characteristics of Schrage and snunt-stator-fed types.
3. ... phase motors - principles and characteristics of induction series, reluctance and repulsion motors.
4. Synchronous motor. Methods of starting, V-curves, power factor improvement. Synchronous induction motor.
5. D.C. motor speed control. Use with grid-controlled rectifier. The Ward-Leonard system of speed control.
6. Induction and dielectric heating. Importance of ... high-frequency A.C. supplies; h.f. and r.f. generation, the inductor-type alternator. Associated cooling problems and their solution.
7. Instrument transformers. Current transformer and potential transformer. Auto-transformer and Scott-connected transformer. Core-type and shell-type transformers, methods of cooling and breathing. Saturable reactors, applications of.
8. Alternators. The salient pole and turbo-type alternator, breadth factor, pitch factor, e.m.f. equation. Types of winding. Basic design problems. Effect of increased excitation. Estimation of regulation.
9. Rotating d.c. amplifiers. Cross-field generators, metadyne and amplidyne.

10. Types of switch gear. Oil-immersed circuit breakers. Switch gear, protection, overload and earth leakage. Rupturing capacity, inverse current relays.

BIBLIOGRAPHY

Applied Electricity, A.W. Hirst, Blackie (London).

Design and Performance of A.C. Machines, M.G. Say, Pitman.

Performance and Design of A.C. Commutator Motors, E. Openshaw, Taylor, Pitman.

Alternating Current Machines, Prof. E. Cotton, Cleaver-Hume.

Advanced Electrical Power and Machines, Brosan and Hayden, Pitman.

Electrical Machines, Draper, Longmans.

The General Theory of Electrical Machines, Adkins, Chapman and Hall.

FOURTH YEAR – MECHANICAL ENGINEERING – SUBJECT 1

STRENGTH OF MATERIALS

In the first semester of the fourth year this subject is studied by the mechanical engineering students.

The ability of engineers to design equipment to sustain loads or hold fluids under pressure is of considerable value when modifications of existing equipment are called for. The basic analysis of loaded components which this syllabus contains provides an adequate basis for examining many such modification problems.

The subject is well suited to both analytical and experimental techniques including the use of computers and analogues. It is intended that the experimental work should be of a very diverse nature, using conventional test equipment together with strain-gauge apparatus and photo-elastic benches. Full use is to be made of the mathematical ability developed in the student during the first three years of the course.

Like many analytic subjects there is a danger that the treatment may tend to become over-academic. To counter this trend and also as part of the policy of establishing links between the Engineering School at Seville and local industry, the staff responsible for this course should seek to establish a flow of actual problems in this topic which have arisen in industry. Such problems should be presented to the students as far as possible in the context in which they have arisen.

SYLLABUS

1. Beam Theory

Elastic analysis of beams, beam reinforcement.

Plastic theory of bending of beams, plastic hinges and moment of resistance.

Collapse load analysis of simple frames.

2. Two dimensional stress systems

Determination of principal planes, principal stresses and maximum shear stress.

Analysis of two dimensional strain systems.

3. Struts

Elastic stability of struts.

Eccentrically and laterally loaded struts.

4. Thick cylinders

Analysis of thick cylinders, shrinkage and press fit allowances.

5. Strain Energy

The concept of strain energy.
Strain energy in tension, bending, torsion and complex stress systems.

6. Component failure

Theories of mechanical failure, design criteria.

7. Stress concentration

Introduction to stress concentration.

Application to design for endurance for components subjected to cyclic loading, use of half-range mean-stress diagram.

8. Stress superposition

Principle of stress superposition.

Application to stresses in rotating discs.

9. Experimental stress analysis

Strain gauges, brittle lacquer, photoelasticity.

Interferometric measurement of small deflections.

Use of models and analogues.

BIBLIOGRAPHY

General

Timoshenko S.P., Elements of Strength of Materials, Van Nostrand, 1962.

Crandall S.H. and Dahl N.C., An Introduction to the Mechanics of Solids, McGraw-Hill, 1959.

Singer F.L., Strength of Materials, Harper, 1962, 2nd Edition.

Specific

Hetenyi M., Handbook of Experimental Stress Analysis, Wiley, 1950.

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FOURTH YEAR - MECHANICAL ENGINEERING - SUBJECT 2

DYNAMICS OF MACHINERY

This subject is taken by mechanical engineering students in the second semester of the fourth year.

All mechanical engineers are concerned with equipment containing parts whose motion ranges from simple rotation to the complex space-time patterns required by printing or textile plant. The low damping, inherent in metals, gives rise to the amplification of periodic forces by extremely large factors. This syllabus is intended to convey the fullest realization possible of the dangers of vibration, by careful analysis of both the sources of disturbance and of the amplifying mechanical systems.

The treatment seeks to inculcate a positive approach to dynamic problems in the student by sections devoted to the modification of existing systems in order to improve their vibrational behaviour.

Once again there is to be heavy emphasis on experimental work involving the use of modern vibration transducers and associated display, measuring and recording equipment. Whenever possible, equipment should be designed to provide amplitudes of motion clearly discernible by eye so that the students' visual capacity for learning may be employed using stroboscopic techniques.

SYLLABUS

1. <u>Friction</u>

The effect of friction on the performance of machines.

Friction as a source of damping in oscillatory motion.

Friction as a vibration exciter.

2. <u>Periodic quantities in reciprocating machines</u>

Turning-moment diagrams, speed fluctuation, use of flywheels.

Reciprocating parts, balance of inertia forces.

3. <u>Rotary balance</u>

Dynamic balancing machines.

Field balancing.

4. Vibration

Free and forced vibration of multi-degree-of-freedom systems.

Vibration control, use of isolation mountings, dynamic vibration absorbers and damping units.

Introduction to coupled modes of vibration.

Transient analysis of vibrating systems, methods of isolating equipment from shock.

Transverse vibration of beams, whirling of shafts with concentrated inertias.

5. Gyroscopic motion

Precession, gyroscopic torque.

BIBLIOGRAPHY

General

Hartman J.B, Dynamics of Machinery, McGraw-Hill, 1966.

Specific

Den Hartog J.P., Mechanical Vibrations, 4th Edition, McGraw-Hill, 1956.

Jacobson L.S. and Ayre R.S., Engineering Vibrations with Applications to Structures of Machinery, McGraw-Hill, 1958.

Crede C.E., Vibrations and Shock Isolation, Wiley 1951.

II. FIFTH YEAR

DEPARTMENTAL SUBJECTS (S) AND OPTIONS (O)

FIFTH YEAR - CHEMICAL ENGINEERING - SUBJECT 1

UNIT OPERATIONS II

This subject may be regarded as the culmination in the professional education of the chemical engineer. It is the applications of the principles of separation based on mass transfer that most clearly distinguish the chemical engineer from other engineers. The importance of these operations is evident in their widespread use in such areas as the petroleum industry.

SYLLABUS

1. Stagewise operations

(This course follows on directly from the Diffusional Operations section of Unit Operations I. This is a simple concept and need not occupy more than two or three lectures.)

1. The ideal stage concept. Single - and multiple-state operation.
2. Calculation of number of stages for multi-component systems with and without reflux.

2. Differential contacting

(Some important new concepts are introduced here particularly in subsections 3 and 4 and some time should be spent on this.)

1. Cocurrent and countercurrent operation.
2. Calculation of length for differential countercurrent operation.
3. The H.E.T.P. and definition of H.T.U.
4. Calculation of N.T.U. and determination of differential height.

3. Application of Mass Transfer

(This brings together material covered in Chemical Process Principles and Diffusional

Operations with sections 1 and 2 in practical applications and should occupy about half the course. Particular stress should be given to sub-sections 1 and 5, not only because of their industrial importance, but also because they give an especially deep insight into the application of mass transfer principles.)

Application of mass transfer principles to the following:

1. Distillation.
2. Absorption.
3. Extraction.
4. Leaching.
5. Humidification.
6. Drying.

4. Non-ideal systems

(These should only be mentioned rather briefly at this stage).

1. Azeotropism, calculation of separation and application of azeotropism.
2. Non-isothermal operation. Unequal molar overflow.
3. Batch operation.

5. Mass transfer equipment

(Apart from sub-section 1, most of this section is descriptive and hence can be dealt with fairly quickly.)

1. Vapour-liquid contacting. Plate operation and design.
2. Packed tower operation and desing.
3. Application to gas/liquid contacting.
4. Design of plate and packed towers for liquid/liquid contacting.
5. The special problems of fluid/solid contacting, Shank's system. Fluidized beds.

BIBLIOGRAPHY

(for Unit Operations I and II)

(a) Specific

Chemical Engineering, Coulson and Richardson, Pergamon.

Process Heat Transfer, Kern, McGraw-Hill.

Mass Transfer Operations, Treybal, McGraw-Hill.

Les Procédés de Rectification dans l'Industrie Chimique, Dunod, Paris.

Elements of Fractional Distillation, Robinson and Gilliland, McGraw-Hill.

Absorption and Extraction, Sherwood and Pigford, McGraw-Hill.

Design of Equilibrium Stage Processes, B.D. Smith, McGraw-Hill.

Liquid/liquid Extraction, Treybal, McGraw-Hill.

Les Opérations Unitaires du Génie Chimique, Loncin.

(b) General and reference

Chemical Engineer's Handbook, Perry, McGraw-Hill.

Petroleum Refinery Engineering, Nelson, McGraw-Hill.

Pilot Plants, Models, and Scale-Up, Johnstone and Thring, McGraw-Hill.

Cooling Towers, McKelvey and Brooke, Elsevier.

Applied Process Design, Vols. I, II, and III, Ludwig, Gulf.

FIFTH YEAR - C[illegible]ICAL ENGIN[illegible]ERING - SUBJECT (2)

APPL[illegible]D [illegible]ERMOD[illegible]AMICS

The chemical engineer frequently uses [illegible]hermody[illegible]amics and needs not only to know the basic laws but also to be familiar with some [illegible]f the[illegible] more important corollaries. This course introduces a number of extensions [illegible]f [illegible]rlier [illegible]rinciples and emphasizes their application to common chemical engineering [illegible]blems.

S[illegible]LABUS

1. Thermodynamics of gases and liquids

(Following a definition of ideal gases, the concept of fugacity is introduced. This continues with equations of state and emphasis is intended to be given to the use of these relationships to predict non-ideal behaviour. Similarly, the Gibbs-Duhem equation leads to Van Laar, Margules and other integrated forms for the solution of problems in vapour-liquid equilibria. This section should occupy almost one third of the course)

The perfect gas mixture.

The fugacity of a single imperfect gas and of a component in an imperfect gas mixture.

Temperature coefficient of the fugacity and stand[illegible]rd chemical potential.

Equations of state and their application to the prediction of intensive properties.

Gas/liquid mixtures. The Gibbs-Duhem equation and its integrated forms. Prediction of non-ideal equilibria.

2. Equilibria of reactions involving gases

(This deals with the calculation and use of the equilibrium constant. Methods of determining this parameter from heats of reaction, free energy of formation, and enthalpy data are covered and applications of equilibrium values considered. This should also occupy about one third of the course.)

The stoichiometry of chemical reaction.

The equilibrium constant for a gas reaction.

Free energies; remarks on simultaneous reactions.

3. Reaction equilibrium in solution - electrolytes

(The ideas of the previous section [illegible] extended to solutions including ionic solutions.

The treatment, although quantitative, will be fairly elementary avoiding undue emphasis on physical chemistry aspects).

Free energy of formation in solution.

Dissociation equilibrium and the chemical pote· l of an electrolyte.

Activity coefficients; phase equilibrium of an electrolyte.

Limiting behaviour at high dilution.

4. Non-equilibrium thermodynamics

(A brief introduction to the new ideas of non-eq ilibrium thermodynamics indicating some of the possible future developments and applications.)

Entropy law and entropy balance.

The phenomenological equations.

Applications - thermal diffusion and Dufour effect.

BIBLIOGRAPHY

1) Heats of reaction and free energy of formation

The thermodynamics is dealt with in many books, the treatment in "Thermodynamics" by Vanderslice, Schamp and Mason, Prentice-Hall, 1966, being easy to follow.

2) Chemical Equilibrium

In addition to Vanderslice, Schamp and Mason which could be used for introductory material, Principles of "Chemical Equilibrium" by Denbigh, Cambridge U.P., 1955, gives a thorough coverage of this topic.

3) (Phase) Equilibria and Chemical Potential

(Chemical potential and partial molar quantities in general ought to appear earlier because the concept is needed for (2)).
Again the elements of the topic are well covered in Vanderslice, Schamp and Mason. For developments in terms of fugacities and activity coefficients reference could be made to Denbigh and "Chemical Engineering Thermodynamics" by Dodge, McGraw-Hill, 1944, and to Pitzer and Brewer's revision of Lewis and Randall's classic, McGraw-Hill, 1923.

From the chemical engineering point of view this is the field of fastest development and mention should be made of the recent developments. Some references of interest are

Wilson, J. Am. Chem. Soc. 127, 86, 1964.

Wilson and Deal, I.E.C. Fundamentals 20, 1, 1962.

Black, I.E.C., 391, 50, 1958 and 211, 51, 1959.

Ellis and Bourne, Brighton Symphosium on Distillation, 1960.

Pierotti, Deal and Derr, I.E.C., 95, 51, 1959.

Redlich and Kister, I.E.C., 341, 40, 1948.

Wohl, Trans. American Institution of Chemical Engineers, 215, 42, 1946.

Other books of interest

Keenan, Thermodynamics.

Zemnansky, Heat and Thermodynamics. McGraw-Hill.

Keenan and Hatsopoulos, Wiley.

Tribus, Thermodynamics and Thermostatics, Van Nostrand.

Hala, Pick, Fried and Vilim, Vapour-Liquid Equilibrium, Pergamon, 1958.

Reid and Sherwood, Properties of Gases and Liquids, McGraw-Hill, 1966.

FIFTH YEAR - CHEMICAL ENGINEERING - OPT N (3)

CHEMICAL REACTION ENGINEERING

Chemical reaction engineering is concerned with studying the types of chemical reactions often found in practice, and with discovering mathematical relationships which can describe them. The flow patterns in the various types of chemical reactors and their influence on the reactor's performance is also studied. These two line of investigation are brought together in this subject to enable reactors to be designed to give good performance.

SYLLABUS

1. Kinetics of homogeneous reactions

(The more usual kinetic models are presented to the student and he is shown how the type of reaction may be inferred from experimental results on batch and on continuous flow reactors.)

Kinetic models for elementary and non-elementary reactions.

Interpretation of batch reactor data.

Interpretation of flow reactor data.

2. Introduction to reactor design

(This introduces the principal types of chemical reactor, examines the influence of temperature and pressure and then goes on to deal with residence time problems. This is the most important section of the syllabus and should occupy slightly more than one half of the course).

Single ideal reactors.

Multiple-reactor systems.

Temperature and pressure effects.

Residence time distributions.

Non-ideal flow and mixing of fluids.

3. Kinetics of Heterogeneous Systems

(Thus far the treatment has been limited to homogeneous systems. The final part of the course (about one-third) considers both non-catalytic and catalytic reacting systems with mixed phases.

After introducing heat and mass transfer restrictions on the reactor, the applications of design are considered. The treatment should be selective in order to give depth and should remain quantitative throughout).

Non-catalytic fluid/solid reactions.

Heterogeneous fluid/solid reactions.

Solid-catalised fluid reactions.

Heat and mass transfer in reactors.

Applications to the design of chemical reactors.

BIBLIOGRAPHY

(a) Specific

Chemical Reaction Engineering, Levenspiel, John Wiley.
Reaction Kinetics for Chemical Engineers, Walas, McGraw-Hill.

(b) General and Reference

Chemical Reaction Engineering, Rietema, Pergamon.
Chemical Engineering Kinetics, J.M. Smith, McGraw-Hill.
Chemical Reactor Design and Operation, Kramers and Westerterp, Chapman and Hall.

FIFTH YEAR - CHEMICAL ENGINEERING - OPTION (4)

PARTICLE TECHNOLOGY

The behaviour of particulate materials is one of the great undeveloped areas of engineering. The difficulties of analytical treatment have led to its neglect by many teachers but the handling of granular materials is so widespread and important that it must come into a sound chemical engineering curriculum.

SYLLABUS

1. Introduction to the meaning and scope of particle technology

(Since all subsequent material and particle operations depend on a knowledge of size, considerable stress should be laid on this section).

1. Definition of a particle.
2. Particle sizing and counting methods.
3. Significance of distributions. Shape factors, dynamic and geometric sizes.

2. Production of particles

(This is largely descriptive and hence need not occupy much of the course. Only simple empirical relationships should be given).

1. Coarse crushing; types of crushers and their characteristics.
2. Fine crushing; grinders, micronizers, ball mills.
3. Precipitation.

3. Applications of interactions between particles and fluids

(This covers most of the industrially important operations concerned with particulate solids and should occupy about half the total course. Particular emphasis should be given to subsections 1 and 4).

1. Separation of solids from liquids
   (a) sedimentation
   (b) filtration
   (c) centrifuging

2. Separation of solids from gases:

   (a) gas cleaning

   (b) electrostatic precipitation

   (c) impact scrubbing

   (d) filtration

3. Liquid droplets:

   separation and filtration

4. Flow through packed beds, voidage, theories of flow. Application to real system.

5. Fluidization:

   (a) gas

   (b) liquid

   (c) Three phase

4. Storage and conveying and mixing of powders

(A generalized and largely descriptive treatment is implied here mainly to introduce the student to some of the problems in this area).

Bulk properties of powders.

BIBLIOGRAPHY

(a) Specific

Small Particle Statistics, Herdan, Butterworths.
Comminution, Bela Béke, Budapest University.
Fluidization, Leva, Rheinhold.

(b) General and Reference

Physics of Flow through Porous Media, Scheidegger.
Mixing, Kubacêk, Pergamon.

FIFTH YEAR - CHEMICAL ENGINEERING - OPTION (5)

PROCESS DYNAMICS

Process dynamics, as a new topic in its own right, is of very recent development but is rapidly growing in importance. It is studied particularly by chemical and electrical engineers, but the treatment required by the former is markedly different. This difference arises from the nature of the processes studied and applied in industry by chemical engineers.

SYLLABUS

1. Definitions

(This introduces the notions of control and control loops in the chemical and process industries. Little mathematical treatment is necessary at this stage).

The closed loop, first and second order derivatives.

First and second order processes. Damping.

Interacting and non-interacting stages.

2. Analysis

(Mathematical and statistical methods for the examination of processes. This is a major section of the syllabus).

Block diagram algebra, polar plots, Nyquist criteria.

Frequency-response techniques on process loops.

Behaviour of open process loops.

3. Processes

(The techniques of the previous section together with that of frequency-response analysis are now applied to real processes. Further and more advanced mathematical models are introduced. This section should occupy about half the total time for this subject).

Behaviour of steady-state processes.

Residence time distribution.

Derivation of equations for solids handling, transport processes and chemical reaction. Applications of digital control.

Use of lumped parameters, Markov processes and other mathematical models.

4. Optimization

(Introduction to the meaning of optimization and simple examples of application. Only a brief treatment is intended).

Static and dynamic optimization.

Introduction to simple ideas of hill-climbing and search procedures. Pontryagin's principle.

BIBLIOGRAPHY

(a) Specific

Process Dynamics, Campbell, John Wiley.
Process Control Systems Design, Young, Butterworths.

(b) General and Reference

Dynamic Programming, Roberts.
Process Optimization, Rosenbrock and Storey.

FIFTH YEAR - CHEMICAL ENGINEERING - OPTION (6)

SEPARATION PROCESSES

Separation processes is one of the key subjects in chemical engineering, applying, as it does, the theories of mass, heat and momentum transfer to the techniques of separating mixtures of substances.

This syllabus is designed to go beyond the usual treatment of the commoner operations such as distillation and extraction.

First it emphasizes the essential unity of all mass-transfer separation-processes and then goes on to study in detail some of the more important newer techniques.

SYLLABUS

1. Transport theory

(A detailed and sophisticated treatment of modern transport theory including three-dimensional work. About one quarter of the course).

Momentum, thermal and concentration boundary layers.

Definition of mass transfer coefficients. Theories of interphase transfer and overall coefficients.

Differential separation theories.

2. Separation analysis

(A brief review of definitions followed by a quantitative treatment including multi-component systems).

Analysis in terms of stages.

Analysis in terms of differential lengths. The basic unity of methods of calculation.

3. Separation applications

(The application of principles adduced in sections 1 and 2 to the processes listed. This will be a quantitative and design section and should occupy about half the course).

Differential and adductive crystallization.

Zone melting.

Electrodialysis.

Sorptive processes, including ion-exchange.

Foam separations.

BIBLIOGRAPHY

(a) <u>Specific</u>

Separation Process, Schoen, McGraw Hill.

(b) <u>General and Reference</u>

Zone Melting, Pfann.
Crystallization, Mullin, Butterworths.
Ion-Exchange Technology, Nachod and Schubert, Academic Press.
Demineralization by Electrodialysis, Wilson, Butterworths.
L'Echange d'Ions et les Echangeurs, Austervel, Gauthier Villars.
Diffusion and Membrane Technology, Tawiner, Reinhold.

FIFTH YEAR - CHEMICAL ENGINEERING - OPTION (7)

MATERIALS TECHNOLOGY

The chemical engineer requires a wide knowledge of materials used for the construction of the process equipment for which he is responsible. Moreover, he is particularly suited by virtue of his training to be concerned with the design and operation of processes whereby metals are extracted from their ores and refined. Thus materials technology is a valuable optional subject to have in the fifth year.

SYLLABUS

1. Metallic materials

(This deals with the extraction of metals from their ores including their beneficiation and emphasising especially the physico-chemical and chemical engineering aspects. The refining of crude metals and their alloying is also dealt with).

Extraction of metals from their ores.

Iron and ferrous alloys.

Non-ferrous metals and alloys.

Methods of metal fabrication and their effect on properties.

2. Inorganic non-metallic materials

(This section considers clays and ceramic materials derived therefrom and emphasizes the special nature of the chemical engineering operations involved and the particular use of the products. Similarly with sand and cements and the related concrete materials. Since much of this material is descriptive, a lot of reading should be left to the individual students).

Minerals, clay, and related materials.

Sand, mortar, and cements.

Concrete.

3. Organic materials

(Here the emphasis is on the production processes for these materials and upon their special uses and application in the chemical engineering industries).

Plastics.

Rubber.

Organic coatings.

Wood.

BIBLIOGRAPHY

(a) Specific

Materials of Engineering, Keyser, Prentice-Hall.
Chemistry of Engineering Materials, Leighon, McGraw-Hill.

(b) General and Reference

Materials Handbook
Technology of Cement and Concre[illegible] Blanks and Kennedy, John Wiley.
Organic Protective Coatings, Fis[illegible] and Babalek, Reinhold.
Glass Engineering Handbook, Shand, McGraw-Hill.
Ceramic Fabrication Processes, Kingery, John Wiley.

FIFTH YEAR - ELECTRICAL ENGINEERING - SUBJECT 1

CONTROL SYSTEMS II (S)

This syllabus content is intended to provide a good understanding of the methods of analysis applicable to non-linear and sample-data systems together with a study of some of the techniques used in system design.

In addition, it is suggested that about one-third of the time available should be devoted to self-contained groups of lectures (4 to 6 lectures in a group) selected from a range of subject headings. In any one year's course perhaps three or four topics could be covered.

SYLLABUS

1. Non-Linear Systems

   Describing function analyses (or the first harmonic approximation), phase-plane techniques.

2. Design

   Series and feedback compensation methods using pole-zero diagrams and frequency-response charts. Multi-loop systems. Non-linear system design. Optimum response.

3. Sample-Data Systems

   Linear sample-data systems. Z-transforms, frequency analysis.

Suggested Topics for Lecture Groups

State variable representation of systems.

Lapunov stability criteria.

Introduction to variational problems and the maximum principle.

Dynamic programming.

Review of optimum-seeking methods.

Stochastic processes.

Analogue computers (hybrid) in optimum simulation.

This list is not exhaustive; other topics from "modern" control theory could be treated in the same way.

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General - In English

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Chestnut and Mayer, Servomechanisms and Regulating System Design, Wiley, 1959.

Kov, Automatic Control Systems, Prentice-Hall, 1962.

Newton, Gould and Kaiser, Analytical Design of Central Feedback Controls, Wiley, 1957.

Tov, Modern Control Theory, McGraw-Hill, 1964.

Athans and Falb, Optional Control, McGraw-Hill, 1966.

General - In French

Nascin, Les Systèmes Asservis, Revue d'Optique.

Gille Peleckin et Decaulne, Théorie et Technique des Asservissements, Dunod (also published in English, German and Polish).

Special

Laning and Battin, Random Processes in Automatic Control, McGraw-Hill, 1956.

Jury, Sample Data Control Systems, Wiley, 1958.

Bellman, Dynamic Programming, Princeton, 1957.

Leitmann, Optimization Techniques, Academic Press, 1962.

Noton, Introduction to Variational Methods in Control Engineering, Pergamon, 1965.

Korn and Korn, Electronic Analogue and Hybrid Computers.

CONTROL SYSTEMS LABORATORIES

For Control Systems I, it would be desirable to have a medium-sized analogue computer (20 amplifiers - half of them integrators) which can be used to simulate the type of systems discussed in the lectures. In addition to this it would be sufficient to provide several kits of components from which practical systems can be built and tested (a number of firms provide such kits, e.g., Feedback Ltd. and Servo-kits).

For Control Systems II, the analogue machine should be extended to include non-linear functions such as multipliers, diode function generators and diode limiting circuits. A noise generator would be required and a range of logic elements.

FIFTH YEAR - ELECTRICAL ENGINEERING - SUBJECT 2

ADVANCED ELECTRICAL ENGINEERING

This subject takes the students to the boundaries of knowledge in their specialized subject. The field theory and network theory presented are both important for the applications of light and heavy current electrical engineering.

Whilst a thorough treatment of theoretical principles is presented it is important to illustrate these at all times with practical applications, particulary in the laboratory exercises.

SYLLABUS

1. Field theory

Method of images in electrostatic problems. Capacitance calculations using mapping methods. Solution of boundary value problems. Flux plotting and electrolytic tank. Vector potential. Further problems on the magnetic circuit . Time-dependent and space-dependent fields, Poynting vector.
Transmission lines and waves. Plane waves. Waveguides and resonators.
Radiation and aerials. The electron in time-varying electric and magnetic fields.
Effect of space charge. Cavity resonators.

Introduction to principles of Rhumbatron, Magnetron and Klystron.

2. Network theory

Foster's reactance theorem and design of filters.

Synthesis procedures.

Power and communication network systems.

Transient and steady state conditions, the 'D' operator and 's' operator.

Response of networks to sinusoidal and non-sinusoidal e.m.f.s.

Laplace transforms.

Multimesh networks; mutual inductance-circulating current conception of networks.

3. Network theorems

Superposition - applications to:

a) generators and transformers

b) polyphase systems

c) non-sinusoidal e.m.f. sources

d) power distribution systems.

4. Reciprocity theorems

Applications to :

a) bridge networks

b) hybrid or differential transformer

c) electromagnetic radiation.

5. Thevenin's theorem

Applications to :

a) bridge networks

b) electronic amplifier circuits

c) transformers in parallel

d) power distribution systems.

6. Compensation theorem, applications, Norton's theorem.

7. Power transfer theorem, principle of impedance matching.

8. Two-port networks, La Cour's theorem.

9. Symmetrical components: introduction to generalized machine theory.

BIBLIOGRAPHY

An Introduction to Advanced Electrical Engineering, C. Jones, English Universities Press.

Advanced Electrical Engineering, A.H. Morton, Pitman.

Electric Theory Analysis, Mittleman, Iliffe.

Matrix and Tensor Analysis on Electrical Network Theory, Stigant, MacDonald.

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FIFTH YEAR - ELECTRICAL ENGINEERING - OPTION 3

APPLIED ELECTRONICS

Applied electronics may be thought of as the culmination of the professional education of the electrical engineer who is going to be interested especially in light current engineering.

It brings together the theoretical work developed earlier in the electrical and mathematics syllabuses with applications to modern electronic devices in a fundamental treatment enabling these systems to be analysed and applied in industry.

SYLLABUS

1. Noise in amplifiers: limitations on signal detectability resistance noise, valve noise, transistors noise, low noise amplifiers.

2. Overdriven amplifiers: applications; clipping and shaping.

3. Equivalent circuits for transistors: 'T' equivalent circuit, 'h' parameters (see 4th year subject, Advanced Electrical Engineering), 'y' parameters, 'Z' parameters.

4. Analysis of linear electronic circuits from an advanced viewpoint, matrix analysis, signal flow graphs. Cascade and similar circuits.

5. Delay-line oscillators, ringing in chokes, squegging.

6. Bisection theorem and symmetrical networks.

7. Current - and voltage-controlled negative resistance.

8. Advanced pulse techniques. Linear and overdriven pulse amplifiers.

9. Charge storage. Charge-control parameters and their application.

10. Unijunction and p - n - p / n - p - n devices.
    Field-effect transistors: theoretical background and comparison with other active devices.

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11. Monolithic and thin and thick film integrated circuits, evolution from conventional circuits, principles underlying their application, compensation of offset voltages.

12. Modification of overall transfer function by external components and connections.

13. Transducers; microphones, pick-ups, loudspeakers and vibration generators. Magneto-striction oscillator.

14. Photo-electric devices and their applications. Cold cathode tubes.

15. Silicon-controlled rectifiers and applications.

BIBLIOGRAPHY

Fundamental Electronics, Ledger and Roche, Blackie.

Thermionic Valve Circuits, Williams, Pitman.

Electronic Fundamentals, Applications, Ryder, Pitman.

An Introduction to the Theory and Practice of Transistors, Tillman and Roberts, Pitman.

ELECTRICAL ENGINEERING - 5TH YEAR - OPTION 4

COMMUNICATION ENGINEERING

The importance of communications in the future technological society need hardly be stressed and it is clear that the electrical engineer will play and increasingly important part in this development. This syllabus stresses the applications of basic principles learnt earlier in the course to communication engineering problems and extends the treatment to include present day developments of importance.

Practical work the supplement the treatment should emphasize the various types of carrier systems of which everyday examples can be found.

SYLLABUS

Circuit theory, repeated 'T' and 'π' networks.

Transmission line theory.

Aerials and propagation.

Carrier systems.

