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ABSTRACT

The National Science Foundation awarded a grant to the Commission on Postsecondary Education of California to examine the interrelationship between education, licensing, and engineering practice with the intent of identifying a mechanism for the continuous monitoring and evaluation of these processes. The study was conducted over a fourteen-month period and included an extensive review of several large engineering projects that had achieved public recognition. These projects were analyzed to identify the major elements or "fields of understanding" that become integral parts of the project and decision-making process. In light of the broad nature of engineering practice, the basic curricula in engineering education were evaluated, and the attitudes of students, faculty, and industry were surveyed. The history, nature, and present status of engineering registration were also reviewed. (Author/JN)

COMMISSION REPORT 81-19

ENGINEERING EDUCATION AND LICENSING IN CALIFORNIA

A Report to the California Postsecondary Education Commission

Professional Engineering and Research Consultants

CALIFORNIA POSTSECONDARY EDUCATION COMMISSION
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iii. FOREWORD

Although engineering education has been one of the most studied activities in the educational field, the primary objectives of this study emphasize the relationship between the education of engineers, the State requirements for licensing of engineers to protect the public, and the practice of engineering. It has illuminated some of the principal elements of the total profession of engineering.

The National Science Foundation awarded a grant to the Commission on Postsecondary Education of California to examine the interrelationship between education, licensing and engineering practice with the intent of identifying a mechanism for the continuous monitoring and evaluating of these processes.

The study was conducted over a fourteen-month period. It included an extensive review of several large engineering projects that had achieved public recognition. These projects were then analyzed to identify the major elements or "fields of understanding" that become integral parts of the project and decision-making process. In light of the broad nature of engineering practice, the basic curricula in engineering education was evaluated, and the attitudes of students, faculty, and industry were surveyed. The history, nature, and present status of engineering registration were also reviewed, and the potential for major changes in registration practices was evaluated.

A mechanism for continuous evaluation of this critical professional field was proposed to provide assistance to both the Commission on Postsecondary Education and the Board of Registration for Professional Engineers in California.

The findings and recommendations of this study are presented to stimulate critique and thought concerning the education and training of engineers and the establishment of minimums, in terms of State licensure, for the protection of the public health, welfare, safety and good. It is hoped that the basic areas of knowledge, or "fields of understanding" identified and defined in this study will become the criteria for, and serve as the mechanism for the implementation of, continuous program evaluation and review in the development of engineering education programs. It is further hoped that the results of this study will serve as an aid in the effective correlation of degree requirements with registration and licensing practices.

I. INTRODUCTION

The California Postsecondary Education Commission is pleased to submit this final report to satisfy the requirements of Grant #SED 75-19328 from the National Science Foundation. The study project was initiated in September, 1975, and was completed in November, 1976. It involved research into many aspects of engineering education, State registration of engineers, and the practice of engineering as exemplified in the conduct of several major engineering projects.

The project manager was Dr. Kenneth B. O'Brien, Associate Director, California Postsecondary Education Commission. Research was conducted by Professional Engineering and Research Consultants (PERC). The principal investigator was Robert J. Kuntz, P.E. Additional investigators included the following people: Paul Hinkle, Project Assistant; Donna Billington, Richard Fryer, and Thomas McCreery, Research Analysts; Dr. B. J. Shell, P.E.; David Justice, P.E.; Leo Ruth, P.E.; Valerie Kubacky and Dr. Alfred C. Ingersoll, P.E., Consultants; and Mark Jacobs, Frank Kampen, and Ken Levy, University of California, Davis, Student Interns.

Numerous other individuals, agencies, and organizations provided assistance to this project. Particular appreciation is expressed to the following for their cooperation in the preparation of this study:

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Milton Lunch, J.D., General Counsel, National Society for Professional Engineers

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Staff of the California Postsecondary Education Commission

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II. PROGRAM DESCRIPTION

The general public and public policymakers have become increasingly aware that technology affects nearly every aspect of modern life. Whether it is in the design and construction of a road or a nuclear power plant, the development of a new aircraft or missile system, or the production of consumer goods, engineering practice directly affects public health, welfare, safety and good. Public policy has been established in many critical areas where a need for protection of the public has been demonstrated. A few examples are the Professional Engineers' Registration Act, the Environmental Protection Act, the California Environmental Quality Act, the Occupational Safety and Health Act, and the Product Safety Act.