U.H.F. and microwave techniques

BIBLIOGRAPHY

Telecommunications, Starr, Pitman.

Communication Engineering, Evertitt and Anner, McGraw-Hill.

Communications Engineering, Defrance, Prentice-Hall.

Telecommunications, Fraser, McDonald.

ELECTRICAL ENGINEERING - 5TH YEAR - OPTION 5

HIGH VOLTAGE TRANSMISSION

This subject is likely to be of considerable importance to the growing economy of the country, and is therefore worthy of inclusion in the course for electrical engineers. At the same time, it is sufficiently specialized to be included as an optional rather than compulsory study at this level. It will be of particular value to those students who are likely to be concerned with mains engineering.

SYLLABUS

Short transmission lines.

Hyperbolic solution for long lines.

General circuit constants.

Circle diagrams for constant voltage transmission lines.

Load studies; networks.

Short circuit currents and stability.

Travelling waves.

Skin effect in round conductors.

Cost of resistance loss.

Current-carrying capacity and temperature rise.

Geometric mean distance.

Reactance.

Capacitance.

Projection.

Sag calculations.

Economic assessment of transmission systems.

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ELECTRICAL ENGINEERING - 5TH YEAR - OPTION 6

ELECTRIC TRACTION

This subject treats of the application of electrical engineering to transport particularly in railways, trolley buses and subways. This is likely to be of future importance especially to the students concentrating on heavy current engineering.

SYLLABUS

General considerations, present position and merits of electric traction in comparison with alternative methods.

Comparison of merits of a.c. and d.c. systems.

Mechanics of train and vehicle movement, accelebation, resistance to motion, effect of gradients. Simplified speed-time curves.

D.C. traction motors; construction, characteristics, and testing.

Special points and limitations in design.

A.C. traction motors; principles of operation. Single and 3-phase types. Construction.

Motor control; method and appliances for d.c. motors in trolley buses, locomotives.

Method of control of a.c. motors.

Speed-times curves; deduction from motor and vehicle characteristics.

Electric braking; rheostatic and regenerative braking.

Mounting and coupling of motors. Hand and power brakes.

Contact systems; overhead and third-rail systems.

Feeder and distributor arrangements. Substation locati n. Automatic operation.

Battery and internal - combustion electric vehicles.

ELECTRICAL ENGINEERING - 5TH YEAR - OPTION 7

GENERALIZED MACHINE THEORY

This treats all machines in terms of a unified general theory and emphasizes the fundamental similarities of all electrical machinery.

It is of use in design and manufacture of such equipment but takes the subject to an advanced level.

SYLLABUS

Voltage and Torque equation for basic electrical machines.

Measurement of self, mutual, and rotational inductances.

Saturation hysteresis and eddy currents.

Applications of matrix algebra.

Orthogonal passive transformations.

Symmetrical component transformation.

Phase transformations.

Equivalent circuits and vector diagrams.

Analysis of transient performance.

Slip-ring machines.

Induction motor; phase transformation.

Synchronous machine; phase transformation.

Commutator transformation.

Induction motor; symmetrical components transformation.

Synchronous machine. Balanced steady-state operation.

Synchronous machine. Transient and unbalanced operation.

Commutator machines.

Commutator primitive machine.

Simple d.c. machines.

Cross-field d.c. machines.

Single-phase commutator motors.

Three-phase commutator mechanics.

Schrage motor.

FIFTH YEAR - MECHANICAL ENGINEERING - SUBJECT (1)

PRINCIPLES OF MANUFACTURE

This subject is studied by mechanical engineering students in the first semester of the final year.

Many students when they leave Seville will find themselves concerned with production problems in either engineering or process industries. The establishment of product quality compatible with production efficiency can be achieved by engineers who have an insight into the somewhat specialized techniques contained in this syllabus.

Wherever possible the syllabus is to be brought to life by experimental work which represents real problems as far as it is possible. Quantity production sufficient to illustrate quality control will require the manufacture of small and inexpensive components or alternatively it may be possible to supply a particular component to an industrial user. The nature of this syllabus is far better served by the l er alternative and it is hoped that this subject will be based on the close cooperation with suitable industries.

SYLLABUS

1. Fundamentals of manufacture

    Basic processes of forming, generating and fabricating.

    Economics and accuracy of manufacturing processes.

2. Metrology

    Standards of length, principles of industrial measuring instruments, sources of error.

    Principles of interchangeable manufacture.

    Comparison of measurement and limit gauging.

3. Quality control

    Tolerance related to product quality and economics of manufacture.

    Statistical approach to quality control.

    Sampling methods and quality control charts.

4. Theory of metalworking

    Tool forces, power requirements and tool life related to cutting speed.

    Economics of one-off, batch and large quantity production.

5. <u>Production Costs</u>

Methods of costing and assessing cost of individual items.

Cost comparison of alternative production processes.

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Begeman M.L. and Amstead B.H., Manufacturing Processes 5th Ed., Wiley, 1963.

Beckwith T.G. and Buck N.L., Mechanical Measurements, Addison-Wesley, 1961.

Burr I.W., Engineering Statistics and Quality Control, McGraw-Hill, 1953.

Moore F.G., Production Control, McGraw-Hill, 1959.

FIFTH YEAR - MECHANICAL ENGINEERING - SUBJECT (2)

CONTROL SYSTEMS II

See Electrical Engineering, Subject I.

FIFTH YEAR - MECHANICAL ENGINEERING - OPTION (3)

REFRIGERATION AND AIR CONDITIONING

This subject is studied by mechanical engineering students in the second semester of the final year.

One of the objectives of technological education is to give students the opportunity of developing a broad approach to new situations. Earlier in the Seville course, strong foundations were laid for the final year subjects which can provide this wider view. "Refrigeration and Air Conditioning" provides a strong educational discipline on account of the many applications of these basic principles which it entails.

Such a syllabus is particularly well suited to Seville where, as industrial development continues and social standards rise, the adoption of air conditioning in factory, office, public buildings and even private houses will rapidly increase. Strong motivation is important, and the experience of students studying in similar latitudes indicates that there will be considerable enthusiasm for this subject.

Not more than a small proportion of the mechanical engineers graduating from Seville will be concerned ultimately with the design of refrigeration or air conditioning systems. Many, however, will be responsible for the installation, operation and maintenance of such equipment. The syllabus, whilst primarily concerned with a thorough theoretical understanding, does endeavour to deal with some of the operational problems. A well planned experimental programme is required to enable the students to become familiar with the actual plant involved. Visits to full scale plant in commercial premises are desirable in view of the limitation of laboratory plant, where it is difficult to provide typical load situations.

SYLLABUS

1. Refrigeration

Revision of thermodynamics of reversed heat engine cycles.

Properties of low pressure steam. Water vapour refrigeration, centrifugal and steam jet systems.

Vapour compression refrigeration cycles employing CO_2, Freon, etc. Use of temperature-entropy charts.

Component requirements: compressors, evaporators, expansion valves.

Practical aspects: purging and charging of refrigeration systems, effect of overcharging and undercharging system, types of expansion valves.

Multiple-effect refrigeration systems.

2. <u>Psychrometry</u>

Mixtures of air and water vapour, absolute humidity, dewpoint, relative humidity, dry and wet bulb temperatures.

Vapour pressure, sensible heat, latent heat, total heat, specific volume.

Psychrometric charts.

3. <u>Human factors</u>

Environment and human comfort, influence of activity on metabolic rate.

Influence of temperature, relative humidity, air velocity and clothing on the dissipation of sensible and latent heat from the body.

Comfort zones on the psychrometric chart.

4. <u>Climatic factors</u>

Statistical data on climatic conditions.

Effect of latitude on solar radiation.

5. <u>Air conditioning</u>

Use of psychrometric chart to illustrate processes.

Sensible heating and cooling, humidification, evaporative cooling, mixing. Combined cooling and dehumidification.

Estimation of air conditioning load.

Air conditioning systems, ducting and distribution problems.

Instrumentation and control.

BIBLIOGRAPHY

Sharpe N., Refrigerating Principles and Practice, McGraw-Hill.

Sparke N.R. and Dillio C.C., Mechanical Refrigeration, McGraw-Hill, 1959.

Hutchinson F.W., Design of Refrigeration Systems for Air Conditioning, Industrial Press, 1963.

Hutchinson F.W., Design of Air Conditioning Systems, Industrial Press, 1958.

Carrier Air Conditioning Company, Handbook of Air Conditioning System Design.

FIFTH YEAR - MECHANICAL ENGINEERING - OPTION (4)

FLUID ACTUATION SYSTEMS

The trend in all aspects of manufacturing industry is progressively to replace the human factor in the positioning and transport of components at various stages of manufacture. As a consequence, mechanical actuation and positioning devices are of growing importance particularly since the rapid development of quite inexpensive fluid logic now permits entirely mechanical devices to determine the sequence and interlocking of series of operations.

This syllabus provides a useful complement to the syllabuses in control engineering, but it is important to appreciate that whilst in one way it may be regarded as a supplement, the syllabus is self-sufficient for many real industrial problems.

SYLLABUS

Fluid power systems, reservoirs, pumps, filters and regulators.

Linear and rotary positioning devices, control valves.

Fluid power circuits, positional control, analysis of systems for speed of response.

Binary logic.

Fluid logic components, turbulence amplifiers and Coanda-effect amplifiers.

Construction of fluid logic systems, component loading limitations.

Modification of systems including flow-rate control valves, directional control valves, fluid sensing devices and fail-safe circuits.

Sequencing.

BIBLIOGRAPHY

Pippenger J. and Hicks T.G., Industrial Hydraulics, McGraw-Hill, 1962.

Thoma J.U., Hydrostatic Power Transmission, Trade & Technical Press, 1964.

Caldwell S.H., Logical Design and Switching Circuits, Wiley, 1958.

FIFTH YEAR - MECHANICAL ENGINEERING - OPTION (5)

METROLOGY

All mechanical engineering students in the fifth year study the rudiments of metrology in the "principles of manufacture" syllabus, and this option arises from the sophistication of present-day manufacture, and the need for a limited number of mechanical engineers with a deeper knowledge of metrology.

The importance of the engineering school at Seville makes it essential that it provides a metrology standard for engineering in the region. The unique equipment required will provide particularly strong support for this optional subject.

SYLLABUS

Kinematic design of gauges and instruments.

Pivots, hinges and ligaments used in instrument construction.

Sources of error in measurement; alignment, rigidity, flex-use, expansion.

Angle measurement, flatness, squareness, roundness and concentricity tests.

Interferometric gauge measurement; theory, equipment and methods.

Moiré fringe and holographic techniques.

Surface texture measurement.

Errors in gear manufacture; gear metrology equipment and tests.

Alignment techniques applied to machine tools.

Remote metrology e.g. ultrasonic, inductive and radiation techniques.

BIBLIOGRAPHIE

Hume K.J. and Sharp G.H., Practical Metrology (Vols. 1 - 4) Macdonald, 1955 - 1962.

Rolt F.H., Gauge and Fine Measurement, Macmillan.

Conway H.G., Engineering Tolerances. 2nd Ed., Pitman, 1962.

FIFTH YEAR - MECHANICAL ENGINEERING - OPTION (6)

LUBRICATION ENGINEERING

The functioning of almost all mechanical assemblies depends on sliding contact of mating surfaces at a number of places within the assembly. Both the correct functioning and working life of such machines depend upon correct lubrication and the minimization of wear. There is an increasing awareness that lubrication design is equally as important as lubrication maintenance, and this subject forms a suitable optional study for mechanical engineers at Seville.

SYLLABUS

Journal Bearings.

Hydrodynamic lubrication, Reynolds' equation, Ocvirk's solution for a narrow bearing.

Dynamic coefficient of oil films, instabilit regimes, influence on rotor dynamics.

Design of typical journal bearings, estimation of losses, oil flow and temperature rise calculations.

Sleeve bearing materials, metal temperature limitations, modes of failure.

Rolling contact bearings.

Herzian stresses, bearing life factors.

Lubrication and application of ball and roller bearings.

Elasto-hydrodynamic lubricati .

Lubrication of gears, modes of failure.

Chemistry of lubricants and metal surfaces.

Foaming , oxidation, sludge formation.

Corrosion, stress corrosion, electro-chemical problems, interaction of lubricant with bearing surface.

Boundary lubrication, additives.

Wear.

Mechanism of wear and of metal transfer.

Techniques of wear measurement.

Hydrostatic bearings.

Oil filters.

Efficiency and pressure loss.

Low friction materials for non-lubricated bearings.

BIBLIOGRAPHY

Fuller D.D., Theory and Practice of Lubrification for Engineers, Wiley, 1956.

Tamm P. and Ulms W., Schmierpraxis, VEB Technik Verlag, 1963.
Monograph on Design Procedures for Statically Loaded Plain Axial Bearings, Wissenschaftliche Zeitschrift der T.H. Magdeburg, No. 7 p. 243-248, 1963.

PART FOUR

MEANS

The originality of the teaching methods advocated by the experts and the new spirit in which the syllabuses are to be taught mean that the Seville School will be quite different from the other Escuelas Técnicas Superiores in Spain. The fact that the present day organization of education does not correspond to the type of training advocated will doubtless make it more difficult to carry out the recommendations contained in this report. The experts therefore considered their task would not be finished unless they had examined the question of the means to permit the new school to function and had submitted to the Minister of National Education a set of detailed recommendations for putting the school into operation.

We have already noted that pilot establi..ments, by their very nature, go beyond the legislation in force; the proper functioning of the Seville School will require the Minister of National Education to take a number of exceptional measures, and we shall show in this chapter that the type of education we have described requires different organization and facilities from those in conventional schools. Those responsible for technical education will be able to use the Seville School to test the effectiveness of the decisions taken and to reexamine the organization of the other Escuelas Técnicas Superiores as a guide to planning a general reform of technical education.

The experts' recommendations will therefore call for measures which will necessarily be temporary; such questions as the recruitment and utilization of teaching staff must be examined much more thoroughly. Some of the recommendations made here could not be generally applied to the Escuelas Técnicas Superiores without running into difficulties because of the several jobs that top level staff usually carry out in Spain. These difficulties will be felt even at the Seville School, but it is all the more necessary to apply the recommendations there so that, some time in the future, one can give concrete evidence of the usefulness and soundness of these measures.

CHAPTER XI

ORGANIZATION OF THE SCHOOL

The organization of the school should essentially be a means to meeting its objectives and should accordingly be adapted to the type of education provided. A form of organization was therefore sought that would permit the most efficient use to be made of both teaching staff and facilities; as a result, the experts recommended a number of changes to be made to the way in which the Escuelas Técricas Superiores at present function.

The method advocated by the experts differs from that normally employed in two respects: the functions of those responsible for the school's administration, and the setting up of departments. The creating of departments is, in fact, in line with the current trend in Spain, this form of organization having been adopted for the Faculties, as shown by the Act of 1965*. The experts' proposals are therefore likely to be accepted, and applied, without any difficulty, people's minds having been prepared. The experts have also studied the the composition and functions of the various advisory bodies concerned in the school's administration, and drew attention to the potential importance of the role played by the "Patronatos".

1. THE ADMINISTRATION OF THE SCHOOL

On the whole, the present administrative organization of the Escuelas Técnicas Superiores is quite well suited to the Seville School; some changes must be made, however, to allow the student's work to be effectively controlled, and inter-departmental co-ordination. The experts consider the present structure of the school's management acceptable, but that the functions of its members should be revised.

The heads of administration as defined by the statutes of the Escuelas Técnicas Superiores, consist of three people, the Principal, the Vice-Principal and the General Secretary. These statutes, which include a detailed description of the functions of each of the three officers, did not meet with the full approval of the experts, who felt that duties should be more clearly separated, each post being made more individual.

The Principal should be a man of great vitality with considerable experience and personal prestige. His function is essentially to formulate the policy of the School within the framework of the general policy for higher technical education, to decide the School's scientific orientation, and to be the official representative in outside matters; these functions are not brought out sufficiently by the statutes of the Escuelas Técnicas Superiores. It is indispensable that this post be filled by an extremely high-ranking professor, who is familiar with the functions of engineers both in Spain and abroad; he must de-

* An excerpt of this Act is given in an Annex.

** An excerpt of the Statutes is given in an Annex.

vote all his time to his work as Principal. If he is expected to follow the latest developments in science and technology, to keep abreast of economic questions, to have a sufficiently detailed knowledge of the various subjects taught at the school, to decide the direction the School's research should take, to give speeches outside the School and to keep in close contact with industry, he cannot be expected to teach a particular subject or to perform lower-level administrative tasks. At the Seville School, the titular professors will carry a very heavy teaching load which cannot be combined with the functions of Principal. Furthermore, during the first few years of the Pilot School's existence the Principal will have to keep a very close check on how the teaching methods are being applied and the syllabuses taught; he must give appropriate instructions to the heads of departments, and evaluate the results of these instructions. Later, he will have to make a report on the Seville experiment and, on behalf of the Minister of National Education, examine the possibility of extending to all the Escuelas Técnicas Superiores the measures taken specifically for the Seville School, after they have been tested.

These considerations also apply to the Vice-Princi[illegible] whose main responsibility is that of director of studies and assistant to the Principal. He is responsible for working out the syllabuses and the smooth working of the system. While in other schools, teachers are left a certain amount of personal initiative, the Seville School objectives require that each course constitute an integral part of an overall training. The director of studies must therefore ensure that the courses are always properly co-ordinated, this making it impossible for him to concentrate on teaching a particular subject. In any case, his work load could make this impossible. The Vice-Principal will be responsible for the application of instructions given to him by the Principal. The Vice-Principal also should therefore be a professor, possibly much younger than the Principal, and be entirely exonerated from teaching duties.

The fact that the Principal and Vice-Principal of the school, must be professors and have no teaching duties raises two questions. First, Is it advisable to appoint them on a permanent basis? In many countries, the heads of institutes of higher learning, and even heads of departments, are appointed for a limited period, usually coinciding with that of a degree course. This arrangement allows the professors, who are first and foremost scientists or engineers, to return to their original jobs and to maintain their reputation in their particular field of science or technology. This is even more important for the director of studies, who, as a relatively young professor with much of his career still before him, will have broadened his outlook considerably during his five or six years as Vice-Principal and gained a better insight into the mutual dependency of the different disciplines in both teaching and research. At present, however, this proposal cannot be formulated as a recommendation and, for the time being, it [illegible] up to the authorities in charge of technical education to consider it. The second question these same authorities must answer concerns the salaries of the Principal and Vice-Principal. The salaries now paid are those of a professor, plus an allowance for the particular post they occupy. This tends to imply that the director's duties are of secondary importance. Therefore an exceptional measure is required here, justified by the special characteristics of the Seville School. Similar problems concerning the salaries of professors will be met in the following chapter.

The General Secretary is responsible for the economic, financial and administrative sides of the school; his functions, as laid down by the statutes of the Escuelas Técnicas Superiores, are purely administrative. The General Secretary should, in fact, be able to relieve the Principal of all duties which are not of a scientific or technological nature. He should be an administrator, first and foremost, and hi[illegible] should have fitted him to manage efficiently an establishment of this size. In schools which are smaller than that at Seville, this position is a full-time one; so it would be preferable, therefore, for the General Secretary of the Seville School to devote all his time to these duties.

RECOMMENDATION 6

The experts recommend that the posts of Principal and Vice-Principal of the Seville School be entrusted to professors who will devote their full time to such activities and should therefore be relieved of all teaching duties; they also recommend that the general secretary assume full responsibility for running the School and for all questions of a non-scientific or technological nature; this post should also be full-time.

This recommendation, which concerns only the senior officials of the School, will require some changes to be made to the functions of junior administrative staff when put into operation. A complete study of the school's organization cannot be made until the School actually begins to function. It is therefore suggested that the General secretary examine the effects of this proposal on the work of his subordinates. This study should lead to a revision of the statutes of the Escuelas Técnicas Superiores.

2. ADVISORY BODIES

Under existing statutes, the Principal may consult two committees set up to assist him in his task. One consists of people from outside the school, to advise him on matters of policy, and particularly to keep him informed of industry's needs and economic trends; this committee is known as the "Patronato". The second committee has a double task: to advise the Principal on scientific matters, and on the implementation of his policy, for both teaching and research. This committee is known as the "Junta" or Board of Professors.

This system is fully in line with the views expressed by the experts, for it ensures that the Principal is kept well informed and at the same time leaves him sufficiently free to formulate a policy whose aim is not simply to satisfy the immediate needs of one or the other of the two committees. It does seem, however, that the Board of Professors' terms of reference should be slightly modified, for some of its prerogatives as described in the statutes should normally fall within the competence of either the director of studies, or the Department of Economics and Social Sciences; the question concerning which of the Vice-Principal's or General Secretary's decisions should be ratified by the board should therefore be examined. It seems reasonable that the professors, like the Principal, should be relieved of practical organizational or administrative duties.

The experts wish to draw attention to the Patronato's role in relation to the School. The Decree of November 1965 * considers that the committee's main task is one of liaison between the School and the world outside. The experts, who are concerned chiefly with the actual functioning of the Seville School and the means to attain its objectives, would like the Patronato to consist of people in positions of responsibility in the economy, and particularly in industry; they also point out that it is one of the Principal's primary functions to represent the School outside its walls, and not just in respect to the members of the Patronato. One reason for the experts' recommendation is that the Principal must be kept informed of economic trends in industry and the repercussions they have on the engineer's work. In addition, he must cooperate with the members of the Patronato to help the Department

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* An excerpt from this Decree is given in an Annex.

of Economics and Social Sciences carry out its programmes, including students' training periods in industry, and such technical assistance as the School may possibly give local firms. In view of this it is hoped the Head of the Department of Economics and Social Sciences will be a member of this committee.

In addition to the members mentioned in the Decree, therefore, it is suggested that the Patronato include the person locally responsible for the Economic and Social Development Plan, representatives of small, medium and large firms in the Andalusian area and also those of nation-wide industries, in particular the Instituto Nacional de Industria, so that the Principal's means of information and scope is not limited to the Seville region. As the Seville School engineers are being trained to meet the requirements of the Spanish economy as a whole, and not just those of local industries, that part of the Decree concerning the Patronato's function of creating professorships to meet local needs does not seem suitable for an Escuela Técnica Superior. It may be useful, however, that an Escuela Técnica Media meet the needs of the surrounding region, and engineers working for a doctorate would probably find it an advantage if their thesis subject concerned local industry, thus providing them with a wider and more concrete field of inquiry. Training at engineer's level however should not be subject to such restrictions.

RECOMMENDATION 7

To assist the Principal of the Seville School in his duties and to facilitate the work of the Department of Economics and Social Sciences, the experts recommend that the task of the Patronato to be set up as an advisory body to the School should be one of liaison, information and assistance in economic and technological matters.

3. THE DEPARTMENTS

A school specializing in such widely different subjects as mechanical and chemical engineering must be sufficiently flexible and effective for the best use to be made of its resources, particularly of teaching staff. The creation of specialized science departments allows this to be done and also permits the concentration of research and teaching facilities. The Act of 17th July, 1965, instituted a departmental system for university faculties, so that the experts' proposal has a precedent. The way in which the departments function, however, depends on the reason for setting them up. The objectives of an engineering school, and particularly those of Seville, are not the same as those of a university faculty. A look at the role departments will play in the Seville School would therefore be useful.

The departments of an establishment of higher learning must be set up so that several disciplines, constituting a coherent scientific unit, can be grouped together under a common administration. Each department will therefore include several sections and professorships, and will consist of a sufficiently important unit of research and instruction to merit a large and competent teaching staff, and equipment which, being expensive, should be used efficiently. The department will thus permit discussions, between teachers and research workers in a given technological branch, and attract graduates wanting to go more deeply into certain subjects. Each department can supply, on request, the type and level of training required by a particular group of students, who thus benefit from a high level of teaching which would be difficult to get in the more conventional schools.

A large university prepares its students for a wide variety of professions, each of which corresponds to a student "stream". Each stream will attend courses in a number of departments, thus showing that the departments should not seek to train specialists in their respective fields, but supply a service adapted to the needs of each professional stream. This type of functional structure was proposed by the Organization's experts for the school to be set up at Cordova, and which will thus be able to train agronomists, veterinarians, plant-biologists and chemists, etc. with only a limited number of departments. This school might in fact economically combine a number of the usual types of professional establishment such as a faculty of veterinary medicine, an institute of agriculture and an institute of farm management.

The experts recommend that the engineers graduating from the Seville School should not be narrowly specialized in a particular branch of technology, but should be trained so that they can deal with the different problems they will meet in industry. The Seville students therefore constitute a single professional stream, at least whilst they are at the School; graduates wanting to do research will find that the departmental system affords ample facilities for specialized study. The departments to be set up at Seville should help to train the type of engineer who will be expected to tackle any sort of job.

The departments at the Seville School are not therefore intended to train students for a number of different professions, and the advantage they have is not that of providing a more economical functional organization However, they should make it possible to organize teaching more efficiently by allowing each member of the staff to be given a specific function, fitting closely into the training as a whole. The professors will thus be able to guide the work of their assistants, whether in teaching or research, and the many part-time teachers can also be guided and supervised, so that their contribution to training of engineers will be co-ordinated better with the other courses. This means that each department will have to be staffed with a very high level nucleus of full-time professors and assistants to set up the syllabus as a whole, define the tasks of part-time teachers and direct research work.

In view of the School's objectives, the experts recommended the creation of five departments which would be responsible for education in the final four years:

(a) The Department of Mathematics

This Department should not try to teach mathematics from the usual theoretical angle adopted in the universities, but for use as an indispensable engineering tool. The various subjects should therefore be studied in view of their applications and their relationship to engineering techniques. This Department should be equipped with a computer.

(b) The Department of Chemical Engineering

This Department will also concentrate on teaching industrial chemistry and chemical engineering. The syllabuses given in Part Three show, moreover, that this Department will play an important part in teaching basic industr l techniques to the students as a whole.

(c) The Department of Mechanical Engineering

This Department will carry much of the responsibility for training the students to develop their practical ability, especially during the first part of their school career. It will teach strength of materials, and the operating principles, use and maintenance of machines.

(d) The Department of Electrical Engineering

This Department will have the normal task of teaching electrical and electronic engineering, but also that of teaching electro-magnetism, since the experts felt it unnecessary to set up a Physics Department.

(e) The Department of Economics and Social Sciences

The Department is to train students for administrative and organizational functions, and will therefore be responsible for teaching economics and social sciences as defined in Part Three, i.e. with emphasis on their practical aspects, and for making arrangements for all training courses of whatever kind. It will therefore be responsible, at operational level, for the contact with industry, hence the recommendation for the Head of this Department to sit on the Patronato.

RECOMMENDATION 8

So that good use can be made of the teaching staff and equipment, the experts recommend that five departments be set up at the Seville School and that these be responsible for education in the last four years. These would be: the Departments of Mathematics, Chemical Engineering, Electrical Engineering, Mechanical Engineering, and Economics and Social Sciences.

The Departments will play an important part in the organization of research at the Seville School. This question has not yet been studied by the experts, however, who have concentrated their attention on the teaching side of the School's functions. It may subsequently be examined in collaboration with the professors who are shortly to be appointed.

CHAPTER XII

THE TEACHING STAFF

The quality of a school's teaching depends essentially on the number and ability of the professors, lecturers and assistants responsible. The recommendations made earlier would be quite useless if the Seville School were not able to recruit a sufficient number of qualified staff.

These recommendations imply much better staffing than is normally found in the other Escuelas Técnicas Superiores, where the teaching staff can no longer cope with the demands made for the training of engineers. Exceptional measures will therefore have to be taken for the recruiting of professors, lecturers and assistants for the Seville School; a study of the way in which the School functions will serve as a basis for the reform of the various regulations governing the status and recruitment of teachers, and which are at present being revised. The recommendations found in this chapter will therefore correspond to temporary measures; a more thorough study will be required to determine what decisions the Minister of National Education can eventually take for technical education as a whole.

1. TEACHING STAFF: NUMBER AND STRUCTURE

The experts' examination of the present organization in the Escuelas Técnicas Superiores first entailed an estimate of the number of teachers required, to inform the Spanish authorities of the situation in good time. This estimate is based on a rapid analysis of quantitative requirements in view of the syllabus and teaching methods to be used. Experience in other countries shows that in an engineering school a suitable ratio is one professor to twenty students and one assistant to every four students.

Only two categories of teachers, professors and assistants, were considered in this estimate. This purely functional classification cannot be compared with that used for administrative purposes in the Spanish rules and regulations. Professors are considered to be responsible for taking a course in their particular field, even though they may receive instructions from their Head of Department; assistants, on the other hand, are responsible for conducting tutorials and for supervising practical work sessions, and depend very closely on the professors they are assigned to. A distinction has also been made between full-time and part-time teachers; it is desirable that the staff of an engineering school include some part-time professors and assistants, i.e. with technical or managerial jobs in industry, when they really have sufficient time for teaching. Unfortunately however, in view of the small amount of industrial development in the Andalusian region, the possibilities of teaching help from local industry are small and the School will have to rely on a large proportion of full-time personnel.

The following table shows the increase in teaching staff required to keep pace with the growth in enrolment indicated in Part One. These numbers are given by way of illustration and depend, to some extent, on how many full-time professors the School is able to recruit. The order of magnitude would, however, be the same. They do not apply to the first year.

Academic Year (*)	1966/67	1967/68	1968/69	1969/70	1970/71	1971/72
Years opened to students	2nd	2nd and 3rd	2nd, 3rd and 4th	2nd, 3rd and 4th	idem	idem
Full-time professors	5	10	18	25	27	30
Part-time professors	-	2	5	10	10	10
Full-time assistants	25	45	60	80	90	100
Part-time assistants	-	20	40	60	75	90

(* If the second year is opened in 1966.)

2. FUNCTIONS OF TEACHERS

One of the most difficult problems the Spanish Government will have to deal with to apply the act on the re-organization of technical education is to increase the number of teachers. At present there is a shortage of staff in the Escuelas Técnicas Superiores due to the methods used to recruit teaching staff, the salaries offered and, in a larger sense, the use made at present of highly qualified people in Spain. The Seville School is a pilot establishment on which is to be based the study for the reform of all higher technical education; every effort should therefore be made to see that the School's organization corresponds to its educational needs.

A. Full-time Professors

The Escuelas Técnicas Superiores have only a limited number of full-time professors on their staffs; some, such as the Oviedo Mining School, have not even one titular professor. The extremely low level of salaries is principally to blame for this. The Ministry of National Education has recognized the inadequacy of the salaries paid to university professors, and the Plan accordingly calls for an increase in their number and salaries. But the needs of the Escuelas Técnicas Superiores are just as urgent, not only because of the immediate impact the number of technicians and engineers, and the quality of their training have on economic development, but also because of the attraction industry has for potential professors. Professors at engineering schools should have a certain amount of industrial experience, nd so sufficient advantages should be offered them to create a sort of osmosis between industry and education. Present conditions are far from ideal, for, apart from the question of salaries, the official recruiting system for professors discourages any engineer from teaching however modest his position. Candidates for a professorship are required to have several years' experience in teaching at university level before sitting for the competitive examinations. This system therefore offers neither stability nor guarantee of employment; it is essentially a restrictive one, ill-suited to a country which needs a large number of teachers. Although, the experts' terms of reference do not cover recommendations on this question; they consider that the regulations on the recruitment and status of teachers need revising, at least for technical education; this question may be studied later. In this report, the experts limit themselves to recommending that special measures be taken to allow full-time professors to be recruited for the Seville School for both the teaching and research posts required.

It is not in fact enough to recruit the required number of teachers; their salaries must allow them to devote themselves entirely to teaching. Most of the professors at the Escuelas Técnicas Superiores are obliged to take on outside work to achieve a reasonable salary. This does not apply only to professors; most of those occupying important posts in Spain are obliged to have two or three jobs, any one of which would be full-time in another country, but which are insufficiently paid in Spain. True, senior management staff may delegate certain tasks to subordinate personnel, but this is not possible in the teaching profession. Spanish professors give too small a part of their time to their teaching duties. This leads them to use the formal-lecture system of teaching; in a school of any size, they are unable to supervise the progress of each student, train their assistants, or direct research.

The training of engineers to meet the needs of the Spanish economy represents a heavy task for the teachers, who are also responsible for the research carried out at the School. They should therefore devote all their time to teaching. Although it may be desirable for teachers giving engineering courses to keep in touch with industry and to collaborate in the work of certain firms, such activities should be of secondary importance. Teachers should devote at least six or seven hours daily to their different functions, and have an office at the School where they can be reached at any time. This corresponds fairly well to the "dedicación exclusiva" mentioned in the Spanish regulations and for which a special allowance is paid, allowance which will doubtless prove insufficient to attract highly qualified people.

The teachers recruited for the Seville School will, in fact, have to combine a fair amount of industrial experience with a sufficiently thorough knowledge of the subject they are to teach. The experts consider they should be young enough to be able to adapt themselves to teaching methods that are different from those in other schools. This means that a fairly large proportion will have to be recruited from industry, in view of the very limited number of teachers meeting these requirements.

In addition to teaching and doing research in their field, some teachers will be made responsible for a department, as a result of their knowledge of the industrial techniques used in Spain and abroad rather than of recognition of their scientific reputation. It is not expected that Heads of Department will be able to do any work outside the School, and one of the professors should act as Departmental Director of Studies and see that the classes, practical work and research are properly coordinated, i.e. he will assist the Head of Department in much the same way as the Vice-Principal assists the Principal. These posts should carry allowances corresponding to the additional work involved.

RECOMMENDATION 9

The experts recommend that a sufficient number of full-time teachers be employed at the Seville School. These teachers must have a good industrial experience, be young enough to adapt themselves to new teaching methods and give at least six or seven hours a day to their job. In each Department two professors should be appointed as Head of Department and Director of Studies respectively, in addition to their teaching and research responsibilities.

B. Full-time Assistants

The training of engineers requires the collaboration of a number of assistants to take charge of group, work and see that students take an active part in the exercises and practical work. The description of teaching methods in Part Two of this report clearly shows the importance of the assistants' work. Although to a large extent this work may be done by part-time staff, each professor must have at his disposal a group of full-time assistants to help him prepare the work for their part-time colleagues, and to work on the various research projects; these assistants will also organize, under the control of the professor, the training periods the students spend in a firm, and ensure that nothing goes wrong. This means that each professor should be assisted by two or three full-time assistants.

As far as possible, these assistants should be young engineers, preferably with one or two years' experience in industry. This brings up once again the question of salaries. Assistants at the Escuelas Técnicas Superiores are paid far less than engineers in industry. Only science faculty graduates who are unable to find employment in industry agree to work as assistants; this situation might allow the School authorities to recruit young men with sufficient theoretical knowledge for its courses in fundamental science. It would be difficult for them to endow engineering students with the mentality and experience they themselves lack, however, and the experts advise having recourse only exceptionally to such a practice. Engineering graduates must therefore be offered comparable salaries to those they would earn in big firms.

These young engineers would be able to improve their own knowledge while in the School and should be given the means to prepare the doctorate in engineering created by the Act on the re-organisation of technical education. They might therefore be appointed for a period of two or three years. These young men should not, in fact, remain at an Escuela Técnica Superior and work their way up through the academic ranks, for their training has prepared them to become engineers in industry. The criteria laid down by the experts for recruiting assistants and professors show it to be unusual, in an engineering school, for an assistant to become professor. Before attaining this rank, the assistant will have to acquire a considerable amount of experience in industry. Teaching in Spain has been organized on the basis of a very administrative conception which, while perhaps suited to some Faculties, is not compatible with a school for industrial engineers. The contracts and conditions of appointment should be made as flexible as possible so as to facilitate exchanges between engineering schools and industry. Special arrangements will have to be worked out to allow the Seville School to carry on until the present regulations can be revised.

RECOMMENDATION 10

The experts recommend that at the Seville School each professor have a basic staff of two or three full-time assistants, who should be recent engineering graduates, preferably with one or two years' experience in industry. Assistants should therefore be paid salaries comparable to those of young engineers working in industry, and should be allowed to prepare an engineering doctorate.

C. Part-time Teachers

For various reasons it is strongly advisable for an engineering school to employ part-time teachers. The first and most important of these concerns teaching: although it is essential, if the training is to be of high quality, for each department to be well staffed with full-time professors and assitants, the collaboration of part-time teachers, i.e. of engineers and senior staff in industry, provides students and the other teachers with first-hand experience of the problems and mentality of the staff in firms - particularly important when teaching engineering techniques. The firms which allow their staff to take off time for teaching also benefit, for these engineers are obliged to revise their knowledge of the fundamental sciences, and to keep abreast of the latest developments in technology and the practical and economic problems raised by their application. The teaching and research responsibilities of a school such as that in Seville do not warrant an exclusively full-time staff of professors and assistants; the employment of part-time teachers allows the school a certain amount of flexibility in its organization, and so permits a gradual adaptation to requirements.

Part-time teachers must nevertheless become an integral part of the educational system i.e. they must be able to give the required amount of time to teaching. At present, the part-time teachers at the Escuelas Técnicas Superiores give very little time - usually no more than that required by a lecture - to teaching. We have already seen that the lecture system is not suitable for training engineers. At the Seville School, the part-time professors will have the same duties as their full-time colleagues, without, however, having the responsibility of training assistants or co-ordinating research programmes. This means they will have to spend almost a whole day at the School and, since their subjects will generally cover a four-month term with one teaching unit per week, the teaching load of a part-time lecturer responsible for one subject may be estimated at roughly fifteen days' presence at the School per year.

Engineers who agree to help at the Seville School will ordinarily have the job of an assistant, which is a very important one in engineering training. In any case, it is very improbable that a large number of engineers or top-level staff with the necessary qualifications to take responsibility for a course are to be found in the Seville region, but it should be quite easy to recruit qualified assistants ready to accept the discipline of the department and adapt themselves to the School's teaching methods. Heads of departments and the School authorities should not forget the importance of the work done by part-time assistants, who will be in direct contact with the students and will represent industry in their eyes. These engineers must be energetic, fairly young, and have good experience in production.

RECOMMENDATION 11

The experts recommend that the Seville School authorities call on engineers and managerial staff in industry, to act as part-time professors and assistants, particularly for teaching engineering techniques; such teachers must become an integral part of the general organization of the School, i.e. they must accept the discipline of the department to which they are assigned.

3. APPOINTMENT OF PROFESSORS AND OF ASSISTANTS

The system to be used for recruiting teachers for the Seville School can be decided only by the Spanish Ministry of National Education; the experts have already called its attention to the fact that the existing regulations are not adapted to the requirements of technical education, and would not allow sufficient qualified teachers to be recruited for the Seville School. The Spanish authorities must therefore work out a system which will provide these teachers with a special statutes and scale of salaries; the experts are not competent to define such a procedure. They therefore restrict themselves to suggesting that the question of revising the teachers' statutes be examined later, and offer to take part in this; they give elsewhere in this report a number of indications concerning the most suitable qualifications for the teaching staff of each department, and the additional training such people might be given with the cooperation of the Organization.

In addition, the report comments on the order in which these teachers should be recruited, so that the Spanish authorities may prepare a schedule of faculty appointments. These indications should not be regarded as definitive however, for the first teachers to be recruited will probably not have exactly the right qualifications, so that the criteria for selecting the rest of the faculty will have to be adapted to compensate for these differences.

A. Department of Economics and Social Sciences

Staff for this department will doubtless be difficult to find; for candidates must have the theoretical knowledge required to teach the various subjects in the syllabus, considerable experience in business problems acquired in a responsible management post over several years, and not just as a business consultant and, at the same time, be willing to teach. Young Spaniards in management positions who have attended any of the American universities where these subjects have been taught for some years would meet requirements. By regrouping the subjects in the syllabuses, it has been possible to draw up a list indicating the type of qualifications required for the various posts.

- An expert in the field of classical production organization methods, familiar with techniques for using manual labour, the industrial requirements and commercial, accountancy and administrative problems. Someone with solid experience of work in a firm would be preferable, who, if he has not had specialized theoretical training, has acquired the equivalent theoretical knowledge through personal experience. This professor would be in charge of: "Organisation of work in the plant", "Basic Activities of the Firm" and "Functions of the Engineer in Modern Society".
- An expert in the sociology of organization, who has taken specialized courses in either the United States or France, and who has been able to try out his theoretical knowledge on practical problems in Spanish or foreign firms. This professor would normally be appointed as Head of Department, if he has sufficient authority. He will also take classes in "Industrial Sociology" and, should a suitable specialist not be found, in industrial psychology as well.
- An economics and finance expert in problems of this type at firm level. This post might be filled, for example, by a university professor who has spent at least a year at an American university and preferably has some theoretical training in statistics. He would take classes in: "The Industrial Firm and the Role of the Engineer", "Economics. Finance and Auditing", and possibly, "Industrial Statistics". If his knowledge of statistics is insufficient this course should be given by one of the other professors with practical experience in the more routine applications of statistics to production.

In addition to their teaching duties, these three professors will be responsible for training their assistants, preparing notes and mimeographed lectures, etc., and directing the preparatory work for the training periods in industry; they must therefore be employed on a full-time basis.

The Department of Economics and Social Sciences may find it more difficult to recruit assistants than professors, for there is very little possibility of finding young management staff already equipped to assume these functions, and they will have to be trained. This training and the experience they acquire when organizing and supervising the training periods in Spanish firms will be of great value to them, and an excellent preparation for subsequent managerial and administrative functions. This should make it possible to find young managers or engineers who have recently graduated and who would be willing to devote two or three years of their career to teaching economics and social sciences. The Head of the Department and the School authorities must however make sure that these people have the necessary ability, general background and authority not only for the post of assistant but also for that they will subsequently occupy.

B. Department of Mathematics

The staff of this department should not be simply theoretical mathematicians, but should have experience in the type of mathematics used in engineering, and be able to teach it. This means they must be familiar with statistical applications and the use of computers in industry, and also able to keep pace with technology's new requirements in mathematics. They should therefore be sufficiently young and energetic. Three full-time professors will be required:

- a specialist in numerical analysis and computer techniques,
- a specialist in statistics and operational research,
- a professor of analysis and linear algebra able to adapt his course to engineering requirements and in particular to problems concerning control and servo-systems.

In addition to its teaching assistants, the Mathematics Department should also have one or two assistants responsible for operating the computer and able to teach the rest of the staff how to use it.

C. Department of Chemical Engineering

The Department of Chemical Engineering is responsible for a wide range of subjects, and it would not be advisable to appoint a full-time professor for each. After examining the full syllabus the experts decided that five full-time, and three part-time professors, should be recruited as follows:

(i) full-time professors

- a specialist to teach thermodynamics to second-year students and applied thermodynamics to fifth-year chemical engineering students.
- a professor to teach fluid mechanics and heat transfer to third-year students and "Unit Operations I" to chemical engineering students.
- a specialist to teach science of materials to second- and third-year students, and the preparation and processing of materials to fifth-year students.
- a specialist in mass transfer to teach part of "Unit Operations" I and II, and of "Separation Processes", as specialized fourth- and fifth-year subjects.
- a professor to teach "Principles of Chemical Engineering" to fourth-year students and possibly a fifth-year optional subject.

The Head of Department should be one or other of the last two mentioned.

(ii) part-time professors

- a specialist in chemical reaction engineering.
- a specialist in particle technology, to teach a part of the courses "Unit Operations" and "Separation Processes" and the corresponding fifth-year option.
- a specialist in process dynamics, to teach this subject to fifth-year students and to collaborate in the teaching of control systems and instrument analysis.

D. Department of Mechanical Engineering

The Department of Mechanical Engineering is largely responsible for developing the students' practical ability, and the key professors and assistants in this department must have therefore, in addition to the required theoretical knowledge of their subject, good workshop experience to allow them to help students develop a feeling for materials. The full-time assistants, who are a very important part of this department, must have had two or three years experience in a mechanical engineering firm, and possess the type of mind which corresponds to the particular aims of this department. The experts consider that four full-time professors and one part-time will be required for this department. Detailed indications for seeting up a recruiting programme for professors and assistants are as follows:

(i) full-time professors

- a specialist in machine construction, to take "Design for Manufacture", "Principles of Manufacture", and a fifth-year option such as "Metrology".
- a professor of applied mechanics, who would normally become Head of Department; this professor will teach "Mechanics of Machines" and "Strength of Materials".
- a professor of refrigeration and air-conditioning systems to take part of the Thermodynamics and Fluid Mechanics c ses and the fifth-year option on refrigeration.
- a professor to teach "Transmission a pplication of Power I", "Dynamics of Machinery", and a fifth-year option

(ii) part-time professors

- an expert in the field of control s stems, responsible for teaching part of the two control systems subjects and, eventually, a fifth-year option.

N.B. The main responsibility of certain part-time assistants will be the organizing of practical work; they will be joined by others for supervision and tutorial work.

E. Department of Electrical Engineering

As the subjects covered by this department call for teachers with a very wide scientific background the experts recommend it be staffed with full-time professors and assistants only. However, there will doubtless be difficulty in recruiting professors with the qualifications shown below, and it is suggested that, in addition to the five full-time professors, a number of part-time teachers be appointed whose subjects complement those of the professors they are to assist. It should be borne in mind that the time given by a part-time teacher is roughly half that of a full-time one. The department will need:

- a professor of electronics to teach Electricity I and II.
- a professor of applied electronics, with expert knowledge of electrical measurements and of control systems. This professor would normally become Head of Department.
- a professor of electromagnetism to teach a number of scientific fundamentals to students specializing in electrical engineering, since the experts do not consider it desirable to set up a Physics Department.
- a professor of electrical machines, to teach fourth- and fifth-year students.
- a specialist in high-voltage transmission, responsible for teaching several fifth-year optional courses. This part might possibly be filled by two part-time teachers.

The persons recruited by the Ministry of National Education to teach at the Seville School will probably have to use a different method from that to which they are accustomed. The experts therefore propose to arrange for them to visit a number of foreign establishments to see, how the teaching methods advocated in this report are put into effect, the spirit in which the courses are given, and a number of typical industrial applications of the techniques they are to teach. Some of the younger teachers might also be asked to undergo from six to nine months' training abroad. Clearly, the type of training required by each teacher will be known in detail only after his appointment when the experts have had an opportunity to meet him and to estimate the additional training he will require.

CHAPTER XIII

BUILDINGS

The experts perceived that the proposed buildings had not been designed for the school's objectives, or for the educational methods advocated. They therefore considered the plans should be revised, to take into account the recommendations made in this report. The work is already at a very advanced stage, however, and it is out of the question for the main structure of the buildings to be changed. The modifications recommended therefore concern only the interior of the buildings, and have been carried out with the collaboration of the Spanish architects who, after studying the experts' report and recommendations revised their plans accordingly. These plans have been approved by the experts and are given in an Annex to the present report.

Slight changes have been made to the plans for the premises for the Chemical, Mechanical and Electrical Engineering Departments; these should make it easier to organize classes and improve services. The changes were generally made for technical reasons or because each department had to be provided with sufficient offices for its professors, lecturers and assistants. The installations housing the Department of Economics and Social Sciences had to be improvised out of nothing (by adding another storey to one of the buildings near that for administration); as did those for the Department of Mathematics, which is to be equipped with a computer and a sufficient number of offices and services; this department is located on the site originally intended for the drawing office.

The lay-out of the premises used by all the students, that is, the five-storey building, had to be completely changed so that the working groups of fifteen students advocated earlier in the report could be accommodated. The ground floor of the building is for the use of first-year students and the others of second-, third-, fourth- and fifth-year students. The rooms as planned will be used for tutorial and personal work and are grouped together on each floor to enable the professor to direct and supervise the work of his assistants. In these rooms each student will have his own desk, which can be converted into a drawing table and has space for books and paper. A tower containing four 200-place lecture rooms has had to be added to this building. The students attending lectures will thus be near to the classrooms in which their exercise work is to be done.

The experts, reminding the Spanish authorities that the students will spend the entire day at school, with at most a two-hour break at lunchtime, recommend that the classrooms and the staff's offices be air-conditioned so that both staff and students have the best possible conditions for their work; air conditioning should not be a very costly proposition, as the architects have already included ducts for forced circulation of air in their plans. Moreover, in view of the plant they house, a number of departmental rooms must be provided with special equipment, e.g. for keeping the air dust-free. Lastly, the school has neither a restaurant nor a student centre at present: the construction of such facilities in close proximity to the school will have to be undertaken in the near future.

RECOMMENDATION 12

The experts recommend that the Seville School be built according to the plans contained in this report, which are a modified version of the original plans to bring them into line with the School's educational objectives.

CHAPTER XIV

EQUIPMENT

Students at the Seville School must be trained to apply their theoretical knowledge to the practical problems they will encounter as engineers; hence the importance which must be attached to the means for obtaining information and acquiring direct experience of the practical application of the techniques they are taught. This report contains a number of suggestions concerning equipment and literature for the second and third-year syllabuses. These are no more than indications, however, and only the teachers can draw up a definitive list corresponding to their treatment of the subject. Quite understandably, the experts gave no indications for the fourth and fifth years, for which the syllabuses are more easily changed or have been given simply by way of illustration.

1. LABORATORY EQUIPMENT

By defining the aims of the practical work, Part Two lays down the requirements for laboratory and workshop equipment. It will be recalled that many experimental demonstrations are to be given by lecturers and assistants during the students' junior years; such demonstrations help students to appreciate and understand phenomena and ideas which are difficult to convey in theoretical terms. Most of the equipment, however, will be used for practical work, which represents at least half the students' tasks. For the students' first two or three years in the School, it is hoped that very simple instruments and machinery will be provided to develop their practical ability; in the last two years, very modern plant and apparatus should be used such as students will subsequently install and use in the firms where they work.

It was not possible to meet the wishes of the Spanish authorities and draw up a complete list of the equipment required by the School. In an engineering school or a faculty of science, most equipment is built on the spot, so that a particular experiment can be carried out; usually the apparatus required is not available commercially, as is clearly shown by the indications given for the second and third years. However, the experience of several schools built recently in Germany and the United Kingdom showed the overall cost would be approximately Pts 250 million. This includes the cost of a computer big enough for teaching and research, and which can be used by the School to solve any problems submitted to it by industry. It also includes the cost of the language laboratory referred to in Part III of this report. The equipment needed for research will depend on the research programme decided upon.

2. BOOKS AND REFERENCE MATERIAL

The School's library should contain a large number of books and periodicals for consultation by students carrying out their projects, and also the text books to which the teachers refer in their classes. The experts encountered some difficulty owing to the fact that they were not familiar with the technical books published in Spanish. And, whilst students, especially from the third year on, should be capable of consulting books or periodicals in English or French, the experts were aware that they would find it difficult to learn and understand if the course were written in a foreign language. This means the teachers will have to prepare sufficiently detailed courses in Spanish, a task which should be completed during the first two years of the school's existence.

It was felt that teachers would find it very useful if a number of technical films were available, to provide students with a particularly clear picture of any experiments which would help them to understand the course or to show them various projects or undertakings impossible to carry out in the School or the Andalusian region. A list of such films can be drawn up from the catalogue of scientific and technical films recently published by the Organization.

CONCLUSIONS

The recommendations contained in this report, and the suggestions for implementing them, should make it possible to set up an engineering school which is better adapted to the needs of modern Spain. Their main objective is to produce top-level staff who can make an effective contribution to industrial development; students at the Seville School should be trained to use the equipment placed at their disposal, organize production, and run a firm. Their education will be quite different from that provided by the other Escuelas Técnicas Superiores; and a period of adaptation will doubtless be necessary.

This period of adaptation should make it possible to recruit and train the professors and assistants, and to work out detailed syllabuses for the courses and practical work. Many problems will have to be settled and the results obtained will be of great interest, not only to Spain, but to all the other countries requiring a growing number of engineers trained for jobs in industry. The success of this type of training will depend on the quality of the staff and the way in which the experts' suggestions are interpreted. For this reason, the experts consider their task does not end with the completion of this report, but that there must be co-operation between them and the staff during the first few years of the School's existence. Some suggestions may not have been stated clearly enough, while others may need to be revised in view of local conditions.

The experts should also assist the school authorities to make any later adjustments in teaching of the various courses. Modifications will probably have to be made to the syllabuses, teaching methods, and timetables. The suggestions contained in this report should, however, be put into effect long enough for the experts to have some elements on which to base their judgment; meetings should be held periodically to allow them to keep track of what is happening in the various branches of the School. The experts should also help prepare the staff to put their recommendations into practice. Short visits to foreign schools should be arranged for the teachers for them to see how the teaching methods are applied and the laboratories organized. Six- to twelve-month training periods should be arranged for some of the younger teachers to allow them to study the teaching of a particular subject.

[illegible] experts' conclusions based on the Seville experiment might lead to a r[illegible] Escuelas Técnicas Superiores. The preparation of this report brought t[illegible] of shortcomings in the present rules and regulations which, after a [illegible] study, might call for new recommendations to be made. Other points will doubtless arise as the result of a detailed examination of the working of the Seville School. The experts' task will then become much broader, for they must suggest measures to make the Escuelas Técnicas Superiores more efficient and so improve the use made of human resources. One of the most important problems to be dealt with is training for engineers at a level below that of the Escuelas Técnicas Superiores. This might be done either by establishing a new type of school or adapting the present ones to make them the normal outlet for holders of upper secondary school leaving certificates.

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ANNEXES

ANNEX I

THE TECHNICAL CO-OPERATION PROGRAMME

(a) Technical Co-operation Programme for 1965 (Extract)

Activity 50: Scientific and Technical Education in Spain

As a follow-up to the Mediterranean Regional Project report, emphasis is being placed on the development of scientific and technical education.

i) The Spanish authorities hope to have the services of higher - and middle-level technical education experts in 1965 to examine and complete the existing plans drawn up by national organizations. Assistance is also requested for the curriculum reform, the practical organization of technical institutions and for training the teachers for these schools.

ii) The authorities also intend to set up a working group of Spanish and foreign experts, who with the help of the experts mentioned above, will examine the whole question of technical education in Spain and publish th[illegible] onclusions in a general report.

(b) Technical Co-operation Programme for 1966 (Extract)

Activity 32: Scientific and Technical Education in Spain

The Spanish Development Plan includes the creation of a number of technical education establishments for which the co-operation of OECD has been requested by the Spanish authorities. The work of OECD consultants in 1965 made it possible to decide on the type of training required by scientific and technical personnel in view of employment conditions and prospects in various fields. In 1966, the general principles can therefore be applied for deciding the syllabuses and the methods and organisation of teaching in these establishments. OECD should concentrate on the preparation of a small number of engineering schools (pilot establishments) of which one would be for agricultural engineers; the first-year course in these schools should start in October 1966. The aid requested for 1966 from the Organization will be in the form of foreign consultants to help carry out this work.

ANNEX II

MISSION SENT TO MADRID TO COLLECT INFORMATION

December, 1964

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ANNEX IV

LIST OF RECOMMENDATIONS

It was considered that the recommendations contained in this report might usefully to grouped together in an annex, for they correspond to a number of decisions to be taken by the Spanish Authorities. Three comments are required:

a) the experts recommendations take on their full meaning only in their context in the present report;

b) the manner in which the recommendations are to be carried out is indicated in the report, and this information is often more important for running the School than the recommendations themselves;

c) the nature of certain points precludes their being covered by recommendations.

The experts recommend that:

1 – Every year, a maximum of two hundred students be admitted to the second-year at the Seville School, once the school is working normally;

- During the first few years of the School's existence the number of students admitted to the second-year be much smaller; in 1967, it should not exceed 90;
- Normally all these students should complete the course for the engineering diploma within four years.

2 – Since the Seville School's aim is to train engineers who are expected to have to adapt themselves to the many functions alloted to them, specialization should be deferred until the fourth year; the common syllabus for the first three years should constitute a whole, and not be considered as a preliminary phase of specialization;

- The general engineering degree conferred by the Seville School should not contain any reference to the specialization chosen by the student.

3 – Only one subject should be taught throughout each day to make the students feel the close connection between theoretical knowledge and its practical use;

- The greater part of this unit of instruction should be devoted to tutorials and practical work sessions carried out in small groups under the supervision of assistants;
- Only a very limited amount of time should be given to formal lectures.

4 – That students at the Seville School spend, in the course of their academic career, three seven-week training periods in industry: as a manual worker, a foreman and an engineer respectively;

– These periods which are part of the engineer's training are compulsory, and imply close co-operation between the school and the management of the firms accepting the students.

5 – To encourage students to work steadily and effectively, the traditional system of examinations be replaced by continuous supervision of their work;

– Professors, lecturers and their assistants should always keep a close check on the the work of students to discover those whose work is not up to standard;

– At the end of the year only these students should be required to take an examination to see whether they are to be admitted to the next year's class or spend a training period of one year in industry.

6 – The posts of Principal and Vice-Principal be entrusted to professors, who should devote their full time to this work and should, consequently, be relieved of all teaching duties;

– The General Secretary should assume full responsibility for running the school and for all questions of a non-scientific or non-technological nature; this post should also be full-time.

7 – To assist the Principal of the Seville School and facilitate the work of the Department of Economics and Social Sciences, the terms of reference of the Patronato to be set up should be to provide contacts, information and assistance in economic and technological matters.

8 – To ensure that the best use be made of the teaching staff and material resources, five departments should be created to be responsible for all education in the last four years, namely, the Departments of Mathematics, Chemical Engineering, Electrical Engineering, Mechanical Engineering, and Economics and Social Sciences.

9 – Sufficient full-time teachers, with a fair amount of industrial experience be recruited; they must be young enough to be able to adapt themselves to new teaching methods, and spend at least six or seven hours a day on their job;

– In each department two professors should be appointed as Head of Department and Director of Studies respectively, in addition to their teaching and research responsibilities.

10 – Each professor should have an assistant staff of two or three full-time, recent engineering graduates, preferably with one or two years' experience in industry; Assistants' salaries should be comparable to those of young engineers in industry; facilities should be made available for them to prepare a doctorate in engineering;

11 – The Seville School's authorities should try to recruit engineers and managerial staff in industry to act as part-time professors and assistants, especially for technical engineering subjects; such teachers should become an integral part

of the School's general organization, i.e. they should accept the discipline of the department they belong to.

12 - The School's buildings should be in line with the plans included in this report, which are a version of the original plans modified, to bring them into line with the School's educational objectives.

ANNEX V

ECONOMIC AND SOCIAL DEVELOPMENT PLAN

(1964 - 1967)

Technical Education

It is generally recognised that a country's resources in technicians and engineers has a direct and decisive effect on its economic level. This makes it imperative that legislative and financial steps to increase the number of engineers and technicians be taken immediately.

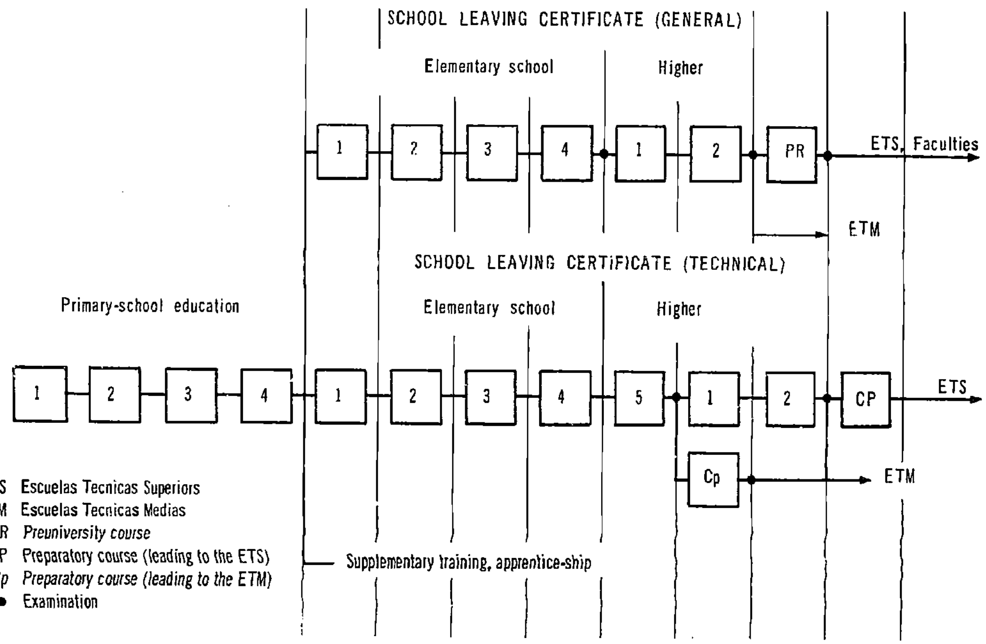
Financial forecasts indicate that at least 9,000 additional places could be provided in the Escuelas Técnicas Superiores and 6,000 in the Escuelas Técnicas Medias, thus bringing the total number of ingenieros and peritos by 1970 to 26,000 and 53,400 respectively.