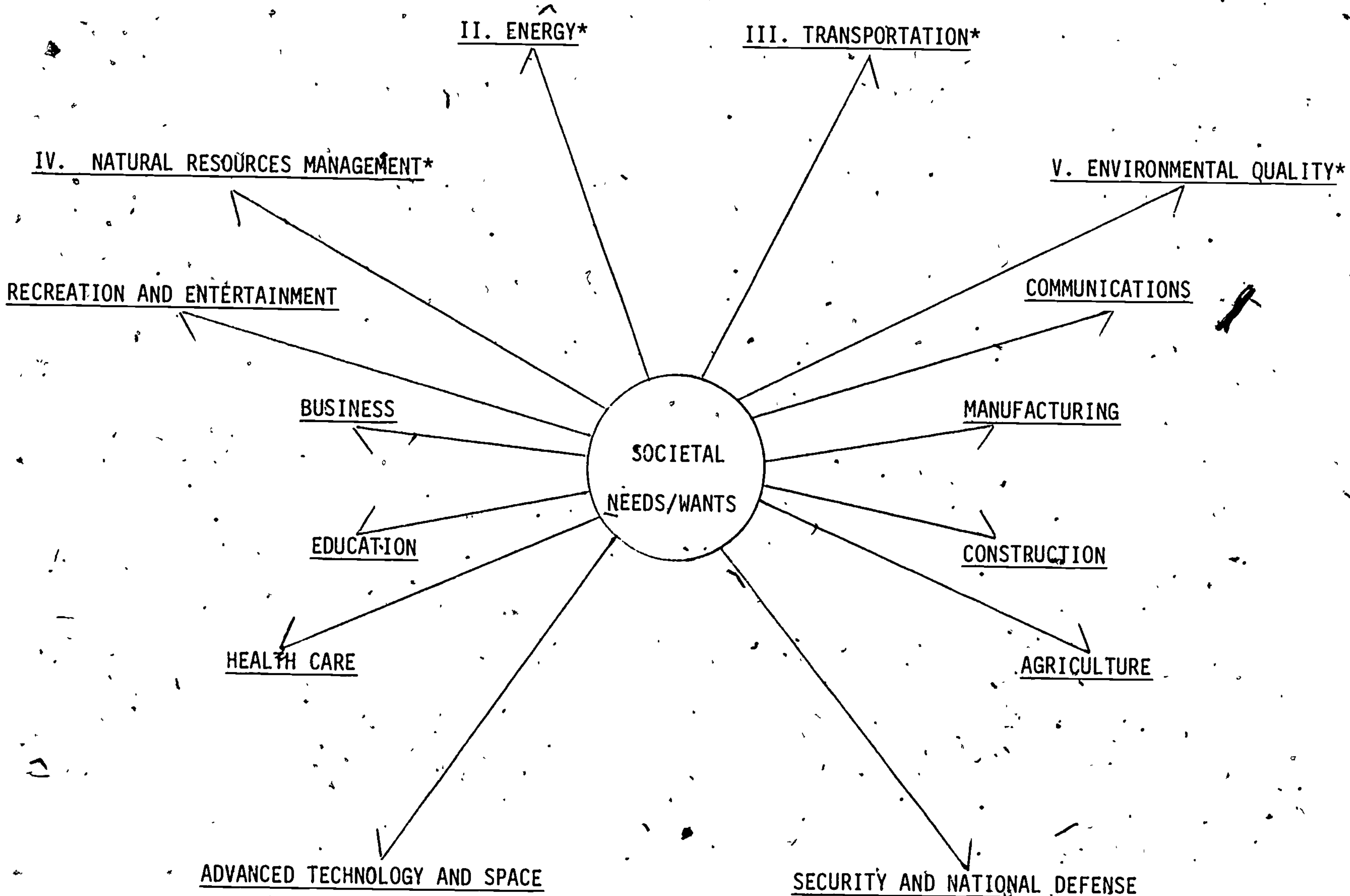
The actions of policymakers have added many legalities and nontechnical considerations to the practice of engineering so that engineers must have not only a knowledge of the technical skills necessary to produce the goods and services that society demands, but also must be aware of the nontechnical considerations which often have an overriding effect on engineering projects. Consequently, engineering education, whether institutional, continued or otherwise, must provide both the technical and nontechnical understanding necessary to practice the profession in the modern social environment.