For an estimated cost of 100,000 pesetas per enrolled student in the higher level and 45,000 pesetas in the intermediate level schools, the amount of funds required are as follows:

	Pesetas
Ingenieros	863,300,000
Peritos	270,000,000

Annex VI

STRUCTURE OF SECONDARY EDUCATION (1964)



ETS Escuelas Tecnicas Superiors
ETM Escuelas Tecnicas Medias
PR *Preuniversity course*
CP Preparatory course (leading to the ETS)
Cp *Preparatory course (leading to the ETM)*
● Examination

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ANNEX VII

ACTS CONCERNING THE RE-ORGANIZATION OF TECHNICAL EDUCATION

a) Acts of 20th July, 1957

An extensive programme of industrialization and an adequate social and economic organization have placed our country in an exceptionally favourable position for further development and progress, necessitating the availability of a large number of technical personnel whose training is sound enough to meet the requirements of modern technology. This means that the present system and methods of education must be revised to achieve a rapid increase in the number of technical personnel, who will be able to bring a major contribution to the common welfare. One of the aims of this act is to set up a system designed to make the best use of the precious human potential desirous of taking part in such an important task - a system which be sufficiently flexible to be adapted to rapid and continuous technological change.

The Schools of Advanced Engineering, the Schools of Architecture, and those for sub-engineers, works managers and technicians have certainly accomplished a great deal since they were founded, but will need to be re-organized immediately if they are to continue to be as effective in the future as they have been in the past. Originally certain schools concentrated on the training of civil servants, and a corps of civil servants was created accordance with a very administrative conception of the profession. This was understandable when the demand for technical personnel was small, but is unthinkable now that the main initiative comes from private industry, and that the State requires its employees to carry out the specific tasks they are responsible for and no longer to be simple bureaucrats. Furthermore, most schools, when they started, acted independently inside their technological branch; but this cannot continue, for technological knowledge now constitutes a large autonomous unit with its own character made up of well-defined branches of technology which call for mutual collaboration.

The present act tends to remedy this situation by re-organizing all technical education inside a coherent and dynamic system in which knowledge is suitably broken down into specialties and levels, by linking this knowledge to science in the university, from which technology receives its impulsion, and maintaining the present interpenetration of technical activities between engineers and the university, which has lead to the best results, and by establishing contact with vocational education, where training is provided to carry out the projects conceived by the technical personnel.

The Act stipulates that technical education be provided at two levels by two distinct categories of schools. The Escuelas Técnicas Medias provide the specialized practical training required to perform a particular technical job and confer the titles of overseer (aparejador) and technician (perito) with mention of the specialization The Escuelas Técnicas Superiores provide a wide, solid scientific base, followed by the professionnal specialization required to practise as an architect or engineer. Graduate architects or engineers may also undertake advanced work at these schools, to supplement their professional training, and thus prepare for teaching or research work, with a doctorate after passing the required examinations.

Schools in existence at the time of the Act will continue and will be transformed as and when is considered most suitable; they will be placed under the authority of the Ministry of National Education and be required to adopt common standards for their names and administrative organization.

The Act does not list the specialties into which each technological branch should be sub-divided, as this is considered subject to variation and will therefore require additional rules; but the need is stressed to replace the traditional concept of the encyclopaedic technician by that of the specialist, by greater specialization at each training level. This is necessary in any case in view of the prodigious advances in every field of modern technology.

Entrance to the Escuelas Técnicas will be through selective courses replacing the traditional entrance examinations. Such courses have already proved effective both in universities, where they have been in existence for some time now, and in a number of Escuelas Técnicas Medias and Superiores where they have recently been tried out with highly satisfactory results. The selective courses are open to all candidates of the required level whether their knowledge was acquired in technical, secondary, or equivalent schools. The many possible sources, plus an effective system of aid to students, ensures the admission of all capable candidates, particularly those already working in industry, who are thus granted access to all levels of technical education. Similarly in addition to public education on a full-time basis, the Act recognizes private education for those unable to attend State schools, but, in this case, takes the necessary steps to ensure that the proper practical training is provided. A new form of training is being introduced, which with suitable hours and organization will make it possible to combine study at an Escuela Técnica with work in a firm or office.

The importance of practical laboratory and shop work is stressed when the general standards are decided for the syllabuses and also of the need to develop the human qualities and cultural background of those who, in the course of their career, will frequently have managerial posts affecting broad cross-sections of society.

An important aspect of technical education is co-ordination between the various specializations and levels and between the levels and similar forms of education. As opposed to the traditional system of isolated units, the Act adopts the principle of granting full academic credit for subjects taught in one establishment but which are applied in another. The Act develops this basic idea by establishing courses which are partly or completely common to a number of specialties or establishments, plus a system of equivalence for similar subjects and a reduction in the length of the course for qualified candidates who have taken similar courses in other establishments.

The Act also establishes close contact between all the Schools by creating the Board of Technical Education, to serve the Ministry as an advisory body for all questions relating to technical education, syllabuses and organization in the establishments, without infringing on the prerogatives of the National Education Council.

The Act gives particular attention to the teaching staff of the Escuelas Técnicas and emphasizes the prestige attached to teaching. It establishes regulations which are applicable to all establishments, and which concern the system of selection, the duties and the prerogatives of teachers and, in conformity with its principles, makes university lecturers eligible for chairs in the Escuelas Técnicas and vice versa, thus opening up new opportunities for exchange and co-operation between the two branches of education.

The Act tries to increase the technical establishments' activities by linking them to the engineering profession through information and refresher courses for university graduates, creating special chairs and holding seminars, and promoting the establishment of laboratories for technical research and industrial co-operation, which will help them participate actively in the industrial and economic development of the country.

The Act makes provision for the recognition of technical education given in private establishments which are equipped and operated according to the standards set up for State schools. The Ministry of National Education may thus award the titles of "aparejador", "perito", architect or engineer to anyone who has attended a recognized establishment and taken the preliminary aptitude tests before official examination boards. This is a means of securing the co-operation of society as a whole in this type of education, which is necessarily expensive to provide, for it requires a number of properly equipped workshops and laboratories and also sufficient staff for the classes to be broken up into small groups of students. It must be borne in mind that the change resulting from the Act, which is one of its principle aims, will cause a considerable increase in the number of students. It is therefore no exaggeration to say that the success of the new system will depend mainly on the availability of the financial resources necessary to put it into operation. Recognizing this, the Act emphasizes the vital need for the State to provide its educational establishments with the staff and material means of all kinds required by modern technical training, and relies on the Ministry of Finance to adopt such measures as may be required to carry out the plans proposed by the Ministry of National Education.

The problems raised by the gradual transition from the present system to that created by the Act have been examined in a special study of temporary and permanent measures concerning not only the educational difficulties due to the co-existence of two distinct teaching methods, but in particular the social repercussions due to the creation of new specialties and new occupational titles.

The Act provides an answer to all the questions affecting previous rights and interests in a spirit of comprehension.

In view of this , and in consideration of the proposal made by the Spanish Cortès, I hereby decree:

CHAPTER I

GENERAL MEASURES

ARTICLE ONE - Scope

1. Civil technical education, officially organized and supported by the Spanish Government at intermediate and higher levels, shall conform to the clauses of the present Act and to the complementary standards which have been laid down for its development and implementation.

2. The general principles of the present Act shall also apply to civil technical education organized and supported by recognized non-official groups, as stipulated in article 16.

3. The Spanish Government recognizes the right of the Church to provide technical education, in conformity with the Concordat signed by the two Powers.

ARTICLE TWO - Board of Technical Education

1. The Board of Technical Education is set up as a consultative and advisory body for educational matters; its members consist of the Principals of all the official Escuelas Técnicas Superiores, five Principals of Escuelas Técnicas Medias representing these Establishments as holders of diplomas corresponding to this level, and the Chairman of the corresponding section of the National Council of Education. The Minister of National Education may extend membership of the Board to one additional member representing recognised non-official establishments when justified by the number or importance of these establishments.

The chairmanship falls to the Minister of National Education and the vice-chairmanship to the Director General of Technical Education.

2. The Board's terms of reference shall be to:

a) Give an opinion concerning total or partial modifications to the syllabuses for the Escuelas Técnicas and the question of equivalence for the subjects taught in these establishments;

b) Give an opinion concerning the co-ordination of the various forms of training standardized by the present Act, and on co-ordination between this type of training and that corresponding to different levels and types of education;

c) Examine the general proposals concerning technical education put forward by the establishments and make a report thereon.

d) Seek agreement on the various questions with which the members of the Board may have to deal in relation to the internal organization of the establishments, and submit them to the Higher Authority for a ruling.

e) State its opinion concerning the draft version the statutes of the schools.

f) Propose methods for improving the training of technical personnel at higher and intermediate levels in view of national requirements and, subsequently, submit to the Higher Authority any such measures it deems appropriate.

g) Give its opinion concerning the recognition of each non-official technical education establishment.

h) Assist the Minister in all matters on which it is consulted, in all matters which the present Act and its supplementary clauses require it to do so.

These functions shall not conflict with those assigned by law to the National Education Council.

3. The Board of Technical Education shall be represented on such Governmental bodies as are concerned with the teaching side of technical training.

ARTICLE THREE - Educational Establishments and Fields of Specialization

1. The educational establishments officially entrusted by the State to provide civil technical education shall be the Escuelas Técnicas Superiores and the Escuelas Técnicas Medias.

These establishments shall all be placed under the jurisdiction of the Ministry of National Education.

After the Technical Education Board and the National Council of Education have presented their findings, the Government may grant legal status to the Escuelas Técnicas Superiores and Medias, which would then be eligible for the advantages granted by law to officially recognized foundations, and could receive endowments.

2. The Government, on the proposal of the Ministry of National Education and after hearing from of the Board of Technical Education and on the advice of the National Council of Education, shall determine the fields of specialization to be established at each level of technical education. Similarly, the Government may establish new schools and fields of specialization and modify, group or abolish those already existing, as progress in technology and the needs of the country may require.

The founding of a school along lines differing from those referred to in articles 9 and 13 must be enacted by Act.

3. After the Board of Technical Education has presented its findings and the National Education Council has given its opinion, the Ministry of National Education shall be authorized to set up in each Escuela Técnica any of the specializations it considers suitable among those laid down by the Government.

ARTICLE FOUR - Degrees and Diplomas

1. Candidates who pass the examinations corresponding to the subjects taken and obtain the diploma conferred by the Establishment attended shall be awarded the following degrees and diplomas by the State:

- Escuelas Técnicas Superiores: Architect and Engineer
  Doctorates in Architecture and Engineering
- Escuelas Técnicas Medias : Aparejador (works supervisor) and Perito (Assistant Engineer)

The degrees or diplomas shall indicate the establishment awarding them and section in which specialized study has been undertaken.

2. The degree in architecture or engineering represents the most complete training for exercising the corresponding profession whether in private industry or the civil service, in conformity with the rights, duties and prerogatives laid down by the regulations governing each case, without the holder's specialization prejudicing his legal competency to exercise a profession in other specializations of the schools concerned.

This degree also authorizes the holder to occupy the posts laid down by the Act and its supplementary clauses and qualifies him for the rank of assistant lecturer in university faculties; it also qualifies him to read for a doctorate.

A doctorate in architecture or engineering constitutes the highest academic title and, in addition to the Engineer's or Architect's degree, indicates concentration on research or teaching and makes the holder eligible for a chair in either an Escuela Técnica Superior or a University. These degrees confer special advantages, to be determined in each case, for teaching or research.

3. The Aparejador or Perito diploma represents specialized training of a very practical nature and gives holders the right to work in a definite branch of technology with all the rights, duties and prerogatives the regulations provide in each case.

This diploma also confers the right to occupy a teaching post determined by the regulations for official vocational training and technical establishments; it also confers the right to teach the subjects indicated in article 6, at the Escuelas Técnicas Medias.

Lastly, it makes the holder eligible for admission to the Escuelas Técnicas Superiores, under the conditions laid down by the present Act, and to the Faculties of Science, after passing special tests after a preparatory course not exceeding one year.

ARTICLE FIVE - Syllabuses

1. Teaching shall be in keeping with the principles underlying the dogma and teachings of the Catholic Church and shall be inspired by the points contained in the programme of the National Movement, with sufficient time given to physical education and sports. The aim shall be essentially one of training; in addition to the relatively technical subjects, the syllabus shall include basic science and general cultural subjects. Sufficient consideration will be given to economic and organizational problems.

There will also be compulsory practical work including that intended to illustrate the theoretical classwork, that carried out in the establishments' shops and laboratories and that in the industries, firms or services connected with the students' future activities.

The syllabuses shall be sufficiently flexible to be easily adaptable to rapid technological change and to the regional characteristics of the establishment. They shall also contain optional subjects to allow students greater possibilities in exercising their calling.

The Ministry of National Education in conjunction with other Ministries, may set up courses for further training in these schools for students who have already qualified, to improve the quality of Government service; such courses shall be defined and paid for by the Ministries concerned.

Similarly, courses corresponding to those taught in other countries may be given to allow diplomas to be given carrying recognition elsewhere.

The technical education establishments shall hold either individually or in co-operation with other establishments, specialization and refresher courses, seminars and special lectures for students who may or may not already have a diploma.

Similarly, every effort shall be made to set up Institutes and Laboratories for applied research and industrial co-operation, together with technical and pedagogical library information services. These services shall exist at both levels and shall be under the supervision of the Officials of the Escuela Técnica Superior, who will ensure that they form a systematic whole.

2. The period of compulsory education laid down in Articles 11 and 15 corresponds to the minimum length of time required to complete the course. These requirements may be reduced or waived by the Ministry of National Education for candidates who, either in Spain or abroad, have taken similar courses to those taught at the Escuela Técnica in question, and if recommended by the National Council of Education on the advice the Board of Technical Education and the establishment's staff.

3. Technical education shall constitute a coherent system of courses and fields of study; to this end, the rules shall establish standards to determine an adequate system of equivalence for all official courses of the same level, advanced courses in the State Schools of Architecture and Engineering, and those in the Universities.

Admission and subsequent courses, may be totally or partially waived for students who have attended equivalent courses in an official Spanish or foreign establishment, if recommended by the Board of Technical Education and the National Council of Education.

4. Outside students may attend the Escuelas Técnicas provided they pass an entrance examination to show they possess required theoretical and practical knowledge in the same way as the other students.

Provision is made for the eventual establishment of a system whereby work in firms can be carried out at the same time as, or alternated with, instruction in the school by suitable arrangement of the school time-table.

5. The statutes shall fix the maximum number of students in any given class, or in practical work groups according to the work being done, to ensure efficient teaching; provision will be made to appoint sufficient teachers to prevent any limitation to the total number of students.

ARTICLE SIX - Teaching staff

1. The teaching staff of the official Escuelas Técnicas shall be comprised of:

a) Titular professors, resident and visiting staff.
b) Assistant professors.
c) Lecturers.
d) Special professors.
e) Assistants for practical work.
f) Workshop or laboratory superintendent and foreman.

The Ministry of National Education is responsible for appointing teaching staff and for defining its duties and prerogatives.

2. Titular professors at the Escuelas Técnicas Superiores and the teachers at the Escuelas Técnicas Medias shall constitute two independent, special bodies, each with its own internal grades.

The number of professors and lecturers at each Escuela Técnica shall be determined by supplementary rules.

When the number of teachers on the staff of each School has been decided, the general grading for titular professors at the Escuelas Técnicas Superiores and for teachers at the Escuelas Técnicas Medias, respectively, shall be established. The range of salaries for titular professors at the Escuelas Técnicas Superiores shall be identical to that for titular professors at the Universities; the range for teachers at the Escuelas Técnicas Medias shall coincide with that of teachers in secondary schools.

The Ministry of National Education shall also establish a general grading scale for workshop or laboratory superintendents and foremen, grouping all such personnel of the Escuelas Técnicas Superiores and Medias.

3. In exceptional cases, the Ministry shall have the right to appoint in the Escuelas Técnicas Superiores, on its own initiative or at the request of the establishment concerned, as external or visiting professors, persons with a higher academic degree, or an established reputation in their field. These nominations, for which reasons must be given, shall carry the opinion of the Higher Scientific Research Council or a similar body and of the National Council of Education.

4. The professors shall be aided in their teaching duties by assistant professors and, where necessary, by the number of assistants for practical work, workshop or laboratory superintendents, and foremen required for efficient teaching.

5. Special professors shall be appointed who are qualified to take religious instruction civics, physical education and sports, and for the supplementary subject.

6. Un-filled professorial posts shall be occupied by assistant professors or, if these are not available, by lecturers. When a chair becomes vacant, if called for by educational requirements, the Principal of the school, after consulting the Faculty Assembly, may suggest to the Ministry of National Education that a titular professor or a professor, be appointed to fill the vacancy.

7. Titular professors shall be appointed by competitive examination; consideration will first be given to the value of the technical preparation of the candidates' personal work and research in the subject of the chair which is vacant, and then on the basis of

competitive examinations designed to test their scientific knowledge and teaching ability. Candidates must have a minimum of five years teaching experience to be eligible for chairs in technology.

The special assistant professors for supplementary subjects, workshop or laboratory superintendents, and foremen shall also be appointed by competitive examination. Special professors shall have four-year tenure, renewable for an equal period, if recommended by the Faculty Assembly of the establishment concerned. Assistant professors are given four-year tenure, renewable for an equal period on condition they have passed their doctorate in the meantime, if appointed before doing so. The Faculty Assembly of the establishment must be in agreement. Assistant professors retain the right to sit for the competitive examinations a second time.

The conditions of eligibility for these examinations, requirements, and examination procedure, will be dealt with in a special set of regulations.

The special professors for religious instruction shall be appointed on nomination by the Church Authorities; special professors for civics, and for physical education and sports shall be appointed on nomination by the Secretariat General of the Movement.

Assistants for practical work shall be appointed by the Principal of the establishment on nomination by the titular professor for the subject in question, on the recommendation of the Education Committee. The appointment shall be for the period of the course.

8. Candidates for the post of titular professor in an Escuelas Técnicas Superior must have a doctorate from either one of the special Schools or a University; candidates for assistant professorships must hold the degree of Architect, Engineer or licenciado or, if appropriate, intendant or notary.

Candidates for appointment to the staff of the Escuelas Técnicas Medias must hold degrees as architects, engineers, licenciados, aparejadores or peritos or, in certain cases, as intendants, notaries or teachers of commercial subjects.

Professors holding a chair shall have same degrees as titular professors, unless an assistant professor or lecturer is acting as professor on a temporary basis to fill a vacant post, in conformity with the dispositions contained in paragraph six of the present article.

Lecturers shall have the same degrees as assistant professors.

The degree requirements for assistants for practical work, special professors for supplementary subjects, workshop or laboratory superintendents and foremen shall be determined by supplementary dispositions.

On the advice of the Board of Technical Education and the National Council of Education, the Ministry of National Education shall fix the degree requirements for each chair; for technological subjects each chair shall correspond to the branch of technology concerned.

9. In the national budget, the necessary sums shall be allocated for:

a) The granting of increments in the salaries of the holders of the post of titular professor.
b) The salary of external or visiting titular professors as indicated in the official appointment.
c) The salaries of assistant professors and lecturers, corresponding to an amount equal to two-thirds of the starting salary of the full professorial post.
d) The salaries of special professors.
e) Salaries corresponding to the steps within the grade for workshop or laboratory superintendents and foremen.

Titular professors, and, in certain cases, assistant professors and lecturers, shall be paid the starting salary corresponding to their rank, from funds provided for the endowment of the vacant chair.

Assistants for practical work shall be paid from the school's budget.

ARTICLE SEVEN - Administrative System in the Establishments

1. The highest post of director and administrator in each school shall be that of Principal, who shall represent the establishment and be responsible for its administration and services.

The Principal shall be appointed by ministerial order on the basis of three nominations submitted in alphabetical order by the Establishment's Faculty Assembly, who shall choose the nominees from among the titular professors of the Escuela Superior, preference being given to those holding degrees from the same type of school.

Supplementary rules shall ensure the co-ordination at all levels of the educational establishments within each branch of technology. The principals of the Escuelas Superiores shall be responsible for this co-ordination.

2. Each school shall have a vice-principal, who shall also be appointed by ministerial order from a list of three titular professors, submitted by the Principal. The Vice-Principal shall act as director of studies, preside over the Education Committee, and perform the functions delegated to him by the Principal whom he will replace if necessary. In the absence of the Vice-Principal he will be replaced by the senior titular professor.

3. There shall also be a Secretary, an administrator and an auditor of finances, and if necessary, a workshop or laboratory director, all of whom shall be members of the School's teaching staff and appointed by ministerial order. The Secretary and the workshop or laboratory director shall be chosen from a list of three names submitted by the Principal; the administrator and auditor of finances shall be appointed from a similar list established by the Faculty Assembly.

4. The Faculty Assembly shall act as an advisory and consultative body to the administration. It shall consist of two committees for economic and educational matters respectively.

The composition and functions of this Assembly, which shall include a representative of the Spanish university syndicate, shall be fixed by statutory rules.

5. After a report by the Board of Technical Education, the Ministry of National Education shall be authorized to establish, at the request of the establishments, a "Patronato" grouping representatives of official bodies, private individuals in direct contact with teaching in these establishments, and trustees and donors of scholarships. The functions of these "Patronatos" shall, in each case, be determined by a set of regulations approved by the Ministry of National Education.

ARTICLE EIGHT - Aid for Technical Education

1. The State shall make available the funds required to provide technical education with the teaching staff and facilities required for its development; it will thus become

fully effective in both theoretical and experimental fields, as called for by modern technical training and the large increase in enrolment resulting from by the reforms instituted by the present Act.

To this end, the Minister of Finances shall take the necessary measures to meet the expenditure entailed by the present Act.

2. The Ministry of National Education shall be responsible for the fixing or changing of academic fees in general, the sending of degrees, diplomas, certificates or similar papers, fixing the fees to be charged for the use of workshops, laboratories or other installations belonging to the official establishments. The charges corresponding to the foregoing items shall be payable in cash and shall be used for the purposes of technical education in the various schools.

Supplementary rules shall govern the percentages to be allotted to overhead expenses, educational material, cultural development, students' aid, social charges, provident funds and bonuses for teaching, and subordinate staff.

CHAPTER II

HIGHER TECHNICAL EDUCATION

ARTICLE NINE - The Escuelas Técnicas Superiores

1. Advanced Technical Education shall be provided by the following Schools; the relative specialization shall be established in each as stipulated by article three:

Escuela Técnica Superior de: Arquitectura (School of Architecture)
Ingenieros Aeronáuticos (School of Aeronautical Engineering)
Ingenieros Agrónomos (School of Agriculture)
Ingenieros de Caminos, Canales y Puertos (School of Civil Engineering)
Ingenieros Industriales (School of General Engineering in Industry)
Ingenieros de Minas (School of Mining Engineering)
Ingenieros de Montes (School of Forestry, including watercourses)
Ingenieros Navales (School of Naval Architecture and Marine Engineering)
Ingenieros de Telecomunicación (School of Telecommunications Engineering).

ARTICLE TEN - Requirements for Admission to Higher Education

One of the following diplomas shall be required for admission to the selective courses leading to the Escuelas Técnicas Superiores: the diploma of aparejador or perito in any branch of technical education; the upper secondary technical school leaving certificate or the upper secondary certificate carrying admission to the university.

2. The process of selection for admission to these schools shall consist of two stages; only those candidates who pass the first stage shall be admitted to the second.
These stages stages are as follows:

Stage one. - A selective course consisting of mathematics and the physico-chemical and natural sciences, offered by the Escuelas Técnicas Superiores or the Faculties of Science. Candidates may not repeat a course more than once. Only two rakings, "suitable" and "unsuitable", shall be given; acceptance is valid for either the Escuelas Técnicas Superiores or for the Univers , faculties. To be elegible for admission to these establishments, candidates with aparejador and perito diplomas shall be required to take the course referred to in the last paragraph of Article four of the present Act, and those with the upper secondary

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Ingenieros Industriales (School of General Engineering in Industry)
Ingenieros de Minas (School. of Mining Engineering)
Ingenieros de Montes (School of Forestry, including watercourses)
Ingenieros Navales (School of Naval Architecture and Marine Engineering)
Ingenieros de Telecomunicación (School of Telecommunications Engineering).

ARTICLE TEN - Requirements for Admission to Higher Education

One of the following diplomas shall be required for admission to the selective courses leading to the Escuelas Técnicas Superiores: the diploma of aparejador or perito in any branch of technical education; the upper secondary technical school leaving certificate or the upper secondary certificate carrying admission to the university.

2. The process of selection for admission to these schools shall consist of two stages; only those candidates who pass the first stage shall be admitted to the second.

These stages stages are as follows:

Stage one. - A selective course consisting of mathematics and the physico-chemical and natural sciences, offered by the Escuelas Técnicas Superiores or the Faculties of Science. Candidates may not repeat a course more than once. Only two rakings, "suitable" and "unsuitable", shall be given; acceptance is valid for either the Escuelas Técnicas Superiores or for the University Faculties. To be elegible for admission to these establishments, candidates with aparejador and perito diplomas shall be required to take the course referred to in the last paragraph of Article four of the present Act, and those with the upper secondary technical school-leaving certificates shall be required to take a course, which will be created in due time, for converting the technical school-leaving certificate into that for general secondary carrying admission to the university.

Phase two. - An introductory course in architecture or engineering, including further work in mathematics and physics, engineering drawing, and a group of subjects of the type taught at the establishment. This course shall be taken at the Escuela Técnica Superior and candidates may repeat it only once. A single system of grading, "satisfactory" or "unsatisfactory", shall be adopted for the entire course. The introductory course shall be common to all the specializations taught at the establishment. Students marked "unsatisfactory" may re-enroll in an introductory course, but in a different Escuela Técnica.

3. Candidates for admission who have either the aparejador or perito diploma, are exempted from taking the subjects covered by these certificates in the selective and introductory stages; these subjects shall be determined, in each case, according to the previous specialty of the applicant.

4. The questions on the examinations, the tests students shall be required to pass and the composition of the examination boards shall be standardized by statutory regulations.

ARTICLE ELEVEN - Lenght of Course

1. The minimum period of attendance at the Escuelas Técnicas Superiores shall be four years, but may be increased to five years where necessary. The period shall be reduced by one year however for students holding the aparejador or perito diploma, by granting equivalence for the technical and practical knowledge acquired by those holding such diplomas.

2. To complete the final course, each student shall be required to prepare a thesis on a related subject to test his knowledge. Approval of this project is required for the awarding of the Architect's or Engineer's degree.

ARTICLE TWELVE - Doctoral Programme

1. Architects or engineers who wish to obtain a doctorate shall apply to the official school specializing in the branch of technology mentioned in their diplomas; the Faculty Assembly, in agreement with the applicant, shall appoint the professor or specialist who is to act as thesis director.

To obtain a doctorate, the candidate must:

a) Take the required courses, together with any additional subjects suggested by the Professor or specialist acting as thesis director.

b) Write and have an original thesis accepted.

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2. The period required for a doctorate shall be at least one year. The Faculty Assembly may authorize doctoral candidates to study certain subjects in other research or educational establishments, in Spain or abroad, when considered advisable.

3. The doctoral thesis shall be submitted to a jury consisting of the thesis director and four titular professors appointed by the Faculty Assembly. If there are not enough specialists at the school, titular professors at other Escuelas Técnicas Superiores may be called upon.

4. In recognition of to the traditional value accorded to existing titles, those of future holders of a doctorate shall be:

Doctor Arquitecto (Doctor of Architecture)
Doctor Ingeniero aeronáutico (Doctor of Aeronautical Engineering)
Doctor Ingeniero agrónomo (Doctor of Agriculture)
Doctor Ingeniero de caminos, canales y puertos (Doctor of Civil Engineering)
Doctor Ingeniero Industrial (Doctor of General Engineering in Industry)
Doctor Ingeniero de Minas (Doctor of Mining Engineering)
Doctor Ingeniero de Montes (Doctor of Forestry, including water courses)
Doctor Ingeniero Naval (Doctor of Naval Architecture and Marine Engineering)
Doctor Ingeniero de telecomunicación (Doctor of Communications Engineering)

The field of specialization shall be mentioned after the title.

CHAPTER III

MEDIUM-LEVEL TECHNICAL EDUCATION

ARTICLE THIRTEEN - The Escuelas Técnicas Medias

Medium level technical training sh[illegible] be provided by the following schools, wher[illegible] the existing specialization shall contin[illegible] [illegible] each, and be amplified if necessary, in accordance with article three:

Aparejadores. Works superintendent[illegible]
Peritos, (technicians or sub-engine[illegible]) in Aeronautical Engineering
Peritos, in Agriculture
Peritos, General Engineering
Peritos, Mining and Metals
Peritos, Forestry (including water courses)
Peritos, Naval Architecture and Marine Engineering
Peritos, Civil Engineering
Peritos, Communications Engineering
Peritos, Topography.

ARTICLE FOURTEEN - Admission requirements

1. An applicant for admission to the selective course for the Escuelas Técnicas Medias must hold either an upper secondary school-leaving certificate of any type, or a certificate in book-keeping, or one as primary school teacher or works foreman, or industrial skilled worker, as stipulated by the Act of 20th July, 1955, or qualify as a category-one worker or equivalent, with at least two years' service.

Those with a general secondary-school leaving certificate or the workers referred to in the preceding paragraph, shall be required to take a preparatory course in mathematics, physics and chemistry, given in an appointed school and successfully complete it in not more than two years. The examination shall be similar to that required for the upper secondary school-leaving certificate and shall be valid for all Escuelas Técnicas Medias.

2. Admission shall be subject to the successful completing of a selective introductory

course in the related branch of technology, including mathematics, physics, chemistry, engineering drawing and one of the special subjects taught at the School. This course shall be taken in the establishment, within a maximum time limit of two years. Only the grading "satisfactory" or "unsatisfactory" shall be given, and students graded as "satisfactory" may study any one of the specialties taught at the establishment. Students whose work is graded "unsatisfactory" may repeat the introductory course once, but must do so at a school specializing in another branch of technology.

Candidates who have passed the selective course for admission to the Escuelas Técnicas Superiores are exempt from the introductory course except for engineering drawing.

3. Standards for the list of questions and for the tests taken by students when before the Examining Boards of the respective establishments will be given in supplementary regulations.

ARTICLE FIFTEEN - Length of Course

1. Training in the Escuelas Técnicas Medias shall last three academic years.

2. During the final year each student shall be required to carry out an overall project in the field of his specialization and to give proof of his proficiency. Approval of this project is required for the granting of the aparejador or perito diploma.

CHAPTER IV

PRIVATE ESTABLISHEMENTS OF TECHNICAL EDUCATION

ARTICLE SIXTEEN - Recognition and Conferment of Diplomas and Degrees

1. Private establishments providing technical education at the higher and medium levels may be recognized by governmental decree, provided they meet the conditions set for the official Escuelas Técnicas. These establishments must meet the standards established by the present Act in respect of admission requirements, syllabuses and qualifications of the staff.

The Ministry of National Education is responsible for the recognition of these Establishments and the education they provide and for an effective and constant supervision.

If a private establishment falls below the standards required for State recognition, it shall be revoked by the Ministry of National Education on the findings of the Board of Technical Education and the advice of the National Education Council. The establishement may appeal against the revocation according to the procedure laid down.

2. The examinations which the State requires the candidate to pass before it awards the corresponding certificate shall be marked by boards of examiners appointed by the Ministry of National Education according to the following rules:

a) The chairman, who must hold an equivalent or a higher degree than that required of the Establishment's titular professors, in whatever branch of technical education is concerned, shall be chosen by the Ministry from a list of three names submitted by the National Education Council.

b) Two members nominated by the Board of Technical Education from among the titular professors of the official Escuelas Técnicas of the same level.

c) Two members proposed by the Administration of the private establishment in question and elected directly from among the teaching staff.

Only those students whose training is at least equivalent to that of students in official establishments shall be allowed to sit for these examinations which shall consist of an overall project and a final examination, for candidates for the aparejador and perito diplomas, and of final tests including a thesis for candidates for the degree of Engineer or Architect.

3. Students who have passed their final examinations may request the Ministry of National Education to grant the appropriate certificate of aparejador, perito, architect or engineer; this diploma shall constitute the sole requirement for admission to a course

at the next level or for exercising a profession, as stipulated by the rules and regulations guaranteeing equality of opportunity with those awarded similar degrees by an official establishment.

The diploma shall mention the grantor establishment and the field of specialization.

4. Graduates in architecture or engineering who wish to obtain a doctorate shall apply to an official Technical School, where they may continue their studies in conformity with Article 12.

5. Any student wishing to transfer from a recognized private establishment to an official establishment before completing his course shall be required to take such theoretical and practical examinations, as the official establishment to which he has applied considers necessary; the examinations shall be set by the Principal of the establishment and the titular professors in charge of the subjects for which equivalent credit is sought.

6. In the private establishments which have earned recognition, the Faculty Assembly shall act as in consultative and advisory body to the director and shall include, as the official establishments, a representative of the Spanish University Syndicate.

A director of technical studies in these establishments shall be required to hold a degree in the corresponding specialization, and his appointment shall be subject to confirmation by the Minister of National Education.

7. Additional standards will govern the setting up of private technical education establishments under the joint control of the State and other corporate bodies.

CHAPTER V

SYSTEM OF STUDENT AID

ARTICLE SEVENTEEN - Student Aid

1. The system of student aid in technical education establishments coming under the present Act shall comply with the principles and regulations laid down in the Act of 19th July, 1944 and the supplementary clauses.

Articles 12 and 15 of this Act shall apply to official establishments, and particulary to "honorary" enrolment (exemption from fees for the best students) and to the percentage of free enrolment. The percentage of day students exempt from fees at private technical education establishments shall be as indicated in Article 16 of the aforementioned Act.

In addition to the increase corresponding to the budgetary funds made available by the State, the Board of Technical Education should sollicit financial contributions from private firms and official organizations in order to finance the special system of student aid in the establishments which come under this Act. To this end, agreements shall be made between the Board of Technical Education, the Syndicates, public corporations or organizations and private foundations, to attain these ends by the use of their own budget, either in the form of scholarships or of loans on honour to meet tuition expenses.

3. Similarly, technical education establishments are authorized to collaborate with the firms and industries which employ their students in setting up special sandwich courses for those who continue to study while earning. Where the subject is not suitable for sandwich courses, the firms shall be required to grant scholarships, or loans on honour, to those of their employees who have the necessary aptitude and wish to take medium-level training, and those with medium-level diplomas who are exceptionally efficient on their job and would like to train for a higher diploma but are financially prevented; in all such cases, the positions occupied by these people will be kept open for them. The State shall allocate special budgetary funds to enable government employees with medium-level technical diplomas and who wish to study for a more advanced diploma to do so without losing their seniority rights.

4. Student aid for those who are teaching and enrolled as students at the same time shall comply with the regulations set up by the Ministries of National Education and Labour, on the advice of the Board of Technical Education.

In conformity with the dispositions of Article 22 of the Act of 20th July, 1955 concerni[illegible]cational training for industry, the recipient Ministries and Organizations shall de[illegible] part of the proceeds from the tax instituted by the Decree of 8th January 1954 and the [illegible]ncrease authorized in Paragraph c) of Article 12 of the aforementioned Act, to set[illegible] funds for such forms of assistance.

Temporary measures

F[illegible] The Head of the Spanish Government shall take the necessary measures to place th[illegible]ial School of Civil Engineering, the School for engineering assistants in public [illegible]d the engineers' and assistants' section of the official School of Telecommunications [illegible] the jurisdiction of the Ministry of National Education before 1st October, 1957, in compl[illegible] with Article 3 of the present Act; the last-named establishments shall be converte[illegible] Schools for training engineers and "peritos" in telecommunications, as called f[illegible] Articles 9 and 13 of the present Act.

Similarly, the training of assistants in forestry work shall be entrusted to the official School of Forestry set up under Article 13 of the Act.

The sums now being allocated to the aforementioned schools and types of education in the budgets of the Ministries of Public Works, of the Interior and of Agriculture, or the corresp[illegible]ding share of the overall funds, shall be transferred integrally to the budget of the Mini[illegible]ry of National Education and earmarked by the Ministry for this purpose.

Second. - The existing Escuelas Técnicas shall change their names as laid down by Articles 9 and 13 of the present Act.

The Tarrasa School of Textile Engineers shall be converted into an Escuela Técnica Superior, a[illegible] shall train general engineers for industry, with emphasis on textile application[illegible]

The Ministry of National Education shall decide which of the existing Schools of Mining Technicians shall be converted into Schools for assistant engineers in Mining and Metallurg[illegible].

Th[illegible]. - The students enrolled in the Escuelas Técnicas at the time the present Act is promul[illegible]ated shall continue under the existing system. Upon completing their studies they shal[illegible] be awarded the corresponding diplomas and have the same rights as architects, engineers, peritos industriales, peritos in agriculture, aparejadores, peritos in communications, civil engineering and public works, mining and metallurgy technicians, peritos in aeronautical engineering and topography; these diplomas also confer the right to enter directly, without competitive examinations, the State Service corresponding to those fields of specialization for which this right was established prior to the Act of 20th December, 1952, now in force.

F[illegible]. - As from the date the present Act comes into force, the next three classes enteri[illegible]g [illegible] Escuelas Técnicas Superiores and the next two classes entering the Escuelas Técnicas Me[illegible]s shall be selected according to the system existing prior to the Act, without prejudice [illegible] the establishment of the system set up by the Act as soon as the latter takes effect. Students in these classes shall remain subject to the existing rules. All other students shall be subject to the regulations in the present Act, and will obtain

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recognition for the subjects they have passed along with those defined by the regulations in Articles 10 and 14.

Fifth.- The approved selective courses in the Faculties of Science, under the conditions specified in paragraph 2 of Article 10, of the present Act shall be considered to authorize admission to the introductory course, at the Escuelas Técnicas Superiores. Similarly, universities shall recognise subjects passed in the Faculties of Science by candidates seeking admission to the Higher Schools of Architecture.

Sixth. - The Ministries of National Education, and of Finances shall respectively be responsible for constituting and financing the various steps in the grades of titular professors at the Escuelas Técnicas Superiores and Medias, and those of shop or laboratory superintendants and foremen, as stipulated in Article 6 of the present Act.

At the outset, one of these steps shall be applied to personnel in the existing Escuelas Técnicas. Credit shall be given to length of service as titular professor, lecturer, shop or laboratory superintendant, or foremen, and when the length of service is equal, to age. Any redundant titular professors, lecturers, shop or laboratory superintendants, or foremen will be given the step corresponding to their qualifications.

Any professors at the Escuelas Técnicas Superiores and Medias who are not on the payroll of the Ministry of National Education but on that of an other ministerial service paying its staff out of its own budget, shall be included in the appropriate step of the titular professors.

The posts of assistant lecturers who continue in their present function shall be placed in the "to be abolished" category, and the occupants shall be promoted to assistant professorships as soon as vacancies occur.

Seventh. - Those who have already graduated as architects, aeronautical engineers, agriculturalists, civil engineers, "industrial" engineers, mining engineers, forestry experts (including watercourses), naval architects and marine engineers, communications engineers, and textile engineers, shall keep their present titles and shall continue to have the rights and duties recognized by the legislation in force; this also applies to those with doctorates in architecture or engineering, including any who occupy teaching positions, referred to in Article 6, Paragraph 8 of the present Act.

They may obtain, under the rules referring, the title of Doctor of Architecture or Engineering if they establish proof of their achievements and personal qualifications in the academic or professional world, and submit a thesis, which may consist of an original project carried out previously.

Eight. - Those holding a certificate as aparejador or as assistant engineer in aeronautics, communications, forestry and watercourse conservation, public works, mining metallurgy, agriculture and topography shall also continue to have the rights and duties provided by the legislation in force as well as those referring to aparejadores and peritos, in the present Act or in subsequent rules. A special scheme set up under the present Act will facilitate the admission of these certificate holders to the corresponding Escuela Técnica Superior; equivalence shall be established in these schools for the subject concerned in each case and attendance waived in view, of the candidate's achievement and academic and professional qualifications.

The "peritos industriales" shall also continue to enjoy the full rights recognized by the legislation now in force, and shall retain their title until such time as it disappears; in addition, measures shall be taken to facilitate their admission to the corresponding Escuela Técnica Superior, to grant equivalence in the subjects concerned in each case, and to waive attendance at school. The special status of existing peritos industriales will be taken into account as far as their duties, achievements and other academic and professional characteristics are concerned.

Ninth. - The Ministry of National Education shall gradually put this Act into effect, taking into consideration the resources required, as stipulated in Article 8, the capacity of the available installations, and the recruitment of teachers.

Final measures

First. - Independently of the proposals contained in the present Act, the Universities, under their own rules, may continue to provide the form of technical education they feel most appropriate, either in its present form or with such modifications as may subsequently be deemed advisable.

Second. - The Ministries of the armed forces shall maintain the right to establish their own schemes of technical education and certificates as defined by their regulations; these certificates shall have equivalence with the corresponding subjects in civilian Schools, as stipulated by Article 5 of the present Act; they shall correspond to the professional capacity to be defined by law.

Third. - The doctorate in geophysics which is hereby recognised to all useful ends, shall be awarded in conformity with the special standards to be defined by the Head of the Government.

Fourth. - The specialization of project designer will be standardized subsequently as stipulated by Article 3 of the present Act; the possibility will be examined of creating these sections in the schools concerned by means of a decree.

Fifth. - Drawing teachers who hold the official diploma granted by the School of Fine Arts for the purpose of admission to the selective course for aparejador shall be assimilated to upper secondary school leaving certificate holders.

Sixth. - Any activities carried out before the coming into force of the present Act in research or testing laboratories, installations for practical work and the like in the educational establishments shall continue under the regulations now in force.

Any laboratories or research institutes concerned in the training affected by the present Act, and established by other Ministries or public Corporations, shall continue to be used by the Escuelas Técnicas, although still under the authority of these Ministries or Corporations.

Seventh. - The special School of Civil Engineering shall retain the legal status it enjoys at present.

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Heighth. - The Catholic Crafts and Trades Institute, officially recognized by the Decree of 10th August, 1950, shall adopt the standards laid down in Article 16 of the present Act.

However, anyone who graduated from this Institute prior to present Act may obtain the corresponding diploma after submitting an overall project to the Board of Examiners referred to in Article 16 of the present Act.

Ninth. - The Ministry of National Education shall establish full co-ordination on a reciprocal basis in the application of the regulations contained in the present Act, and in particular in Article 6, paragraphs 7 and 8, and the application of the regulations governing universities, secondary and vocational education, and industrial and vocational training, and the related decrees.

Tenth. - The Ministry of National Education is hereby authorised to take any measures that may be required to implement the present Act.

Eleventh. - All measures contrary to the present Act are hereby annulled.

Effected at the Palacio del Pardo, 20th of July, 1957

Francisco Franco

b) Act of 29th April, 1964 (Official Gazette, 1st May)

Article 16 of the Presidential Decree of 23rd November, 1962, which established standards and preliminary measures for the Development Plan, requested a Committe of representatives of the Ministries concerned presided over by the Minister of National Education to propose suitable measures for intensifying and accelerating the training of top and medium level scientific and technical personnel. These two problems, apart from considerations of development policy and even anticipating science policy, have already been raised in countries which still have an educational structure ill suited to present day scientific knowledge.

The Act of 20th July, 1957, concerning the organization of technical education represented a definite step forward in this direction and certainly provided a suitable framework for any future structure. It is for this reason that the reform rendered necessary by the reduction, which proved quite feasible, in the lenght of the course, requires only a few slight changes to the articles of the Act as a whole; all that need be done is to define, with any necessary extension, a few principles already included and to incorporate others made necessary by a vast expansion of educational possibilities.

The complete course at the higher level will henceforth take five years. On the basis of a pre-university course and an upper secondary school-leaving certificate, both of which have recently been modified, and which in principle guarantee admission to establishments of higher education, further weeding-out may take place during the five years without its being necessary to use other means, as traditionally happens in the Faculties which have the same systems and length of course as those now adopted.

Clearly, all this must be accomplished by attempting to improve the quality of the training, rather than by lowering it. Such an improvement should be obtained by bringing the system of departments up to date so as to provide it with a solid basis of fundamental disciplines and make it possible for the system to cover both the new disciplines which constant progress in science and technology make necessary and the main fields of specialization long since recognized. Each Decree will contribute to the educational structure by bringing the courses as effectively as possible into line with the plans at present followed in the most highly developed countries; theoretical subjects will be so placed in the timetable that the period allocated to the workshop or laboratory will be sufficient for the techniques and a working environment to be acquired during experimental work.

Technical education at medium level has been shortened, proportionally, to three years and for the same reasons. The variety of specializations must be broadened so as to meet more effectively the urgent needs of industry and agriculture.

As laid down by the Act of 20th July, 1957, the possibility of access to both levels of technical education and, through the rank of perito, to that of engineer, is explicitly re-affirmed for skilled industrial workers; this rising line of technical competence thus converges with that followed by one or other of the upper secondary school leaving certificates.

Many applied research establishments have already started courses in their special field, in response to the need for making the best use of our educational facilites. This experiment, duly extended, thus widens the range of possibilities offered. It makes effective use of an elite trained abroad and selected while engaged exclusively on scientific or technological work. It will facilitate the systematic training of more highly specialized technicians by means of courses prepared for holders of university degrees. In view of the training already acquired, numerous groups of certificated technicians covering various specialties can be created in a very short time, who will be of great importance in the future development of our country.

In response to this need and with a view to co-ordinating the various schemes of education, the existing Board of Technical Education has been given a new statute to expand its membership and to make it more flexible.

By vertue of the foregoing and in view of the proposal drafted by the Spanish Cortès, I hereby decree:

Article one

Direct access to the establishments providing advanced technical education shall be granted to holders of upper secondary school leaving certificates in any branch who have passed the examination for the pre-university course or its equivalent in the technical secondary schools.

Direct access to these establishments, with subsequent granting of equivalence for education acquired shall also apply to Army officers who have taken the regular general Military Academy courses at the corresponding special academies, the Naval or Air-Force Academies, and also to medium-level technicians in any of specialty and to teachers of commercial subjects.

Article two

Direct access to establishments providing medium level technical education shall be granted to holders of an upper secondary school leaving certificate in any branch, to holders of a commercial technician, diploma to shop instructors and to primary-school teachers.

Access to these establishments shall also be granted to holders of an elementary technical-school leaving certificate, except in the administrative branch, subject to their taking an adaptation course.

Access to these establishments shall also be granted to skilled industrial workers and farm and forestry overseers holding diplomas awarded by State or officially recognized schools, subject to their taking a preparatory course.

The adaptation and preparatory courses shall be valid for all the Escuelas Técnicas Medias.

Article three

Five academic years shall be required to complete the course at the Escuelas Técnicas Superiores; these establishments shall offer the basic disciplines and their specialized branches of technology.

The basic disciplines shall be taught for at least the first two years, and students shall be required to complete satisfactorily each year's work in the same establishment before being admitted to the following year. When these one-year courses are similar in content they may be taken at any of the Escuelas Técnicas Superiores; the first-year course, the whole of which must be successfully completed before admission to the second-year course, may also be taken in the Faculties, and vice versa.

In the Escuelas Técnicas Medias, the course shall last three academic years, during which basic and specialized subjects will be taught, special emphasis being given to the practical side. The basic disciplines shall be taught during the first year, and students shall be required to complete successfully this course in the same school before going on to the following class; if this course is similar in content to that offered elsewhere, it may be taken at any one of the Escuelas Técnicas Medias.

The length of the course, as laid down in this Article, does not necessarily include any compulsory practical training periods held at the end of the course as a requirement for full and unrestricted professional activity.

Article four

The requirements for a doctorate in architecture of engineering shall include two years of study, as defined by the statutory regulations, in addition to the architect's or engineer's degree, and the acceptance of a thesis to be defended in the conditions stipulated by these regulations. Some of the work may be carried out in research or educational establishments, in Spain or abroad.

Article five

Escuelas Técnicas Superiores and Applied Research Institutes shall be authorized to provide courses for the awarding of diplomas in various specializations for certificate holders at higher and medium levels who are desirous of completing their formal education; the conditions governing the awarding of such diplomas shall be laid down in each case by the Ministry of National Education in agreement with the findings of the Senior Board of Technical Education and the recommendations of National Council of Education.

Article six

The Government, on the proposal of the Minister of National Education, shall determine the structure and composition of the Senior Board of Technical Education to ensure the preferential representation of the Escuelas Técnicas Superiores and Medias. The Board shall also include representatives of the National Council of Education, the Faculties and Research Institutes which offer a similar type of education, and the Spanish University Syndicate.

Article seven

The Senior Board of Technical Education shall advise the Minister of National Education in such matters as its opinion may be called for, and specifically as regards syllabuses, the co-ordination of the various types of education, the criteria for granting equivalence, and the internal organization and statutes of the various establishments, with the understanding that this shall not infringe on the prerogatives of the National Council of Education.

Article eight

In all Escuelas Técnicas Superiores or Medias a "Patronato" shall be set up containing representatives of: the professional bodies and associations, the syndicate, and the individuals or corporations most directly connected with the training offered by these Establishments. The functions of these Patronatos shall, in each case, be regulated by statutes approved by the Minister of National Education.

Article nine

The new syllabuses called for by the present Act shall begin during the 1965-1966 academic year.

The regulations covering these syllabuses and the system of equivalences between these and the admission courses introduced by the Act of 20th July, 1957 shall be promulgated before 1st May, 1965.

Without prejudice to what was said in the preceding paragraphs, the Minister of National Education shall publish, prior to 1st October, 1964, the syllabuses for the basic courses given at the Escuelas Técnicas Superiores, to determine equivalence with the present selective and initiation cour[illegible]s. The adaptation and preparatory courses for admission to the Escuelas Técnicas Medias shall be introduced during the 1964-1965 academic year.

Article ten.

The Minister of National Education shall be authorized to promulgate any regulation required to develop and implement the present Act.

Article eleven

Any regulations conflicting with the implementation of the present Act are hereby annulled.

Final measures

First - On the proposal of the Minister of National Education, the Government shall promulgate, in conformity with the findings of the Senior Board of Technical Education and the recommendations of the National Council of Education and the Council of State, the codified text of the measures contained in the present Act and in any previous Acts, still in effect.

Second - The medium-level diplomas for which the training is regulated by the present Act shall be those of Architect and Engineer corresponding to the branch of technology in which they have been awarded. Prior to 1st May, 1965, the Government shall define the titles of architects and engineers, distinguishing those with advanced degree from those with medium-level diplomas, together with their attributions and the steps which present holders of diplomas from the Escuelas Técnicas Medias must take to acquire the new titles.

Temporary measures

First - Students who, at the beginning of the 1965-1966 academic year, have been approved after taking the introductory course, or have passed in all subjects in the preparatory courses designed for holders of upper secondary school leaving certificates who wish to enter the Escuelas Técnicas Superiores, may choose either to continue their studies under the old system or to transfer to the new one set up under the present Act, with the necessary equivalence and as the corresponding courses are set up.

Second - Students who, while enrolled in the introductory course to the Escuelas Técnicas Superiores, or in the preparatory course for holders of upper secondary school-leaving certificates and who, at the end of the academic year, have passed only some of the required subjects, may choose either to transfer to the new system, with the necessary equivalence, or, for the year 1965-1966 to continue in the introductory or preparatory course, as the case may be; they shall be allowed to sit only once more for their examinations as provided for by the regulations.

In all other cases, students shall continue under the new system set up by the present Act, without prejudice to such systems of equivalence as may subsequently be established.

Third. - Students who have passed the final examinations of the selective introductory course at the end of the 1964-1965 school year for admission to the Escuelas Técnicas Medias, may choose either to continue under the existing system or to transfer, with the necessary equivalence, to that instituted by the present Act, as the corresponding courses are progressively set up.

Fourth. - Students who, at the beginning of the 1965-1966 academic year, have not passed any of the subjects in the preparatory course leading to the Escuelas Técnicas Medias, shall be required to transfer to the system instituted by the present Act, insofar as the diplomas required for admission to the aforesaid Schools are concerned; such students shall continue under the system set up by the present Act, and shall be granted equivalence for the subjects in which they are considered to be satisfactory.

Fifth. - The Minister of National Education shall draft the necessary measures to allow students who, in the 1964-1965 academic year, enrol in the preparatory courses set up under the Act of 20th July, 1957, to register for and take their examinations by separate subjects so that, during the 1965-1966 and subsequent academic years, these may be fitted into the syllabus set up under the present Act and the system of equivalence between the old and new systems.

The necessary measures shall also be taken to allow students who have been successful in certain subjects in the preparatory course set up under the Act of 20th July, 1957 to request equivalence for these subjects in any other School, according to the equivalence; this shall apply even after the date set for enrolment, and independently of the examination session or of the School concerned, so that the measures previously in force may be effectively applied.

The Ministry of National Education is authorised to take any measures necessary to cope with the different situations which might arise for students who began their studies under the system prior to that instituted by the present Act.

Six. - Students completing the course in architecture or engineering under the system instituted by the Act of 20th July, 1957 may obtain a doctorate without further enrolment; they shall be required to submit a doctoral thesis as provided for by Article 12 of the aforementioned Act.

Seven. - The Ministry of National Education on the report of the Senior Board of Technical Education and the agreement of the National Council of Education shall establish admission rules to the Escuelas Técnicas Superiores for upper secondary school leaving certificate holders under the system instituted by the Act of 20th July 1957 and earlier Acts, on the basis of the subjects taken to obtain the secondary school certificate.

Effected at the Palacio del Pardo, 29th of April 1964

Francisco Franco

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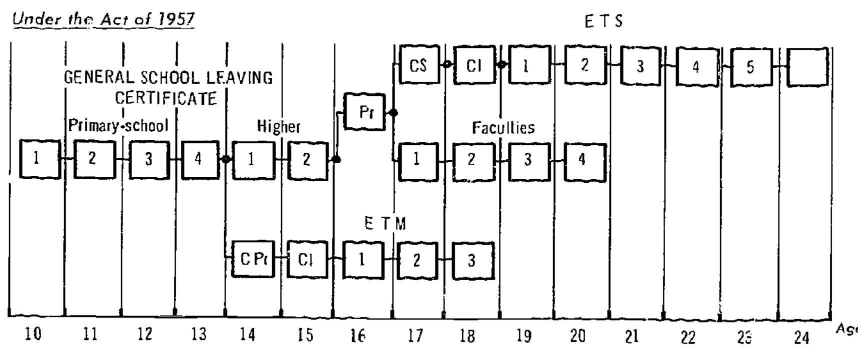
Annex VIII

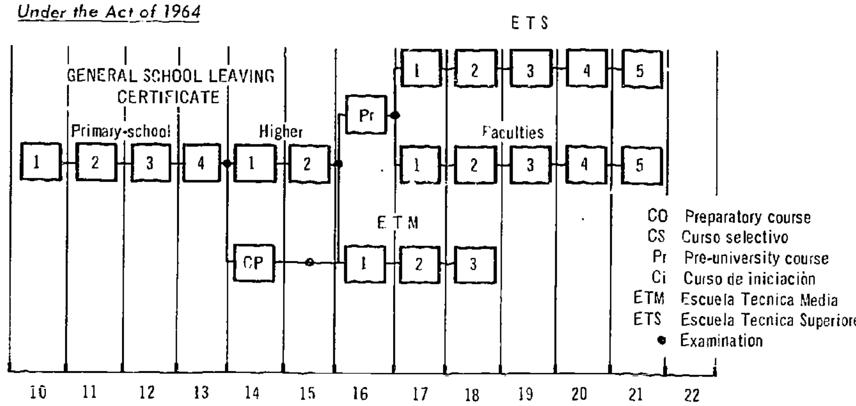
CHANGES IN THE STRUCTURE OF TECHNICAL EDUCATION

The following diagrams show the various possibilities open to pupils in general secondary schools and the different choices open to them

Under the Act of 1957



Under the Act of 1964



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ANNEX IX

Level of students on admission to the first-year course

Admission to the Escuelas Técnicas Superiores is not restricted to those holders of upper secondary school leaving certificates who have passed the examination of the pre-university course; holders of other types of diplomas, particularly those awarded by the Escuelas Técnicas Medias, are eligible for admission, and many of them take advantage of this opportunity. While such measures should be encouraged, this report is concerned mainly with the great majority of the students, and these enter the first year straight from secondary school, without any experience in industry. It is also to this category of students that the following remarks apply.

Most of these young people have grown up either in Seville or the surrounding region, i.e. in a part of the country which is only slightly industrialized and this has some influence on their behaviour. First, the pace of living and the resulting pre-occupation with efficiency and output are not the same as in the more-developed countries; secondly, students have not been brought up in surroundings where science and technology are of prime importance; and, lastly, they have only a vague idea of the role and functions of the engineer. This is a definite handicap, particularly as secondary education, in Spain as in many other countries, is largely theoretical.

It has been possible to get some idea about the level of the students entering the school, (a) by a detailed study of their previous syllabuses, (b) by an examination of the books used and (c) by discussions with some of the students during a visit to Seville.

The students appear to have a reasonably sound theoretical knowledge of the basic principles of physics and chemistry, which are treated in great detail, although very little is taught about their applications, and there is virtually no practical work. In many countries it would be regarded as impossible to understand either physics or chemistry without practical work, and the examinations for admission to the university include both practice and theory in these subjects.

Spain, like other countries, is experimenting with modern methods for teaching secondary school mathematics. The majority of the students who enter the first year of Engineering Schools, however, have had no experience of the new methods, and have taken the traditional courses in Algebra, Trigonometry, Geometry, Elementary Functions and Elementary Statistical Concepts; differential and integral Calculus are included in the syllabus, but are only very lightly touched upon. On the whole, teaching is fairly theoretical and contains very few examples of practical applications.

ANNEX X

DECREES OF 20th AUGUST, 1964 AND 29th MAY, 1965

(Extracts)

I. DECREE OF 20th AUGUST, 1964

Curricula for the first two years at the Escuelas Técnicas Superiores

First Year

Linear algebra
Differential and integral calculus
Physics
Chemistry
Engineering drawing

Second Year

Second-year mathematics
Second-year physics
Mechanical engineering
Engineering drawing
Organic chemistry
Descriptive geometry (four months)
Surveying (four months)

II. DECREE OF 29th MAY, 1965

Curriculum for the final three years at the Escuelas Técnicas Superiores

... The Minister of National Education has decided that:

1) The syllabuses for the third, fourth and fifth years at the Escuelas Técnicas Superiores shall be as indicated in a subsequent part of this Decree, without prejudice to any periods of practical training which may be required of students at the end of their course for the full and unrestricted practice of their profession.

2) The subjects listed shall be taught for a period of four months, on the understanding that no more than six such subjects shall be taught during any given period, provision being made for at least 15 hours to be given to practical instruction each week.

3) This curriculum should not be interpreted too rigidly and, on the suggestion of the schools, the timetable may be changed, including the time allotted to each subject; some subjects may even be abolished, others extended, or new ones introduced for educational reasons, on condition that the number of subjects taught is not increased or the number of hours for practical instruction reduced.