The initial phase of the project involved the development of a program plan which defined the total scope of activities in each of the areas to be examined: societal needs that require engineering and scientific solutions; the content of and parameters affecting engineering education; and the nature and process of the registration of engineers under State law in California. Input models were developed to identify the parameters affecting each of the principal areas of concern (see Fig. II-1, 2, 3). Each of these parameters was analyzed to develop a series of detailed tasks, the rationale behind each, and the methodology for obtaining the data from each delineated source.

This plan identified all of the areas of consideration; however, it was not possible, given the scope of the project and the time allowed, to address all of the tasks. Therefore, those areas having the greatest impact on engineering education and licensing were taken in order of priority. The remaining tasks may be implemented in subsequent studies.

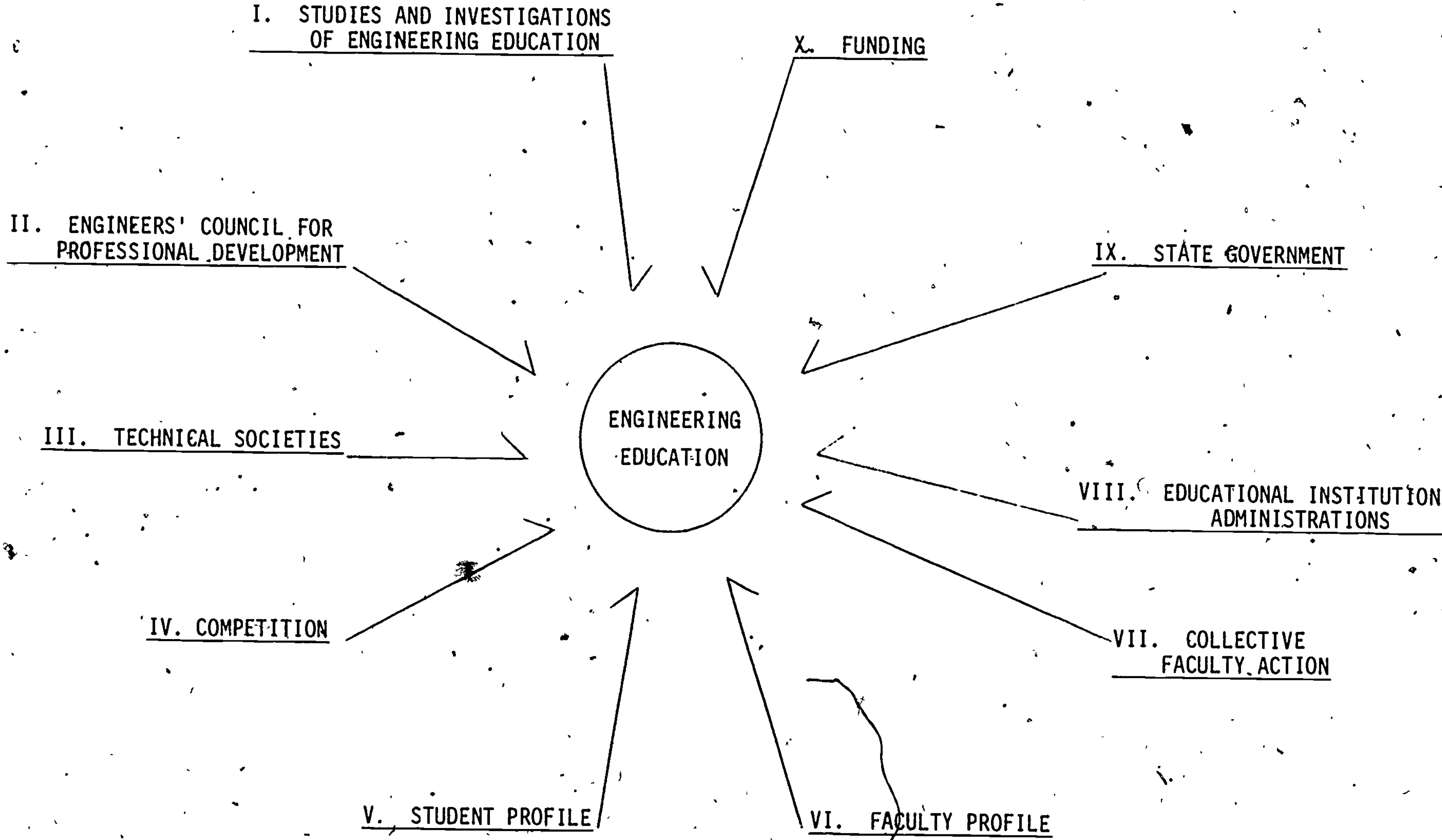
In the Fall of 1975, the California Postsecondary Education Commission was awarded a grant by the National Science Foundation to conduct a study correlating engineering curriculum and California licensing law, in light of societal needs.