A. Mechanical Engineering

Third Year

Theoretical and applied statistics
Elasticity and Strenghth of Materials
Thermodynamics and Physico-chemical Properties
Fluid Mechanics
Electrical Engineering
Kinematics and Dynamics of Machinery

Fourth Year

Economic Theory and Institutions (four months)
Machine Technology
Electronics
Structural Design
Design, building and testing of machines
Metallurgy (four months)
Heat Transmission (four months)

Fifth Year

Projects
Business Administration (four months)
Industrial Buildings
Transport (four months)
Heat Engines
Hydraulic Machines
Regulation of Industry in Urban Areas (four months)
Industrial Techniques in Urban Areas (four months, option)
Safety and Industrial Psychology (four months, option)
Railways (four months, option)
Automobiles (four months, option)

B. Chemical Engineering

Third Year

Theoretical and Applied Statistics
Elasticity and Strength of Materials
Thermodynamics and Physico-Chemical Properties
Fluid Mechanics
Electrical Engineering
Inorganic and Analytical Chemistry

Fourth Year

Economic Theory and Institutions (four months)
Heat Engines
Electronics
Unit Operations
Basic Chemical Engineering Operations
Metallurgy (four months)
Heat Transmission

Fifth Year

Projects
Business Administration (four months)
Industrial Buildings
Inorganic Chemistry Technology
Organic Chemistry Technology
Control Systems and Servo-mechanisms (four months)
Instrument Analysis (four months)
Safety and Industrial Psychology (four months, option)
Petroleum Chemistry (four months, option)
Nuclear Engineering

C. Electrical Engineering

Third Year

Theoretical and Applied Statistics
Elasticity and Strength of Materials
Thermodynamics and Physico-chemical Properties
Fluid Mechanics
Electrical Engineering
Kinematics and Dynamics of Machinery

Fourth Year

Economic Theory and Institutions (four months)
Heat and Hydraulic Engines
Electrical Engineering

Electrical Machines
Power Lines and Networks
Metallurgy (four months)
Heat Transmission (four months)

Fifth Year

Projects
Business Administration (four months)
Industrial Buildings
Electrical Power Plants
Design, Building and Testing of Electrical Machines
Industrial Electronics
Nuclear Physics and Technology (four months)
Control Systems and Servo-Mechanisms (four months, option)
Electrical Measurements (four months, option)
Electric Traction (four months, option)
Safety and Industrial Psychology (four months, option)

ANNEX XI

Extract from the Statutes of the Escuelas Técnicas Superiores

Article 1. The objectives of the Escuelas Técnicas Superiores are to:

1 - offer a full course of study leading to degrees in the various fields of specialization.

2 - examine the qualifications of people who, in conformity with the legislation in force, seek recognition of similar degrees granted by foreign establishments.

3 - declare sufficient, by means of any tests that may be required, the knowledge acquired by those who attend in a private capacity the courses offered by the School.

4 - offer more-advanced instruction in those subjects included in the syllabus as stipulated in the present statutes, and if necessary award corresponding certificates.

5 - issue reports and findings, and either singly or in collaboration with other Research Centres, conduct testing analysis and other work connected with their specific branch of technology, on their own initiative, when requested by the Authorities, or when asked by firms or private individuals.

6 - keep in contact with other schools, laboratories, museums, and advanced technical colleges in Spain and abroad, in order to be kept fully informed at all time of the progress being made in their field.

7 - provide any supplementary training for higher civil servants decided by the Ministry of National Education in agreement with the other Ministries. Such training shall be given at the same time as normal courses and shall be financed by the Ministry concerned.

8 - set up, singly or in collaboration with other institutions, for both graduates and others, specialized or refresher courses, seminars or special series of lectures.

9 - promote and encourage any steps likely to improve the training of students.

10 - establish Institutes and Laboratories for Technical Studies and Research, Centres for Industrial Co-operation, Bibliographical Information Centres and Services offering documentation of a technical and pedagogical nature, and collaboration Centres for graduates.

Article 5. - As part of the final year's work, each student shall be required to carry out a thesis project on a subject in his field to indicate the proficiency he has acquired. This project must be approved before the title of Architect or Engineer is granted.

Article 6. - Doctoral candidates must file an application with the Principal of the corresponding Escuelas Técnica Superior; the Board of Professors shall designate, in agreement with the candidate, a professor or specialist to supervise his studies and act as thesis director.
Candidates for the doctorate must:

a) take courses in the subjects shown in the syllabus and as suggested by the professor or specialist acting as thesis director. If the syllabus so requires, the Board of Professors may authorize the candidate to take courses at other research or educational establishments in Spain or abroad.

b) defend an original thesis. The preparation for a doctorate shall be a minimum of two years. The doctoral thesis shall be submitted to a board of examiners consisting of the thesis director and four resident professors appointed by the Board of Professors. If the school has not sufficient specialists on its staff,resident professors from other Escuelas Técnicas Superiores may be called upon to sit on the board of examiners.

Article 8. - The Board of Professors acts in an advisory and consultative capacity to the Principal.
The Board of Professors shall be composed of resident and visiting professors, lecturers, special professors, and representatives of the School branch of the Spanish University Syndicate.
It shall convene when convoked by the Principal to examine a set agenda. It may also meet if a third of its members so request in writing, giving the reason for their action, except if the School Directors object because they consider the subject outside the Board's competence. The Board shall meet at least once in the course of each three-month term, irrespective of the method of convocation. Exceptionally, if the Chairman has so requested, assistants, lecturers, workshop superintendents or other persons shall be allowed to attend a meeting of the Board to supply information, but will have no voting rights.

Article 9. - The prerogatives of the Board of Professors shall be:

a) to submit to the Ministry, through the intermediary of the School Directors, an alphabetical list of three resident professors for the purpose of appointing a Principal, in case of vacancy.

b) to nominate, through the intermediary of the School Directors, suitable candidates for the posts of Administrator and Burser.

The Board shall also submit to the Ministry:

1 - the syllabuses and any modifications thereof, together with its choice of technical subjects;

2 - detailed curricula of the subjects taught at the School, drafted by the Professors concerned;

3 - the Programme of practical work, study tours and training periods in industry;

4 - the measures taken for educational improvements;

5 - the allocation of credits and the management made of the School's own funds;

6 - the passes and positions of students at the end of their course, as prescribed by the present Statutes, and proposed by a board of examiners appointed by the Principal;

7 - a list of the members of the training staff who will accompany students on study trips and during their training periods in industry;

8 - all matters on which the Principal of the School or the Authorities may wish to have its opinion.

The Board of Professors may not consider or propose any subjects lying outside its province, as defined by the present Statutes.

Aticle 16. - The task of the Director shall be to govern, administer and represent the School.

He shall be appointed by order of the Ministry of National Education upon submission of an alphabetical list of three romInces chosen by the Board of Professors from among the resident professors, preference being given to those holding the diploma awarded by the school in question and in a position to devote the required amount of time and energy to the performance of these duties.

Article 17. -The role of the Principal shall be to:

1 - observe; and ensure that all concerned observe, the rules, statutes and other regulations laid down by the Authorities;

2 - organize the School as a whole and adopt and necessary measures to ensure that the regime and order are duly respected;

3 - promote and encourage any action liable to make education more effective;

4 - submit to the Ministry a description of the duties and a list of the persons to whom they are to be entrusted by virtue of the present Statutes.

5 - preside in person over all Assemblies, Committees or Meetings held at the School, if he considers this advisable, even though the present Statutes do not explicitly confer such Chairmanship upon him.

6 - inspect teaching and ensure that the staff carries out its duties.

7 - appoint boards of examination on the advice of the Board of Professors, and preside over such boards when he considers this advisable.

8 - appoint assistants for practical work.

9 - sign working and termination certificates for those employed by the School, and also temporary appointments; perform other functions which he is legally required to assume as Personnel Director for all the departments and services.

10 - propose and apply appropriate penalties where necessary, in conformity with the School's rules and regulations.

11 - carry final responsibility for all payments.

12 - submit to the Ministry of National Education an annual memorandum concerning the organization and functioning of the establishment, together with any such literature as the Ministry should receive periodically.

13 - inform the Authorities of any requests made by the staff, students or candidates to the establishment.

14 - ensure co-ordination with other establishments in the same field at the various levels.

Article 18. - The Vice-Principal of the School shall be appointed by order of the Ministry of National Education from a list of three nominees in alphabetical order chosen by the Principal of the school from among the professors at the establishment as being likely to carry out and devote the necessary time the functions of the office.

Article 19. - The Vice-Principal shall:

1 - replace the Principal in case of illness, absence or termination of duty;

2 - preside over the Educational Committee;

3 - act as director of studies; he is reponsible, subject to the agreement of the Principal, for establishing the syllabus and for the organization and inspection of work;

4 - assume any functions delegated to him by the Principal;

5 - submit to the school authorities the academic calendar fixing the dates for terms and final examinations;

6 - receive the official examination results, put them on the notice board for the public, and transmit them to the Secretariat for filing in the records and for use when required for other administrative formalities;

7 - submit to the school authorities proposals for study tours after recommendation by the Educational Committee.

Article 20. - The Vice-Principal shall be replaced by the President Professor next on the promotion list.

Article 21. - The latter shall be appointed by order of the Ministry of National Education from among suitable resident or assistant professors able and willing to devote sufficient time to these duties on the basis of a list of three names in alphabetical order submitted by the Principal of the School. He may at the same time act as Administrator if the Board of Professors so proposes.

Article 22. - The Secretary shall be responsible for the general administrative functions required to carry out the decisions of the School authorities or the instructions received by them, and particularly the following:

1 - supervise the administrative work and act as the immediate head of the staff of the Secretariat and of the establishment's interior service;

2 - Help the Principal work out the School's affairs;

3 - Draugh official correspondence, preserve documents and the minutes of the Board of Professors;

4 - Classify and conserve the files referring to the staff and students of the Establishment.

5 - Classify and preserve the official examination results as issued by the various boards of examiners;

6 - Forward registration certificates with the consent of the Principal and certify papers where required;

7 - Record all receipts made by the Secretariat.

8 - Authorize the registration of students, as instructed by the School authorities, and forward report cards.

9 - Ensure that buildings and facilities are kept in good order and condition; keep an inventory of furniture or other objects.

Article 23. - Should the Secretary be absent or ill, his work shall be carried out by the resident or assistant professor appointed by the Principal to replace him; the principal shall inform the Ministry of National Education of this appointment.

Article 24. - The teaching staff of the School shall consist of:

a) resident and visiting professors
b) assistant professors
c) titular professors and lecturers
d) special professors
e) assistants for practical work
f) workshop or laboratory superintendents and foremen.

Article 25. - The number of teaching staff in each School shall be decided by the Ministry of National Education in view of teaching requirements and in agreement with the Board of Technical Education.

Article 26. - The appointment of the teaching staff as a whole falls on the Ministry of National Education; the choice shall be based on the standards laid down in the statutes.

The Ministry of National Education shall also be responsible for appointing temporary teachers on the proposal of the Principal, whenever a post falls vacant. When appointments as assistant professors or lecturers are involved, the prior agreement of the professor concerned shall be required.
The appointment of assistants for practical work shall be subject to the provisions of Article 36.

Article 27. - Resident Professors

a) whose names have been put on the promotion list for teachers since the publication of the Decree of 9th February, 1961 (Official Gazette dated 20th February, 1961) are required to devote to their teaching and other academic duties at least four consecutive hours each morning, at the School, five days per week. The post of professor shall therefore be incompatible with any other occupation conflicting with this timetable.

b) shall consider their teaching as a special, priority duty, to be carried out with all the exactitude and effectiveness necessary for pupils to receive the best possible training, and for the School's activities to develop fully.

c) must reside in the locality where the school is situated and may be absent only after obtaining authorization, as laid down in the statutes.

d) must submit a complete description of the syllabus of the subjects corresponding to their chair, with their timetable as well as the timetable for any other subjects, in case it should be necessary for them to teach another subject.

e) shall guide and direct the practical exercises and drawing lessons in connection with these subjects to ensure their proper co-ordination with the theoretical instruction. They shall be appointed as heads of Departments and ensure the smooth working and development of these departments if necessary, arranging for them to be properly equipped by submitting to the School authorities the lists of any missing itmes, and thus making sure that they are always properly equipped.

f) submit for the approval of the Principal the curricula for the subjects for which their respective chairs are esponsible after a prior report from the teaching Commission of the Board of Professors. These curricula shall be submitted in triplicate to the Vice-Principal's Office a fortnight before classes begin, and shall be published by the school by means of the funds set aside for this purpose.

g) give students a list of books at the beginning of the course and, if necessary, write up a set of notes on the subjects for which they are responsible.

h) keep abreast of scientific and technical progress in the fields pertaining to their chair and, when necessary, teach these subjects in seminars and refresher courses.

i) direct the theses of degree candidates.

j) suggest subjects for the projects students are required to carry out either during or at the end of their course.

k) provide the Director of Studies with a daily report containing the subject of the day's lesson of practical work, together with an attendance list and the marks given to students.

l) perform the administrative work requested of them.

m) preside over, or sit on, the selection boards for the appointment of professors, decided by the Ministry.

n) help in planning and making arrangements for the training periods in industry and the study tours decided by the School authorities and be personnally responsible for them.

o) attend the meetings of the Boards of Professors and the Committees or any other academic or official meeting to which they may be summoned by the Principal or the Vice-Principal.

p) carry out such work as may be assigned them by the Principal or Vice-Principal of the establishment, as an undertaking characteristic of the work of the School, or as ordered by the Authorities.

q) carry out singly or collectively any instructions or reports requested by the Principal or the Vice-Principal.

Article 28. - The Ministry of National Education shall be authorized, on its own initiative or at the request of the School, to appoint visiting professors who must be university graduates or have established a reputation in their field of specializations.

Such nominations, with supporting statement, shall be formulated by the higher Scientific Research Councils or similar Institutions and by the National Education Council.

The remuneration of visiting professors shall be specified in their contract.

Article 29. - Assistant professors shall:

a) perform the functions of the corresponding resident professor in case of absence. dismissal or illness.

b) assist the aforementioned in his teaching duties and theoretical and practical research, in compliance with their instructions; ensure that the departments, laboratories and workshops for which they are responsible are properly maintained and developed.

c) take part in training periods in firms, or in study tours as required by the Administration, either as leaders or as assistants to the professor in charge.

d) attend academic and official meetings when convoked by the Principal or Vice-Principal.

e) carry out any tasks considered as proper to their school duties, or at the order of the Authorities, when requested by the Principal or Vice-Principal.

f) assist in the setting up of boards of examiners, whether for students already enrolled at the School, or for applicants for admission.

Article 33. - Lecturers shall teach in the field for which they have been appointed, under the guidance of the corresponding titular professor, and participate in teaching practical work when the latter considers it necessary.

Article 34. - The teaching of the supplementary subjects shown in the syllabus shall be entrusted to special professors chosen by competitive examination. Their tenure shall be for four years, and may be extended if the report of the Board of Professors is favourable.

Article 36. Assistants for practical work shall be nominated by the professor concerned and appointed by the Principal of the establishment, subject to the approval of the Education Committee. Appointment shall be for one academic year, and the salaries shall be fixed by the School and paid out of its budget.

Article 37. - The assistants shall take part in the practical work required of students in their subject and in that carried out in the workshops and laboratories, as in instructed by the professor or lecturer.

Article 38. - Each laboratory, workshop or department shall be assigned a superintendent responsible to the professor or lecturer and who shall carry out his instructions as precisely as possible; he will be responsible for any work as signed to him, and possibility help in the practical work in the workshop or laboratory and ensure that the equipment is properly maintained.

Article 43. - In addition to the aforementioned teaching posts, that of director of workshops or laboratories shall also be created when necessary. Appointment shall be by order of the Ministry of National Education form a list of three resident or assistant professors nominated by the Principal of the School.

Article 44. - The Director of workshops and laboratories shall:

a) ensure the coordination of the technical services belonging to the laboratories, workshops and rooms for practical work.

b) see that the general rules ensuring the proper maintenance and working of the laboratories are applied, with the assistance of the resident professors concerned.

c) draw up a general inventory of the equipment and instruments in each laboratory, workshop and room for practical work; submit this inventory each year to the Secretariat, together with any possible improvement or deterioration which might affect the equipment.

d) act as immediate supervisor to all the extra or auxiliary personnel assigned to the laboratories, workshops, and rooms for practical work.

e) request the administration, on the proposal of the resident professors or concerned, to authorize purchases, improvements, modifications and repairs to laboratory, workshop and other equipment and instruments, to make teaching as effective as possible.

f) suggest that the school administration should sell, under the conditions and formalities laid down the equipment or instruments that he and the resident professors concerned consider to be absolute.

Article 45. - The auxiliary technical personnel (laboratory demonstrators in chemistry, museum curators, people in charge of meteorogical laboratories, mechanics, photographers, lab boys and the like) shall be chosen by competitive examination, and carry out, before a board of examiners appointed by the Principal, practical tests bearing on the syllabuses and instructions issued by the Board of Professors. The Ministry of National Education shall make the appointment to each post, taking into account, when necessary, the Principal's proposals.

Article 47. - The administrative staff assigned to each Establishment by the Ministry of National Education according to requirements shall be responsible to the Principal, and under the immediate supervision of the Secretary; it shall be bound by the regulations issued by the ministerial Authorities.

Article 48. - The list of subordinate personnel shall be drawn up in the same manner by the Ministry of National Education.
Although this staff shall serve the educational and administrative functions of the establishment, it shall be under the immediate supervision of the caretaker, who shall ensure that the work is properly carried out.
The caretaker shall be responsible for keeping watch over the building and the objects therein. He shall live at the school and remain there during the hours set by the Principal.

Article 53. - Infractions committed by the teaching staff or students of the School shall be punished as provided for the Regulations concerning academic discipline in official establishments of higher and technical education.

Article 59. - The post of Principal may be occupied by either the Administrator or the Bursar, subject to the approval of Economic Committee of the Board of Professors.
The Administrator, when this post is occupied neither by the Secretary nor the Bursar, shall be a resident or assistant professor appointed by the Ministry of National Education on the basis of three nominations submitted in alphabetical order by the Board of Professors and chosen from among suitable faculty members and able to devote the time required.

Article 60. - The Principal shall:

a) be responsible for the overall administration of the School;

b) submit to the Ministry of National Education the list of three names chosen by the Board of Professors as nominees for the posts of Administrator and Bursar.

c) appoint, upon proposal by the Administrator and the Bursar, the staff they require for their services; fix the salaries, which shall be paid from the School funds.

d) decide how the School's assets are to be invested.

e) ensure the best and safest use of these assets.

f) draw up the School budget, with the assistance of the Administrator and the Bursar, and submit it to the Ministry of National Education as laid down in the regulations.

g) draw up, in due form any special or supplementary budgets which may become necessary during the fiscal year.

h) grant authorization for all the payments to be made under the various budgetary holdings.

i) sign, together with the Administrator or the Bursar, the various papers required to open a current account in the name of the School at the Bank of Spain.

j) inspect and supervise all books in the accounting, administrative and bursar's departments.

k) authorize, by his signature, any certificates concerning the establishment's economy as may be requested, through the intermediary of the Administrator or the Bursar, by any office or service of the School concerned or by any member thereof.

l) establish, with the aid of the Bursar, the yearly accounts for the School's budget.

m) deal with all matters of administration and take any exceptional measures he considers might helps the School's economy and expansion.

Article 62. - The Administrator shall:

a) assume full administrative responsibility for the endowment of the School and collaborate with the Principal or the Assessor in establishing its special budgets.

b) ensure the receipt of the various funds earmaked for the school granted from the general State budgets or by other, independent, bodies.

c) sign, with the Principal, the papers required for the opening and use of a current account in the name of the School.

d) keep a check on the cash periodically withdrawn from the current account to meet the daily expenses involved in running the School.

e) assist the Principal in drawing up the regular budget and any special budgets that may be required.

f) assist the Principal when he establishes the accounts for the school budgets.

g) keep a record of all receipts, whatever their origin, including administrative and school fees, etc., and deposit them in the School's bank account.

h) make all payments provided for in the School's budget, after the usual approval, and issue orders for payment.

i) keep cash account books and all other account required for accurate accountancy, balance the cash receipts with the Principal and the Bursar and sign with them the corresponding voucher.

j) draugh all papers or certificates at the Principal's request concerning the School's finances and submit them for his approval.

k) draw up, as instructed by the Principal, the detailed voucher memorandum of the School's budgets.

l) submit to the Principal nominations for auxiliary administrative personnel authorization for persons and equipment, cashier, etc.

Article 63. - The Bursar shall:

a) take action in all the expenditure and receipts in the School budget.

b) propose the appointment of such auxiliary staff for his service as he considers necessary.

c) consider, prior to authorizing payment, all bills falling due, and subsequently ensure that the orders to pay have been duly executed.

d) assist the Principal in drawing up the regular budget and, when necessary, the special budget, and keep the corresponding accounts.

e) sign, with the Principal, the papers required for opening and using a bank account in the name of the School.

Article 64. - Students may either be officially enrolled, or simply attend lectures but may not do both simultaneously during any given academic year.

Article 65. - It is also possible to have a system which would permit work at School to be done at the same time as the training period in firms, or would allow students to attend sandwich courses, if the time table were suitably arranged. This would depend on the number of students interested and each one's position in these firms.

Article 66. - Candidates for the selective course shall be required to prove that they hold one of the following diplomas: "Aparejador" or "Perito" with specialization in a technical branch; upper secondary School leaving certificate (Technical or University option) giving access to the University; diplomas mentioned in Article 2 of the present Statutes.

When first registering at the School, students shall be required to prove that they have no contagious disease; for this purpose, they may be required to undergo an examination by the School's medical service at the beginning of term and intervals throughout the year.

Article 67. - The student body of the School shall be represented by the Spanish University Syndicate, in compliance with the existing regulations.

Article 73. - The courses shall be organized to ensure that approximately 50 students attend each class at the same time. For drawing and practical work, however, the number may vary according to the type of course.

Article 74. The oral instruction given in the subjects in the syllabus shall be supplemented by:

- drawing work, numerical and analytical exercises and laboratory work in connection with the theoretical instruction
- practical workshop and field exercises
- lectures given by specialists in the various fields
- projects covering one or more subjects in the syllabus as a complete whole
- visits to, and training periods in, works, yards, workings, factories and other installations
- seminars in the various subjects.

Article 75. - Classes shall be held from 2nd October to 15th June. Regular and special examinations shall be held respectively from 16th June to 10th July and during the month of September. Holidays during term time, and the length of the Christmas and Easter holidays, shall be fixed in conformity with the general regulations.

Students enrolled in Officers' Training Courses shall observe the special rules laid down by the Ministry.

Article 114. - A publication service shall be attached to the school to publish books, original works or translations, memoirs or notes on the subjects taught at the school or at other schools in the same branch.

Article 121. - The library of each school shall constitute a unit, regardless of where the books, designs, plans and pedagogical documentation are housed. The library shall have one general catalogue, plus any sectional catalogues considered necessary.

Article 130. - Each school shall set up a medical service for the examination and care of its students and teaching staff; the results all examinations and treatment provided shall be recorded on cards showing the patient's medical history. This service shall keep in touch with the School health services and shall be supported by funds from the School and subventions granted for this purpose by the Ministry.

(Statute of the Escuelas Técnicas Superiores
7th March, 1962).

with the nomination submitted by the Department, subject to the approval of the Dean, and in agreement with the Faculty Boards and the Government. The nomination submitted by the Department shall be obtained on the basis of votes cast by its professors and certificated professors and shall be decided by simple majority.

Appointment shall be for three years and may be successively renewed by the same procedure.

When there is no professor on the staff of the Department, the Rector, acting upon a nomination submitted by the Dean, shall appoint one of the certificated professors on an interim basis as Head.

The Head of Department shall be its representative in dealings with the Academic Authorities, and shall be responsible for co-ordinating the curricula, and developing the courses and the various lines of research, without prejudice to his own teaching and research duties. He shall be responsible to the Dean for ensuring that the class and practical work schedules are observed and that the staff carry out their duties, and shall keep the Dean informed of any anticipated developments.

Article 6. - The rank of certificated professor, the rights and duties of which are defined in the following articles, is set up between that of resident professor and assistant professor.

Article 7. - Certificated professors shall undertake teaching, examination and research work as required by the Faculty, the Department and the Chair; they shall teach at least one course, even in an extra class, in one of the subjects of the syllabus, and may sit on any type of examination board.
When certificated professors are assigned to a Department, the Head of Department shall supervise and direct their work as provided for by Article 3 of the present Act. Should their subject not come under a Department, they shall report directly to the Dean of the Faculty...

Article 9. - Certificated professors shall be required to live in the locality of their Faculty and give all their time and energy to their university duties which will be comulsorily on a full-time basis, and leave no time for professional activity of employment in other state services whether at national, provincial or local levels...

Article 10.- The salaries of certificated professors shall be as fixed by Decree, in conformity with the Act on the Salaries of Civil Servants. In no case shall they receive less then 80% of the salary of a resident professor with the same seniority and employed on a full-time basis.

Article 12. - Appointment to the rank of assistant professor shall be by competitive examination held in the Faculty concerned. Applicants must hold a university degree or a corresponding diploma awarded by an Escuela Técnica Superior, and offer proof that they have worked as assistants for practical work during at least one full academic year, or that they belong, or have belonged for the same period to an official or recognized research establishment or the teaching staff of a medium level establishment; applications must be accompanied by a written statement from the professor under whom they have served as assistants ...

... These professors shall be appointed for a four-year period by ministerial order, on the basis of nominations submitted by the Selection Committee, subject to the agreement of the Faculty Board and a proposal from the Rector of the University; no extension of his appointment can be granted unless the candidate has a doctorate.

Assistant professors may replace professors and certificated professors on official leave with the authorisation of the Head of Department when necessary; they shall be responsible for practical instruction in the clinics, laboratories and seminars, under the guidance of the Head of Department. At the request of the Dean of the Faculty, they may be asked to take a full course in their field, should the number of students require the classes to be split up; in such cases they shall be paid in proportion to their load.

Article 17. - The Rector of the University, on the proposal of the Dean and after consultation with the Faculty Board, may appoint to the rank of visiting professor persons of recognized reputation and proficiency in the field concerned, and holding a university degree or equivalent.

Such appointments shall be for an unlimited length of time by a contract specifying the services to be rendered, the time to be allocated to them and the total salary to be received.

The salary shall be paid from funds set aside for this purpose by the University in its own budget, or from funds earmarked by the Ministry of National Education for such contracts submitted for its prior approval. A special heading shall cover such subsidies in the Ministry's budget. Visiting professors shall have all the prerogatives and duties corresponding to post performed by them under the terms of their contract.

Article 19. - All persons promoted to the rank of resident professor after the promulgation of the present Act shall be required to work full time in the university, to the exclusion of other professional activity or service in other corps, in all the fields to which this decision applies as laid down by the Decrees governing the Faculties.

To encourage teaching and avoid depriving society of the collaboration of university professors, authorisation may be granted by ministerial order for university staff, even with full-time appointments, to offer their professional services to private individuals or firms.

Final measures

The funds necessary for the payment of the salaries mentioned in Article 10 of the present Act, included in the budget of the Ministry of National Education, shall be provided by the Ministry of Finances. Funds shall also be provided for paying the family and residence allowances, and the indemnities for full-time work of certificated professors.

ANNEX XIII

EXTRACT FROM THE DECREE CONCERNING THE "PATRONATOS" FOR THE ESCUELAS TECNICAS

Decree promulgated in November, 1965

Article 1. - In each of the Escuelas Técnicas Superiores and Medias, a "Patronato", representing the various sectors most directly in contact with the School, shall be set up to give its aid and collaboration to the establishment in carrying out its task.

Article 2. - The "Patronato" of each Establishment shall include, in addition to a Chairman named by the Ministry of National Education on its own authority, the Principal, acting as Vice-Chairman, the Vice-Principal, and the Secretary; the president of the corresponding student association, the mayor of the town and the chairman of the local parliamentary group, the president or representatives of the corresponding professional guilds, a delegation from the Union organisation, and at least two parents of registered students who hold higher or medium level degrees, depending on the level of the Establishment. The Chairman may appoint other persons, who as benefactors of the Establishment merit such an honour, or people whose occupation, status and prestige may make an effective contribution to the work of the "Patronato".
The Secretary of the School shall serve as Secretary of the Patronato.

Article 3. - The functions of the "Patronatos" shall be:

a) to help the Escuela Técnica attain its educational, cultural and social objectives, by stimulating society to take an interest in the School's aims and activities.

b) to inform the appropriate Government bodies, of any aspirations or wishes of the social milieu concerned if they have any bearing on these aims, and if this may lead to a report or research for their realization.

c) to suggest and possibly promote the establishment of chairs, equipment and specializations connected with the needs of the region, and also courses, lectures or other form of educational activity.

d) to promote collaboration with other groups and bodies whose objectives coincide with those of the School.

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e) to collaborate with the Establishment's administrative bodies and strengthen its authority and prestige through the moral support provided by the presence of the social status represented within the "Patronato".

f) to channel official and private initiative, by receiving gifts, subsidies, bequests, etc... for the objectives mentioned or for any others conducive to improving the life of the School.

Article 4. - Each "Patronato" shall meet at least twice each year; it may be convened by its Chairman however, if circumstances so warrant or at the request of half of its members.

Article 5. - A "Patronato" shall be set up in every School before 1st February 1966 and within three months of its constitution, shall submit a draft of its statutes to the Ministry.

Article 6. - The Ministry of National Education shall issue the instructions required for the execution and interpretation of the present Decree.

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ANNEX XIV

BREAKDOWN OF THE ACTIVE POPULATION

1 - By sector

Active population in 1964
(thousands)

1) Primary sector		4,185.6
Agriculture, forestry and hunting	4,081.2	
Fishing	104.4	
2) Secondary sector		4,234.6
3) Tertiary sector		3,656.0
Commerce	1,186.5	
Banking and insurance	129.7	
Transport and communications	571.3	
Civil service (including education)	439.4	
Other services	1,329.1	
Total active population		12,076.2

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2° - By sector and vocational classification

Breakdown of the active civilian population by professional category and economic sector - 1960 and 1975

	Agriculture		Industry (3 + 4 + 5 + 6)		Services (8 + 9 + 10 + 13)	
	1960	1975	1960	1975	1960	1975
Active civilian population (thousands)	4,803.3	3,713.2	3,652.4	5,077.6	3,028.6	4,623.1
Percentages	100.0	100.0	100.0	100.0	100.0	
Persons in scientific and technical professions.	...	0.2	0.8	1.1	2.9	
Other persons in the professions	...	...	0.5	0.4	8.6	
Technicians	...	0.3	0.6	1.9	1.9	
	0.1	0.5	1.9	3.4	13.4	
Management and higher administrative personnel	...	0.1	1.6	2.5	2.1	
Clerical workers and salespeople	0.2	0.5	8.4	10.2	35.4	
Farmers, stock-breeders and fishermen	99.7	98.9				
Skilled workers			25.7	30.5	)	
Semi-skilled workers			26.3	26.5	) 49.1	
Unskilled workers			36.1	26.9	)	

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ANNEX XV

Breakdown of engineers and assimilated by sector (1965)

FIELD	Sector					
	Industry	Services		Agricult.	Unclassified	Total
			including public services			
Ingenieros Aeronáuticos (Aeronautical Engineers)	252	223	147		170	645
Ingenieros Agrónomos (Agriculturalists)	200	869	839	110	311	1,490
Ingenieros de Caminos, Canales y Puertos (Civil Engineers)	429	1,356	1,148		217	2,002
Ingenieros Industriales (Plant Engineers i.e. general engineers for industry)	3,575	907	642		464	4,946
Ingenieros de Minas (Mining Engineers)	843	260	242		267	1,374
Ingenieros de Montes (Forestry Experts, including watercourses)	142	580	573		135	857
Ingenieros Navales (Marine Engineers and Naval Architects)	396	71	63		45	512
Ingenieros de Telecomunicación (Communications Engineers)	182	185	40		118	485
Ingenieros del I.C.A.I. (Graduates of the Istituto Católico de Artes y Industrias)	720	126				840
Ingenieros Textiles (Textile Engineers)	769	52				821
TOTAL	7,508	4,633	3,698	110	1,727	13,972
Breakdown of total	53.7%	33.1%	26.4%	0.7%	12.3%	
Breakdown of plant engineers	72.2%	18.2%	12.9%	–	9.9%	

Source: Escuela Técnica Superior de Ingenerios Industriales – Seville.