The necessity of such a study arose from the observation of current concerns expressed by society. In recent years, the rapid advancement of science has been checked by rising public concern over the quality



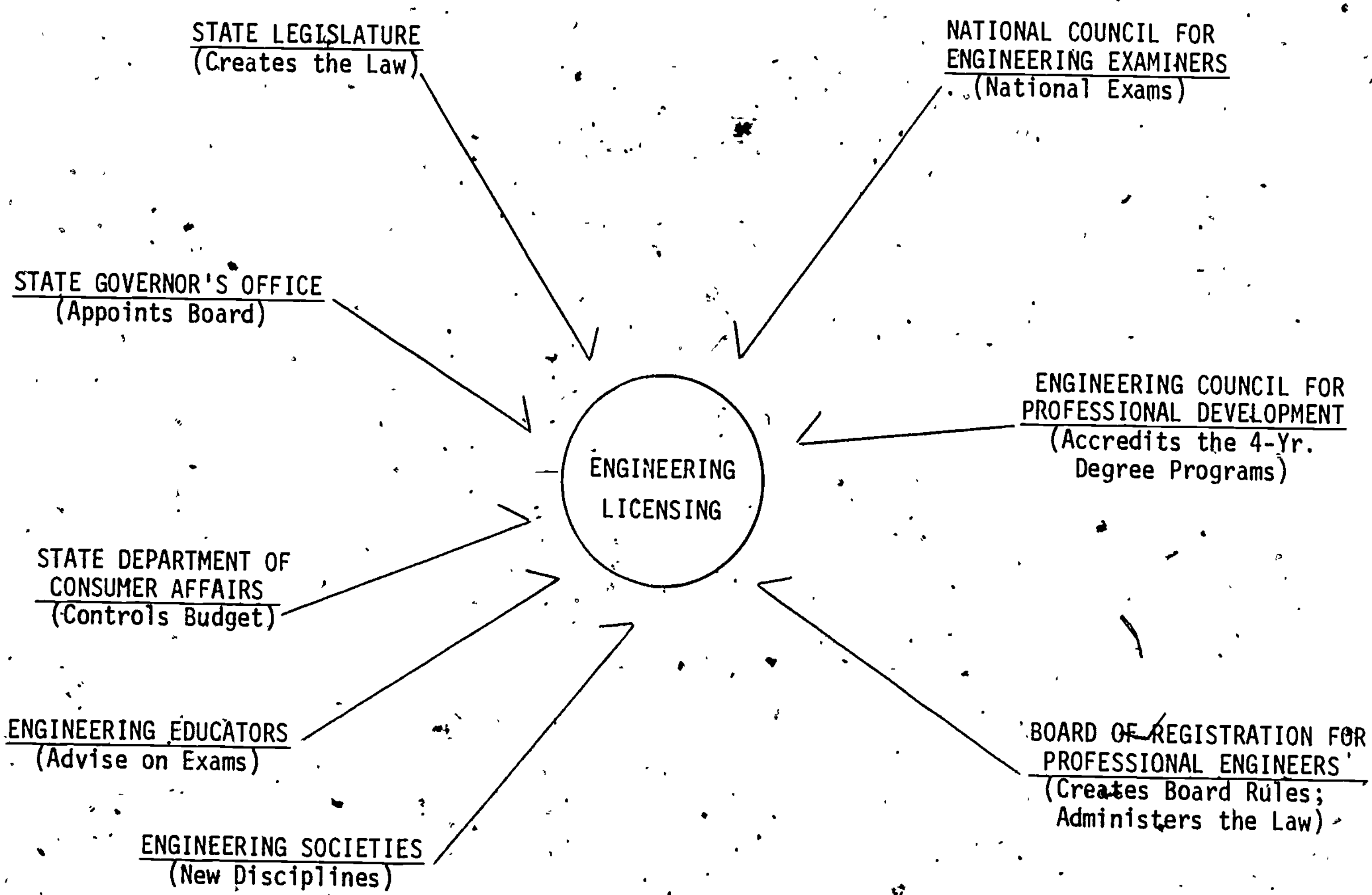
INPUT MODEL - ENGINEERING-RELATED SOCIETAL NEEDS/WANTS

Fig. 1



INPUT MODEL -- FOUR-YEAR UNDERGRADUATE PROGRAM

Fig. 2



INPUT MODEL - ENGINEERING LICENSING LAW

Fig. 3

of life directed by our highly technical society. Engineers have found that they must deal not only with their technological speciality, but also with the issues of environmental quality and resources conservation. Shifts in national and state policies have left hundreds of specialized engineers out of work. Thus, this study addressed the concern of whether future engineers will have the skills and competencies necessary to meet societal needs, thereby providing a meaingful contribution to society. The general goals of the study were the following:

1. To demonstrate the ability of industry, the practicing profession, educational institutions and governmental bodies to work together in an ongoing review of engineering education and licensure and provide a mechanism for their interaction.

2. To determine, in terms of disciplines and skills, what the composition of the profession should be, in order to provide the skills and "fields of understanding" necessary in the future society.

3. To determine if the undergraduate engineering program should stress basic principles, technology, a mixture of these, or liberal arts courses in order to provide the necessary "fields of understanding."

4. To determine how licensing requirements should relate to engineering curricula and to the needs of society in order to promote the public health, welfare, safety and good.

The program objectives are well within the scope of the "State Goals for Postsecondary Education" described in the Five-Year Plan for Postsecondary Education in California: 1976-81 which have been adopted by the California Postsecondary Education Commission. These objectives are:

- To encourage the increased effectiveness of accreditation of postsecondary education institutions in the State;

- To encourage postsecondary education to develop a comprehensive system of valid measures for knowledge gained both inside and outside formal academic programs;

- To encourage the establishment of educational requirements for licensure that are appropriate and reasonable in certifying occupational competency and the development of means for meeting these requirements including both educational programs and competency testing; and

- To work toward public understanding of the nature and significance of academic degrees, incuding their strengths and limitations as a measure of ability and skills.

The program was divided into three major areas of investigation:

1. An examination of societal needs in general, while looking at three large engineering projects specifically;

2. A study of engineering education; and

3. An evaluation of engineering licensure in California.

A planning document was prepared to identify the principal tasks in each of the three areas. This document identified many more subtasks than could be accomplished under the limited scope of the project. Consequently, priority was given to those areas of study that had the most significant impact on the practice, education, and licensing of engineers.

The information presented in this report was gathered from literature review, correspondence, survey questionnaires, individual and group discussions, and a public forum. Observations, findings, and conclusions are presented throughout the report as they relate to the specific area of investigation. Some detail material is presented in the Appendices. A verbatim copy of the transcription of the forum proceedings on engineering registration has been retained in the project file for reference purposes.

III. GENERAL OBSERVATIONS AND IMPLICATIONS OF THE STUDY

Engineering education is probably one of the most frequently studied disciplines in higher education. One major reason for this is that technology affects nearly every aspect of modern life and has a critical impact upon most of the essential elements contributing to the quality of life in the United States and other developed nations.

The periodic evaluation of engineering education coincides with occurrences in society which focus on societal problems and the engineer's role in solving those problems. In the post-Korean War era, engineering education was critically reviewed as the nation reassessed its priorities. With the successful launch of the Russian sputnik, the "space race" began. The federal government significantly increased funding for basic research, and educational institutions responded by strengthening basic principles in engineering curricula. This pattern continues today, with society facing an energy crisis and looking to technology for the solution.

Because of the diverse role of technology in society, questions are periodically raised as to how well engineering education is preparing engineers to provide technological solutions to the complex demands society makes of them. Also, the intense integration of technology into everyday living has prompted policymakers to question whether engineers are trained to consider the public health, welfare and safety as paramount issues.

A review of prior studies indicates that most of them have been conducted by individuals or groups involved in engineering education, rather than involving elements outside of the educational community. One possible explanation for this is that both the practicing engineering community and special-interest groups have not paid sufficient attention to engineering education, leaving the review activity to the educational institution itself.

Numerous recommendations for major changes in engineering education have been made in past studies. However, because these recommendations have lacked mechanisms for implementation, few of them have been directly adopted by educational institutions.