2. BREAKDOWN OF ENGINEERS AND ASSIMILATED BY REGION

(1965)

FIELD	ISLAS	GALICIA	CANTABRO ASTUR SANTANDER	ALTO EBRO	CASTILLA LA VIEJA	MEDIO EBRO	CASTILLA LA NUEVA	MADRID	EXTREMADURA	ANDALUCIA ORIENTAL	ANDALUCIA OCCIDENTAL	LEVANTE	CATALUNA	TOTAL
Aeronautical engineers	14	2	20	2	5	5		498	3	5	38	19	34	645
Agriculturalists	34	44	48	26	170	78	63	606	60	79	146	89	47	1,490
Civil engineers	60	54	169	29	117	78	39	884	31	92	145	131	173	2,002
Industrial engineers	58	87	1,113	80	141	99	38	1,355	21	99	209	243	1,403	4,946
Mining engineers	24	25	417	21	92	10	45	494	14	57	84	43	58	1,374
Forestry experts	15	74	63	28	83	34	37	303	31	44	41	46	58	857
Marine engineers	15	65	116		5			150		5	88	56	12	512
Communications engineers	8	5	23		5	4		395	2	6	8	12	17	485
Graduates of the I.C.A.I.	9	30	68	16	58	12	40	420	5	25	78	34	45	840
Textile engineers					13			82	8	13	16		689	821
TOTAL	237	386	2,037	202	679	320	262	5,187	175	425	852	673	2,536	13,972
Percent	1.6%	2.7%	14.5%	1.4%	4.8%	2.2%	1.8%	37.1%	1.2%	3%	6.1%	4.6%	18.5%	100%
Percent (industrial engineers)	1.2%	1.7%	22.5%	1.6%	2.7%	2%	0.7%	27.3%	0.4%	2%	4.2%	4.9%	28.2%	100%

Source: Escuela Técnica Superior de Ingenieros de Sevilla.

ANNEX XVI

NET OUTPUT PER CAPITA IN 1962

(Andalusia)

Province	Net output (in millions of pesetas)	Population	Per capita output	Position in the 50 provinces
Almeria	4,405.2	361,964	12,170	50
Cadiz	13,469.2	849,125	15,862	36
Córdoba	11,809.6	812,195	14,540	43
Granada	9,729.3	779,622	12,479	49
Huelva	6,742.4	406,867	16,571	33
Jaén	11,676.7	748,568	15,598	40
Málaga	10,910.4	790,129	13,808	47
Sevilla	22,468.3	1,325,837	16,946	31
Total for Andalusia	91,211.1	6,074,307	15,016	
National Total	694,309.7	31,356,898	22,142	
Barcelona	105,758.7	3,062,068	34,538	3
Guipuzcoa	17,607.7	503,175	34,993	1
Madrid	89,725.6	2,755,931	32,795	4

Source: Research Department of the Bank of Bilbao

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ANNEX XVII

INDUSTRIES IN THE ANDALUSIAN PROVINCES EMPLOYING MORE THAN 500 PEOPLE

CADIZ

Metalworking

Astilleros de Cadiz

Ctra. Industrial, s/n

Number employed 3,303

Tobacco

Tabacalera, S.A.

Number employed 615

Alcoholic beverages and allied industries

Pedro Domecq, S.A.

San Ildefonso, 7

JEREZ DE LA FRONTERA (Cadiz)

Number employed 596

CORDOVA

Non-ferrous metal industries

Sociedad Española de Construcciones Electromecánicas (S.E.C.E.M.)

Barriada Electromecánica

CERCADILLA (Cordova)

Number employed 2,781

Metalworking

Constructora Nacional de Maquinaria Electrica

Av. José Antonio, 10

Number employed 1,259

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GRANADA

Sugar and sugar refining

Azucarera de San Isidro
Gran Via, 38
Number employed 508

Azucarera Nuestra Señora de las Mercedes
CANILES DE BAZA (Granada)
Number employed 517

Azucarera Nuestra Señora del Pilar
MOTRIL (Granada)
Number employed 517

JAEN

Metalworking

Metalurgicas Santa Ana
Carretera Vadollano, s/n
LINARES (Jaen)
Number employed 1,668

MALAGA

Textiles (Coton and artificial fibers)

Industrias Malagueñas, S.A.
Oscila, 14
Number employed 903

SEVILLA

Sugar and sugar refining

Azucarera del Guadalquivir
LA RINCONADA (Sevilla)
Number employed 709

Azucarera San Fernando
LOS ROSALES (Sevilla)
Number employed 707

Metalworking

(S.A.C.A.) Sociedad Anonima de Construcciones Agrícolas
Plaza Nueva
Number employed 538

Brewing

La Cruz del Campo
Oriente, 151
Number employed 958

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Textiles (cotton and artificial fibers)

Hilaturas y Tejidos Andaluces, S.A. (H.Y.T.A.S.A.)
Héroes de Toledo, 71
Number employed 886

Wool textile industry

Hilaturas y Tejidos Andaluces
Héroes de Toledo, 71
Number employed 1,112

Textiles (various fibers)

Textiles del Sur
Carretera de Alcalá
DOS HERMANAS (Sevilla)
Number employed 561

Source: Spanish Union organization

ANNEX XVIII

BREAKDOWN OF THE ANDALUSIAN POPULATION BY SIZE OF LOCALITY

Province	Towns of fewer than 10,000 inhabitants	Towns of 10,000 inhabitants and over	Total
Almeria	205.3	155.5	360.8
Cádiz	107.8	711.1	818.9
Cordoba	243.8	554.6	798.4
Granada	448.6	320.8	769.4
Huelva	219.4	180.5	399.9
Jaén	330.0	406.4	736.4
Málaga	283.8	491.4	775.2
Sevilla	348.7	885.7	1,234.4
Total	2,187.4	3,706.0	5,893.4
Percentage total	37.1	62.9	100.0

Source: Statistical yearbook for Spain (1960).

ANNEX XIX

1.) Breakdown of teaching duties by Department

Department of Mathematics	1st term Unit of instruction		2nd term Unit of instruction		Yearly total
	Total	per week	Total	per week	
2nd Year: Mathematics I	24	2	13	1	
3rd Year: Mathematics II	12	1	13	1	
Total	36		26		62

Department of Mechanical Engineering					
2nd Year: Design for manufacture	24	2		-	
3rd Year: Mechanics of machines	24	2		-	
Fluid Mechanics and heat transfer		-	26	2	
4th Year: Transmission and Application of Power 1	30	2		-	
Departmental subject 1	30	2		-	
" subject 2		-	32	2	
5th Year: Departmental subject 1	11	1		-	
" subject 2	11	1		-	
" option 1	11	1			
" option 2	11	1			
Thesis project	11	1	36	3	
Total	163		94		257

Department of Electrical Engineering					
2nd Year: Electricity I		-	26	2	
3rd Year: Electricity II		-	26	2	
4th Year: Control systems I	15	1	16	1	
Transmission and Application of Power II		-	32	2	
Departmental subject 1	30	2		-	
" subject 2		-	32	2	
5th Year: Departmental subject 1	11	1		-	
" subject 2	11	1		-	
" option 1	11	1			
" option 2	11	1			
Thesis project	11	1	36	3	
Total	100		168		268

Department of Chemical Engineering	1st term Unit of instruction		2nd term Unit of instruction		Yearly total
	Total	per week	Total	per week	
2nd year: Science of materials I	24	2		–	
Thermodynamics		–	26	2	
3rd year: Science of materials II	24	2		–	
4th year: Departmental subject 1	30	2		–	
Departmental subject 2		–	32	2	
5th year: Departmental subject 1	11	1			
" subject 2	11	1			
" option 1	11	1			
" option 2	11	1			
Thesis project	11	1	36		
Total	133		94		227

Department of Economics and Social Scienc					
2nd year: Organisation of work in the plant		–	13	1	
3rd year: Basic Activities of the Firm	12	1		–	
Industrial psychology		–	13	1	
4th year: Statistics	15	1		–	
Economics, Finance and Auditing		–	16	1	
5th year: Sociology of organisation	11	1	36	3	
Thesis project	11	1	36	3	
Total	49		124		163

ANNEX XIX (Contd.)

2.) Breakdown of teaching duties by type of activity

Assuming that each teacher should be in charge of no more than two units of instruction per week, his weekly activities may be broken down as follows:

Activity	Number of hours per week
Preparation of unit of instruction - 4 ½ hrs twice weekly	9
Unit of instruction - 4 ½ hrs twice weekly	9
Collaboration with colleagues from other departments in preparing units of instruction	4
Talks with students	1
Meetings with assistants	2
Planning of work	1
Thesis conselling (for 60 students)	12
Personal reading	2
Scientific research	8
Total	48

3.) Student schedule

Activity	Number of hours	
	Daily	Weekly
Unit of instruction	4 ½ hrs	27
Private study	3 hrs	18
Foreign languages - 1 hour three times a week		3
Total		48

N.B. No attempt has been made to split the work loads between the first and second terms, as neither the proportion of part-time assistants and professors actually recruited nor the size of the projected research effort were known.

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ANNEX XX

MODIFICATIONS TO BUILDING RECOMMENDED BY THE EXPERTS

1. General layout

2. Class-rooms and lecture-rooms E.3
(standard floor plan)

3. Class-rooms and lecture-rooms E.3
(ground floor)

4. Class-rooms and lecture-rooms E.3
(basement)

5. Department of Mathematics E.4
(first floor)

6. Building E.5
(large lecture-room and library)

7. Administration Building E.1 and Depar[illegible] Eco[illegible]ics and Social Sciences E.6

8. Chemistry laboratory L1
(ground floor)

9. Chemistry laboratory L1
(first floor)

10. Chemistry laboratory L1
(second floor)

11. Mechanical Engineering laboratories L2
(ground floor)

12. Mechanical Engineering laboratories L2
(first floor)

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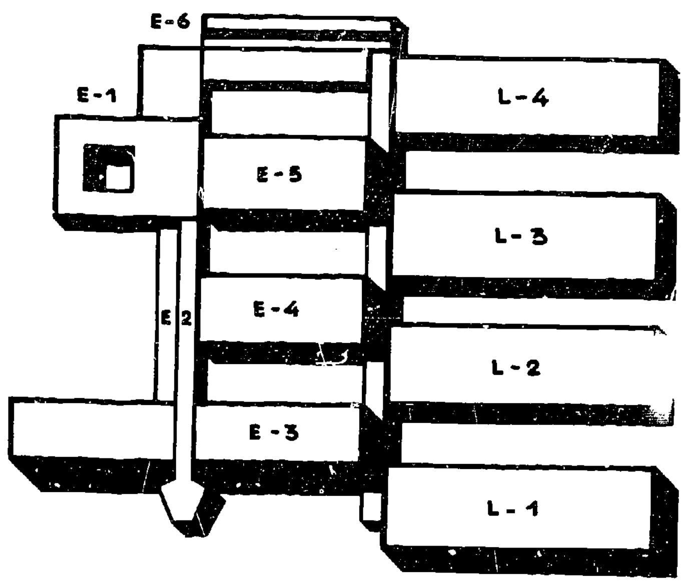
13. Mechanical Engineering laboratories L3
(ground floor)

14. Mechanical Engineering laboratories L3
(first floor)

15. Electrical Engineering laboratories L4
(ground floor)

16. Electrical Engineering laboratories L4
(first floor)

1. GENERAL LAYOUT



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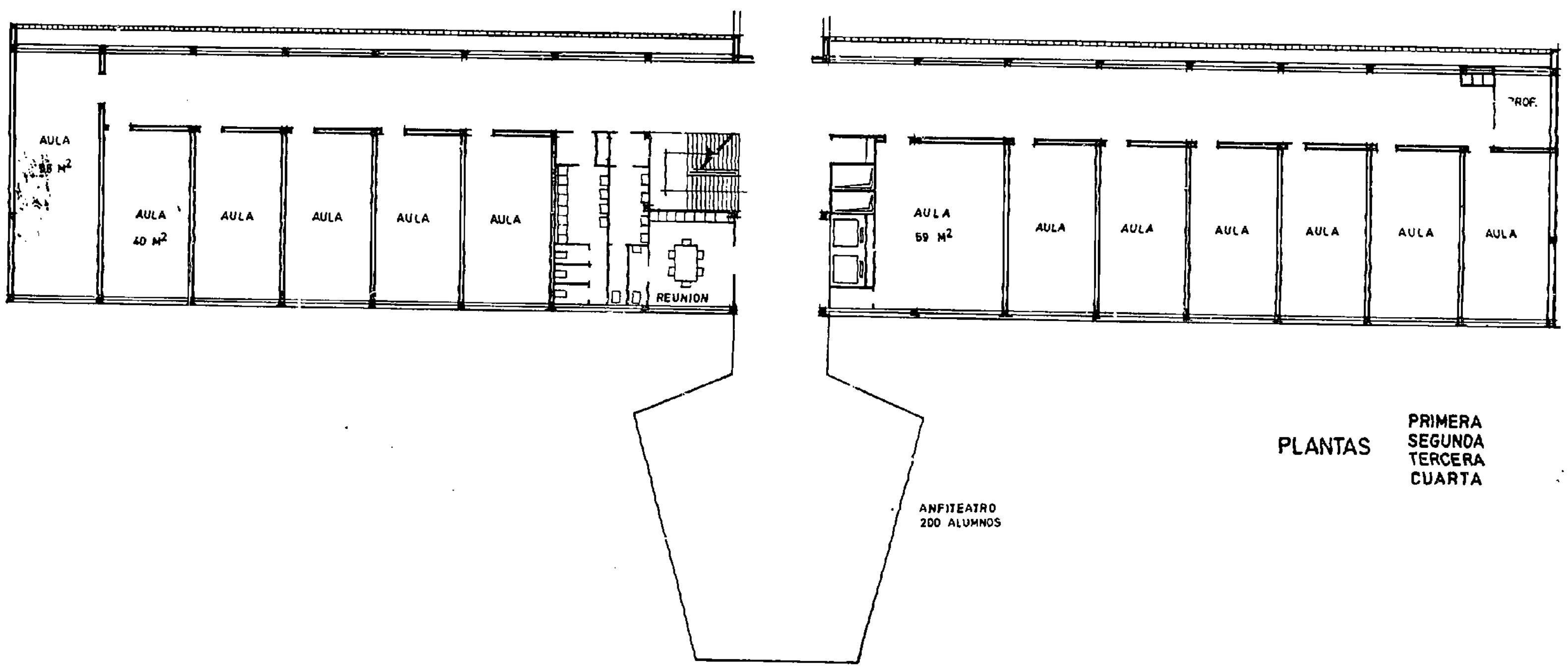
2 CLASS-ROOMS - LECTURE-ROOMS - E.3



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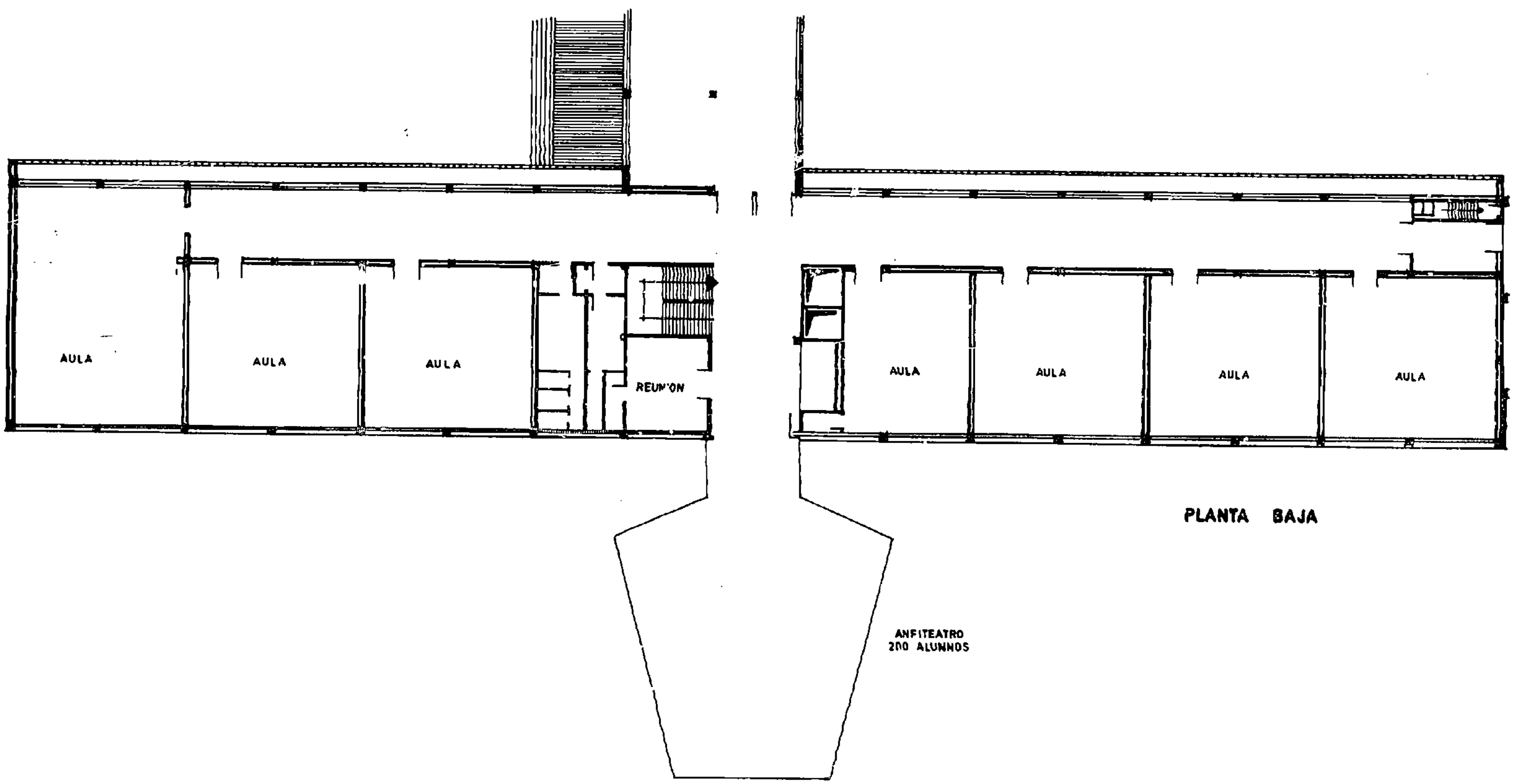
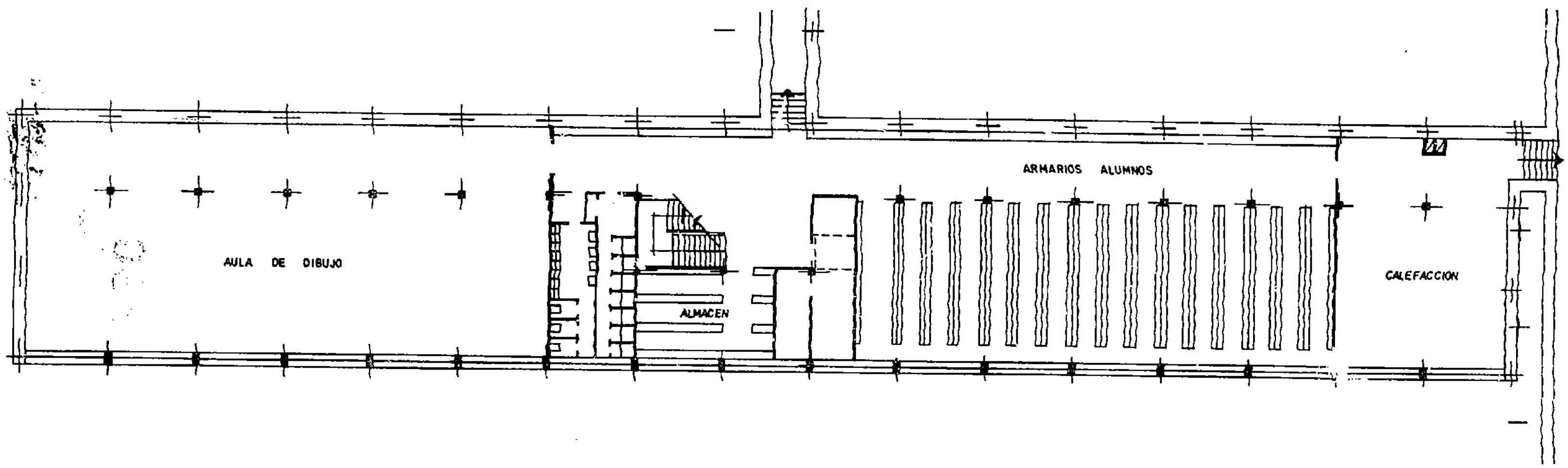
3 CLASS-ROOMS - LECTURE-ROOMS - E.3
Standard floor plan



4 CLASS-ROOMS - LECTURE-ROOMS - E.3
Ground floor



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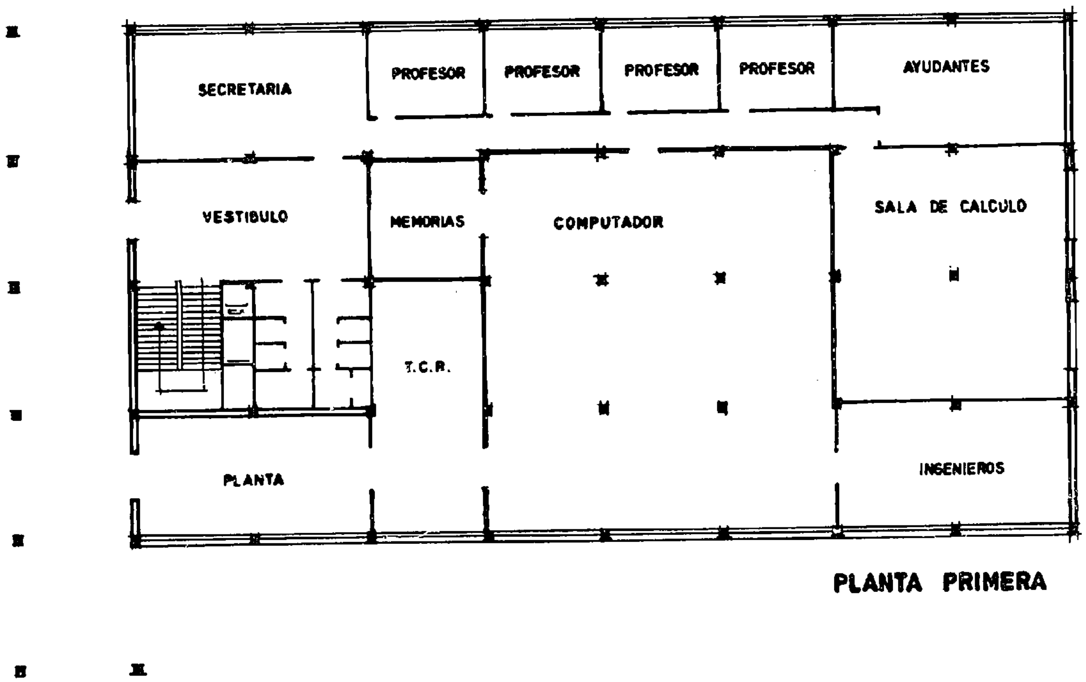
5 DEPARTMENT OF MATHEMATICS - E-4
Basement



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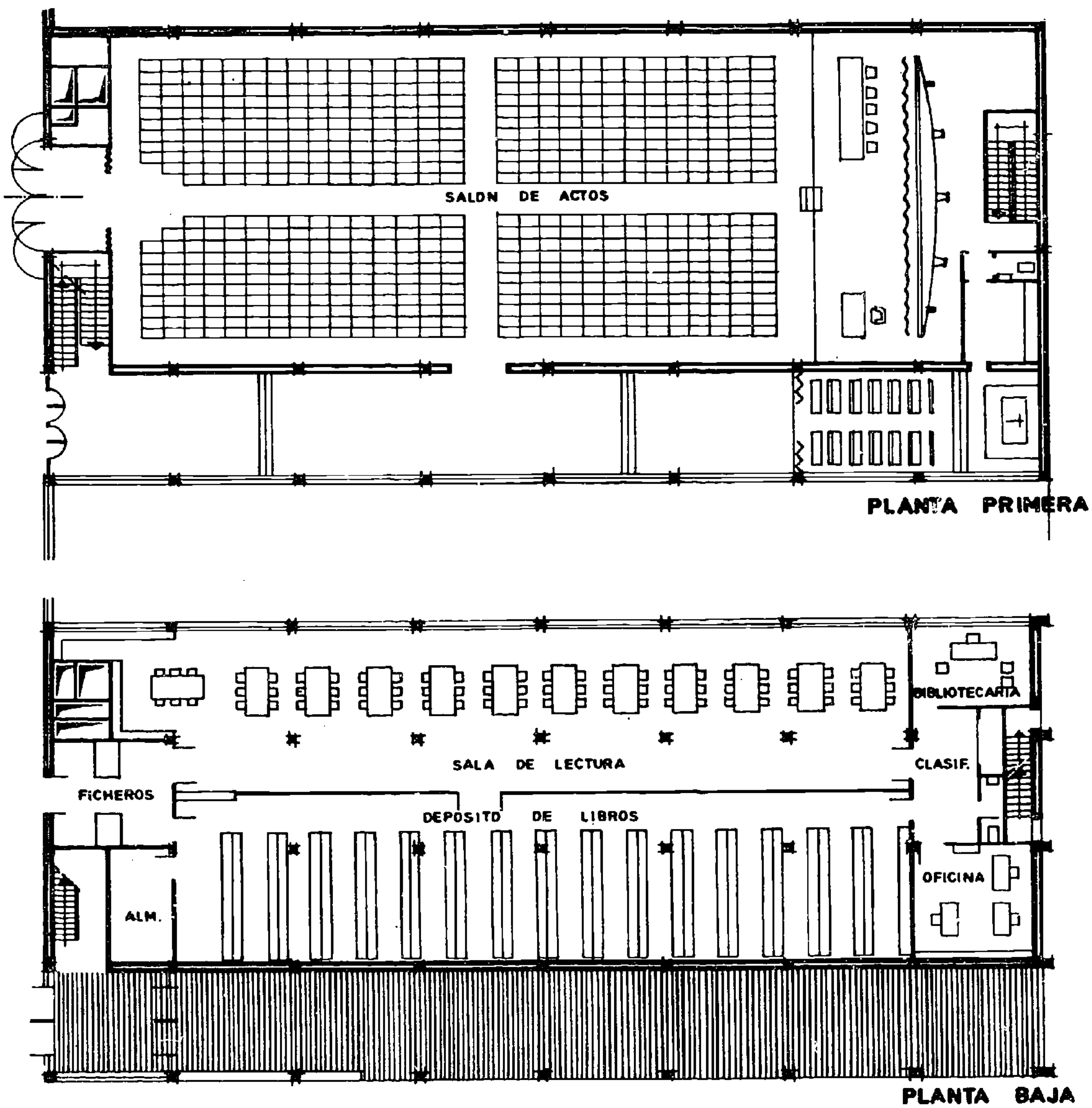
6 BUILDING E-5
Large lecture-room and library



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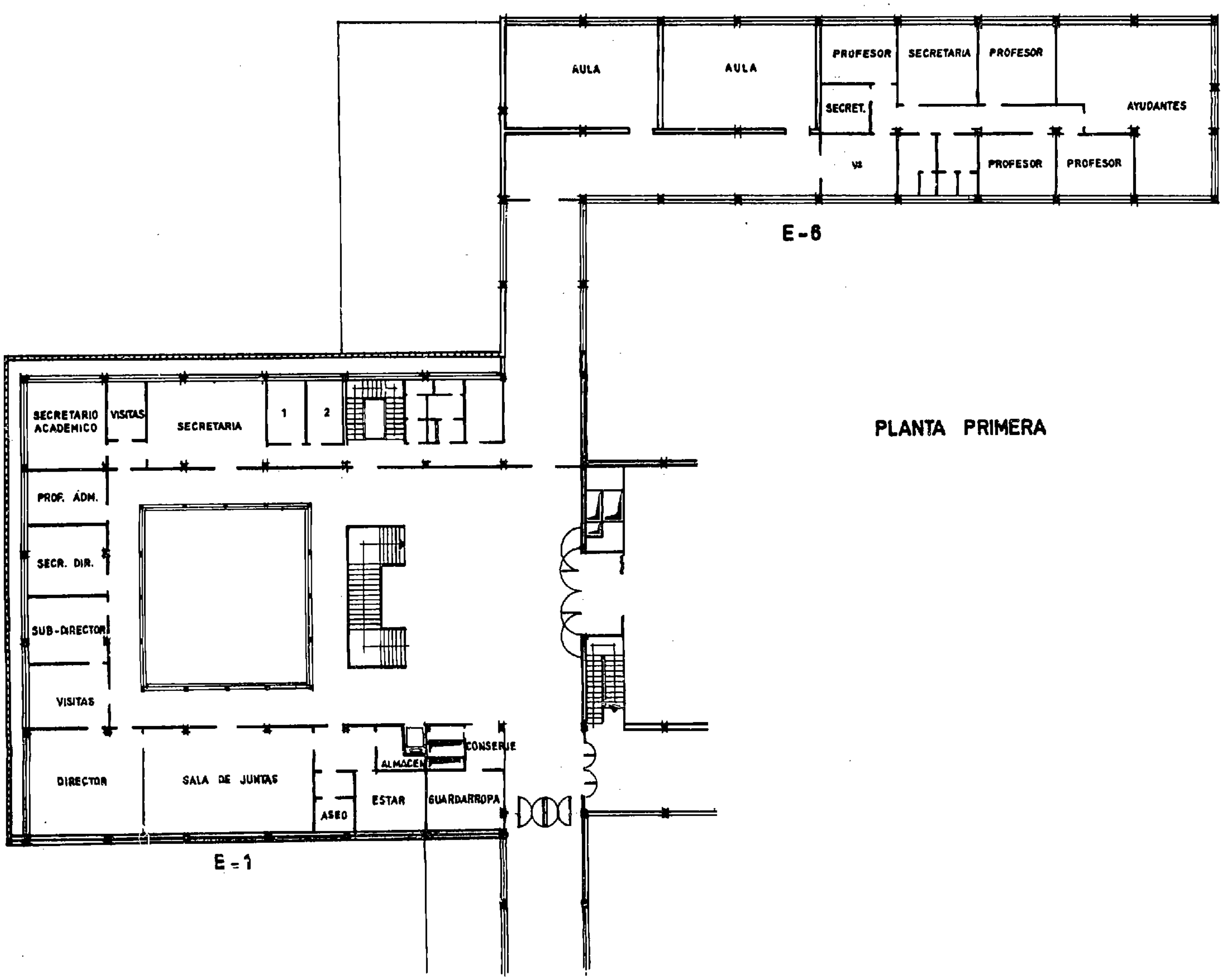
7 ADMINISTRATIVE BUILDING E-1
DEPARTMENT OF ECONOMICS AND SOCIAL SCIENCES E-6



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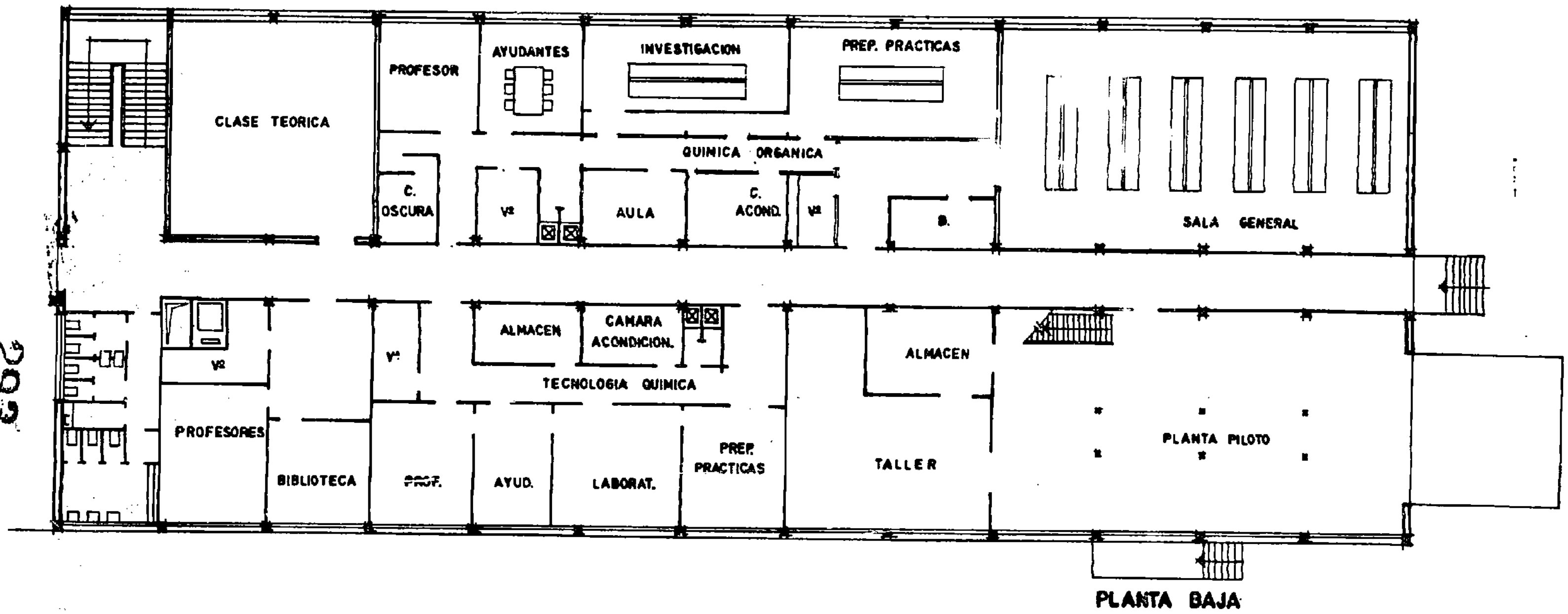
8

CHEMISTRY LABORATORY L-1
Ground floor



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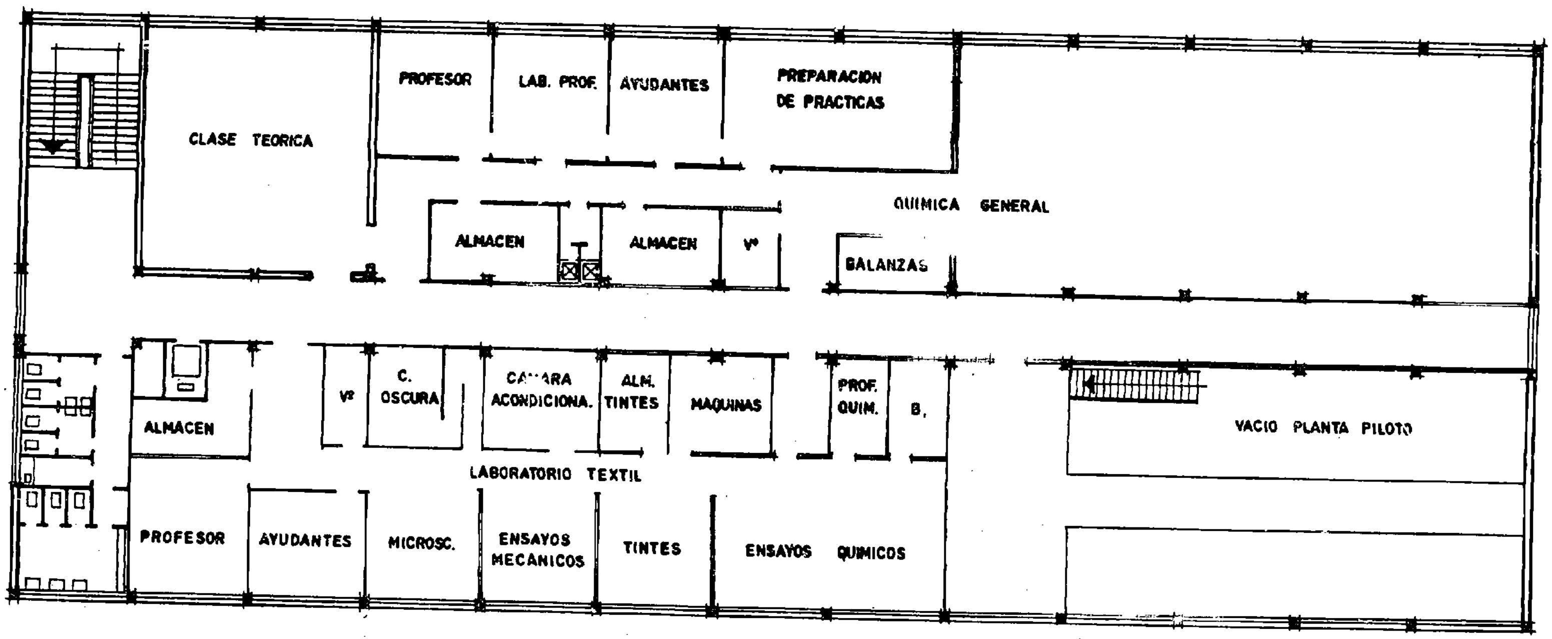
CHEMISTRY LABORATORIES L-1

First floor



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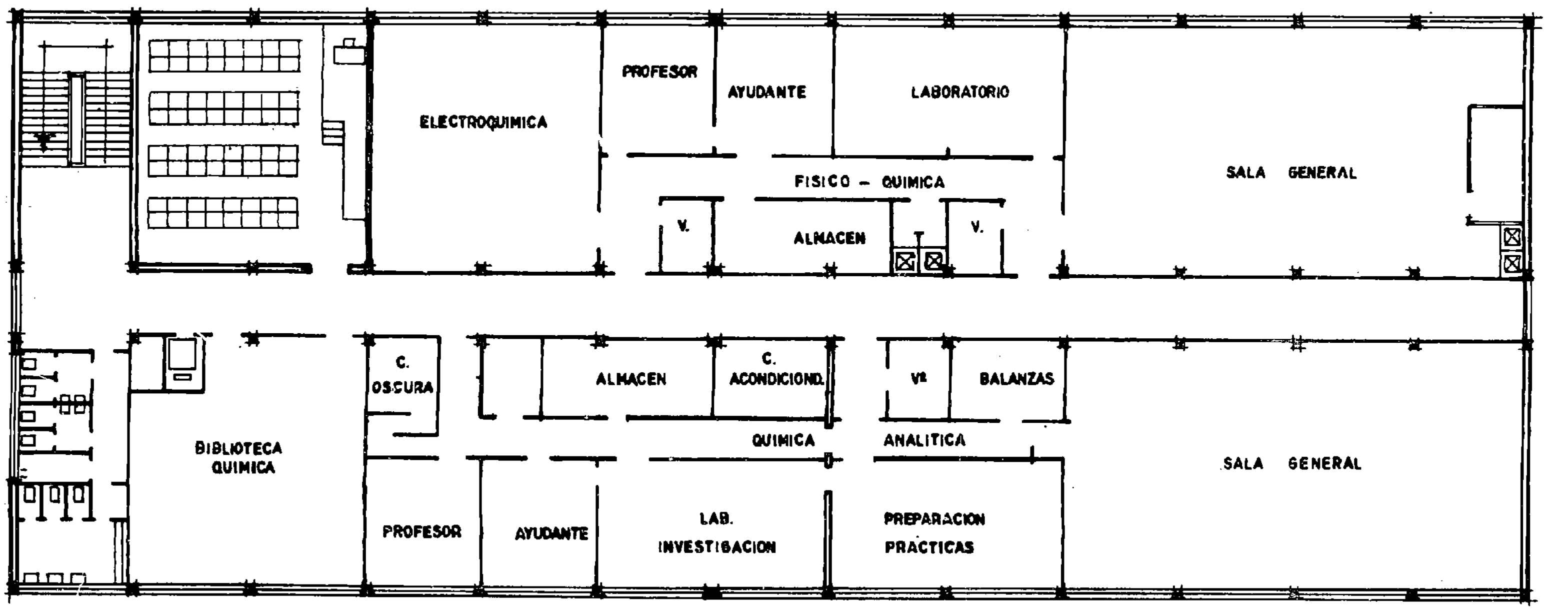
10 CHEMICAL AND CHEMICAL ENGINEERING LABORATORIES L-1

Second floor



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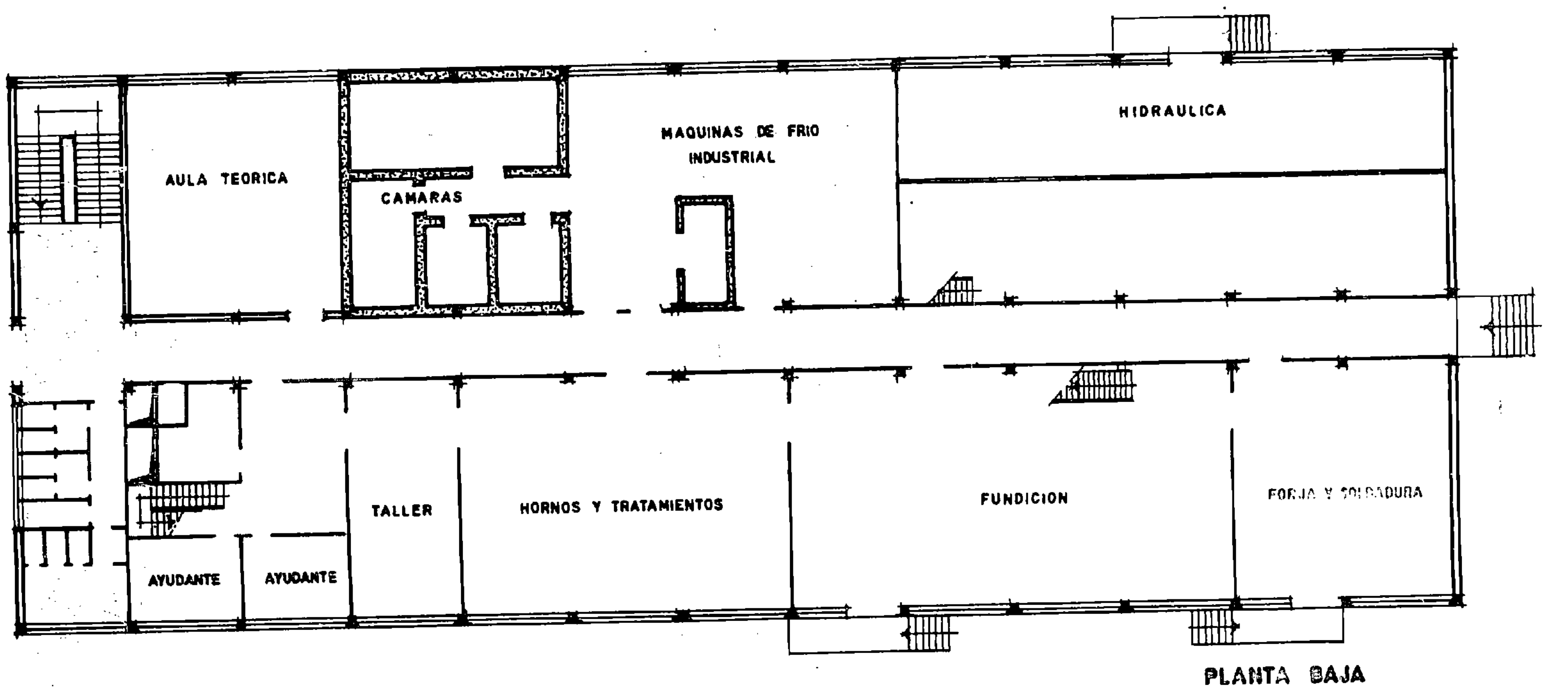
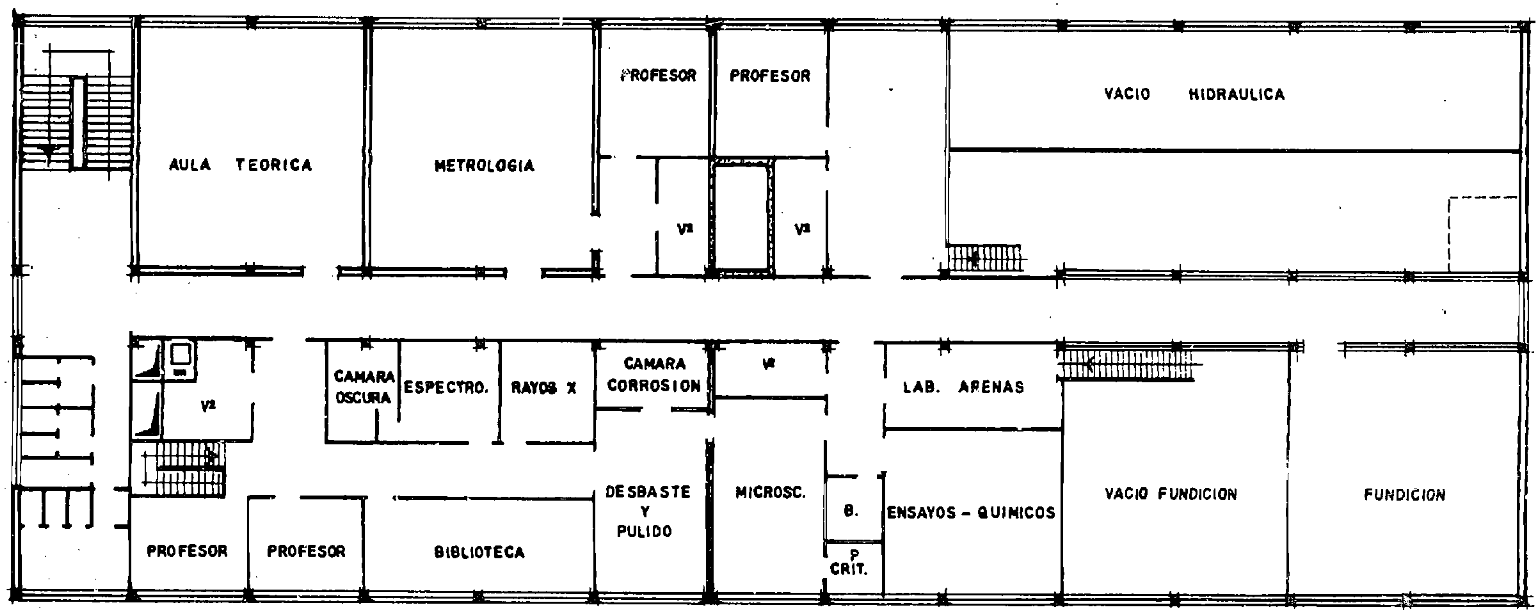
11 MECHANICAL ENGINEERING LABORATORIES L-2
Ground floor



12 MECHANICAL ENGINEERING LABORATORIES L-2
First floor



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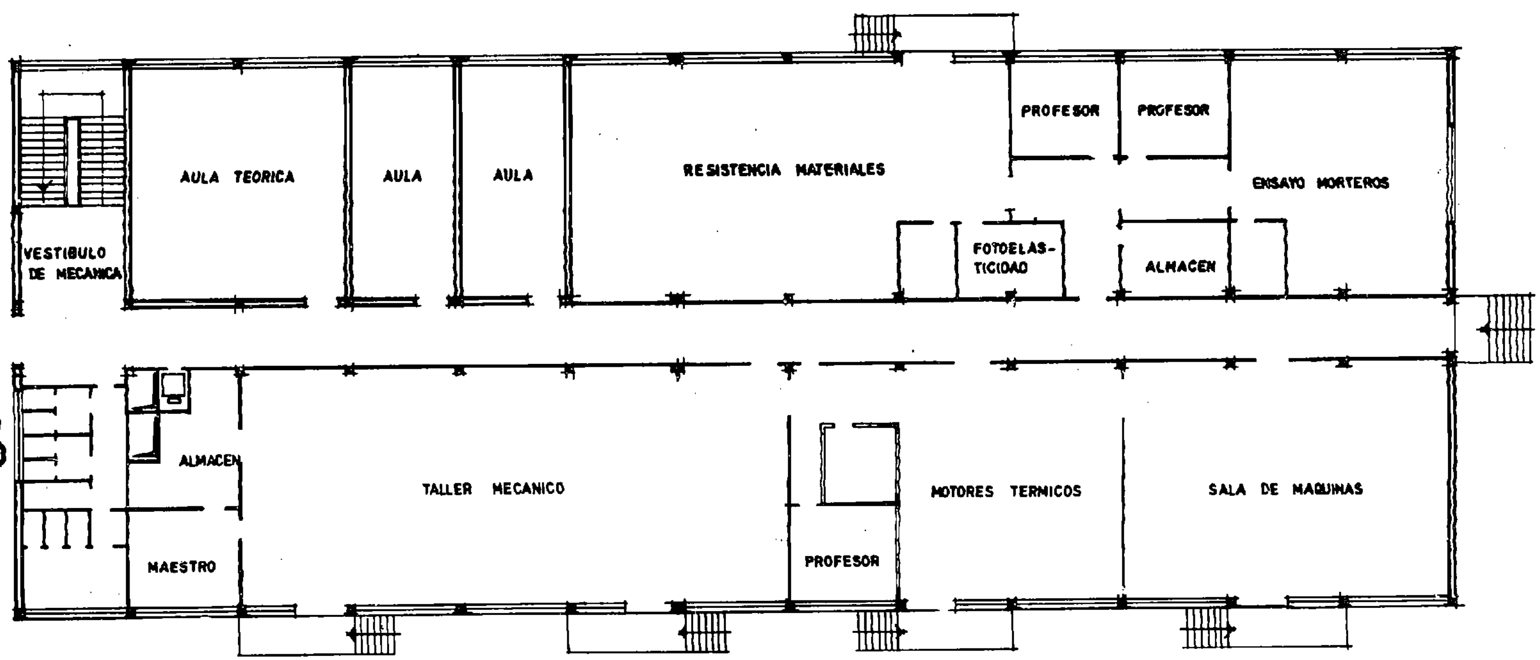
13 MECHANICAL ENGINEERING LABORATORIES L-3

Ground floor



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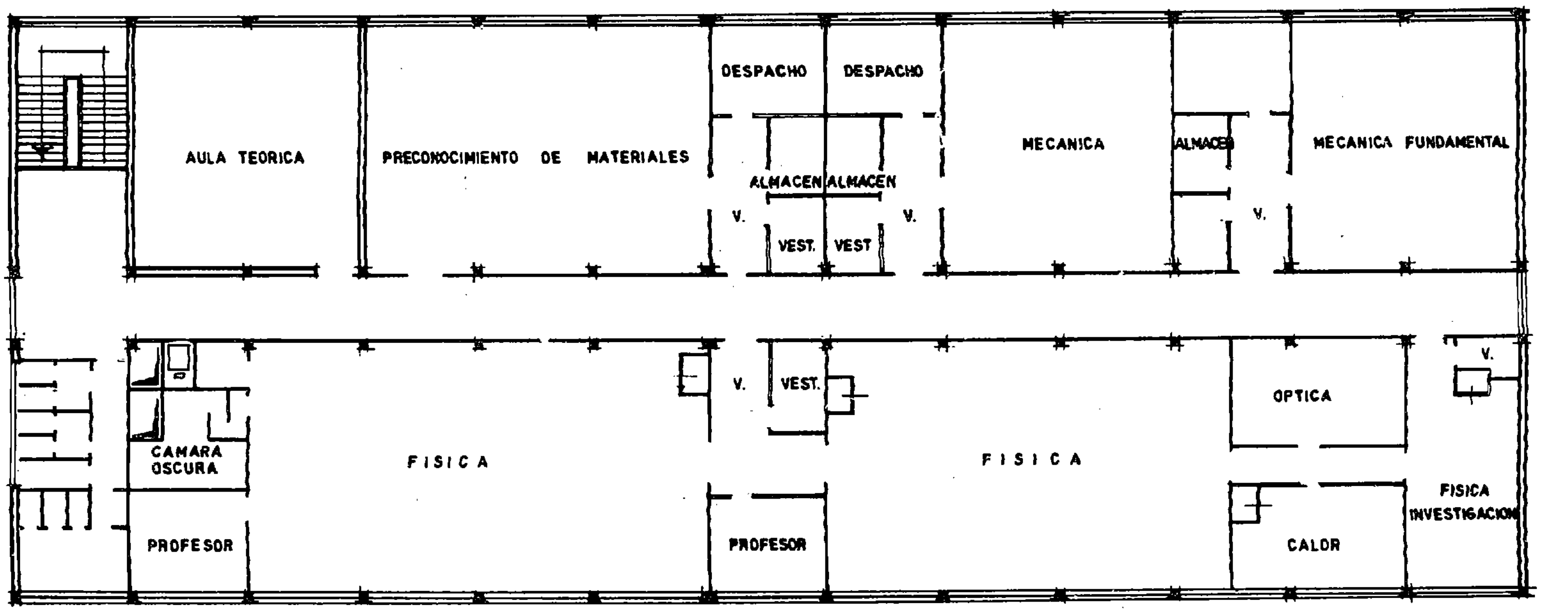
14 MECHANICAL ENGINEERING LABORATORIES L-3
First floor



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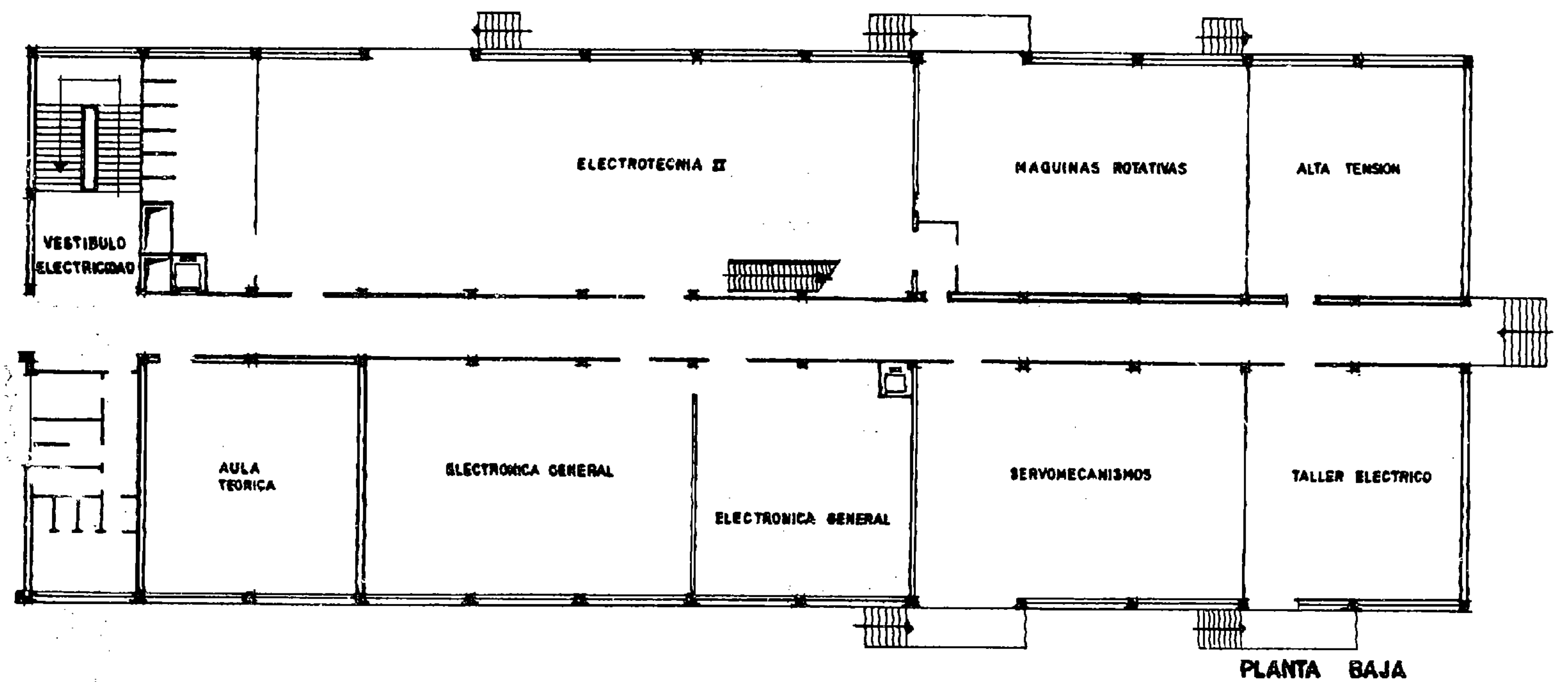
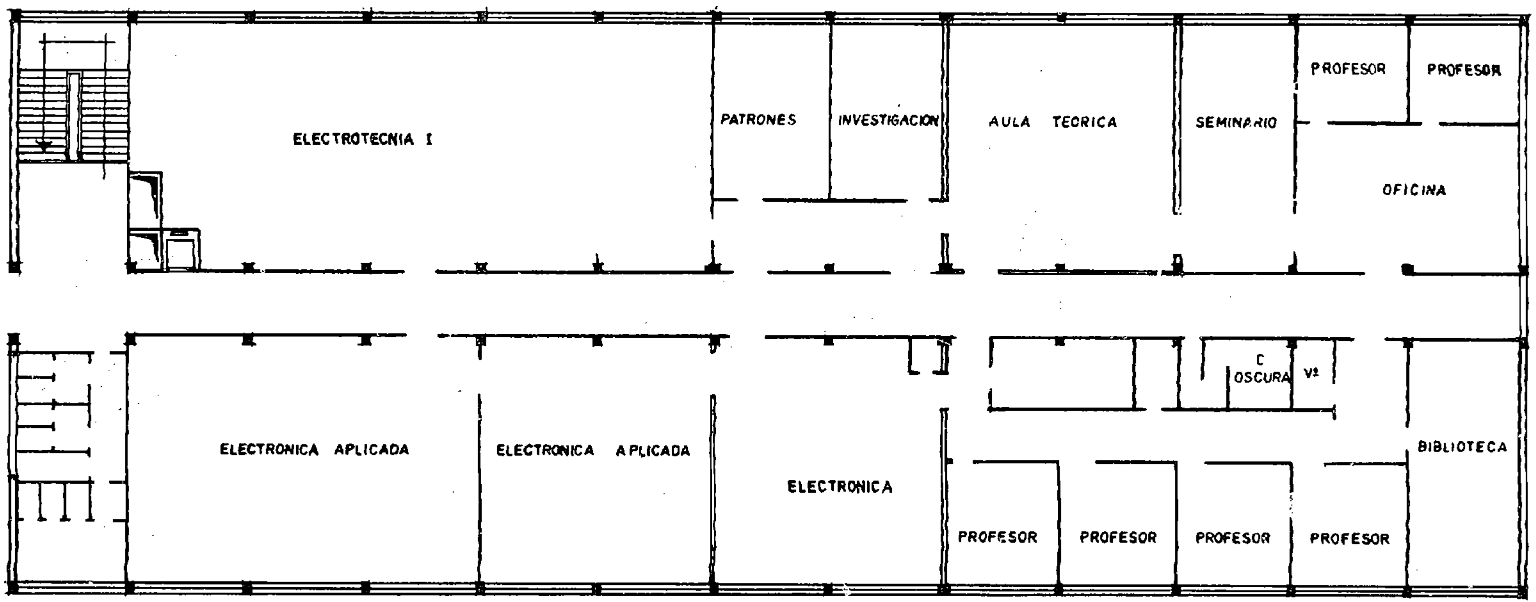
15 ELECTRICAL ENGINEERING LABORATORIES L-4

Ground floor



16 ELECTRICAL ENGINEERING LABORATORIES L-4
First floor



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