The most prevalent recommendation is that of increasing the requirements for the first professional degree in engineering. However, in terms of credit units for a degree, the requirements have decreased. Although it is difficult to compare degree program commitment because of a significant amount of content compression, many critics agree that the curriculum content has been decreased to maintain the competitive position of engineering programs with other degree programs offered. However, the increased emphasis on mathematics and basic science has maintained or increased the student work load for class preparation.

A second commonly mentioned recommendation for the four-year engineering degree program is the need for increased attention to design. However, the curricula have decreased in design content, and a large portion of the technology associated with the practice of engineering has been eliminated. This has created the need for a new degree program in engineering called the Bachelor of Science in Engineering Technology.

The creation of this new degree program was done by the educational institutions without comprehensive consultation with the practicing engineering community, industry, or the State Board of Registration for Professional Engineers. The graduate from the engineering technology programs in some instances, has encountered a hostile environment in the engineering community. He is denied some of the opportunities afforded the graduate of the B.S. program in engineering. It is difficult, or impossible in some states, for a graduate of an engineering technology program to become registered as a professional engineer without obtaining additional education (in basic science, math and principles of engineering science) resulting in a B.S. degree in engineering.

This study identified and defined the basic types of knowledge ("fields of understanding") encountered to a greater or lesser degree in the practice of engineering and related them to engineering education and registration. The review of curricula and registration examinations revealed that many of the "fields of understanding" were not included in engineering education programs, and the registration process did not include examination for competence in a majority of the "fields." In general, the interdisciplinary and nontechnical "fields" are most often omitted in education and registration, yet in the practice of engineering, these aspects can determine the viability of an engineering project.

Some of the individuals interviewed from educational institutions and industrial practice expressed the feeling that it was not necessary for engineers to have an understanding of the nontechnical aspects of engineering practice, since competent nontechnical members of project teams were available to deal with these considerations. However, in cases where the public health, welfare, safety, and good are of prime importance, how much understanding should engineers have of the nontechnical elements of a project and how much technical understanding should nontechnical members of the team have? This question is apropos, since excessive pressure has been brought upon engineering education to incorporate many nontechnical courses into undergraduate requirements, but little or no corresponding pressure has been brought to modify the curricula of nontechnical degree programs.

It was concluded from this evaluation of engineering registration that the licensing process does not involve examination in all of the parameters of engineering practice. The emphasis in both past and present exams is placed on scientific and technical engineering principles. One possible reason for this is that registration applies to only a small segment of engineering practice, perhaps as small as ten percent by funding, and therefore there is no real stimulus for change.

In addition, a philosophy of professional registration is developing which questions whether registration is restrictive, limiting opportunities for minorities, and whether it is in fact a guild-practice which functions to control the market. Some states have enacted "sunset laws" requiring that boards of registration for most professions and occupations be abolished within a specified period of time unless they can demonstrate that their existence is crucial to the protection of the public. The long-range implications, for engineering registration, of these new public policies on engineering registration have not yet been determined. Since the significant majority of engineering practice is exempt from the California Registration Act, and the laws of most other states, the effect of the elimination of the board of registration may be minor.

Presently, California has over 50,000 licensed engineers, and it is estimated that this number will reach nearly 70,000 before the end of 1977. The majority of these registrants are in technical disciplines having only title registration. Why are engineers interested in becoming licensed when most of their employers do not require it and registration may only protect the title? Some critics believe that engineers have a desire to emulate doctors and lawyers and to enjoy some of the financial benefits that engineers feel may be derived from a tightly controlled marketplace. Other observers maintain that the registration process instills in the engineer a greater degree of responsibility and awareness of public need, resulting in a general upgrading of the practice of engineering. There may be numerous other reasons for engineers to seek registration, but the fact remains that thousands of engineers do submit to the process and maintain their licenses through the payment of fees when there is no real requirement to do so.

The public forum on engineering registration, held by Senator Rodda, brought together concerned individuals from nearly every field of engineering--private practice, industry, government, educational institutions, unions, policymakers, and others. The most interesting aspect of the forum was that previous philosophies on the need for change in registration and engineering education were abandoned by the participants when faced with the threat of legislative mandate for change. Representatives of the engineering community even objected to the establishment of an advisory committee, to either the Commission on Postsecondary Education or the Board of Registration, that would periodically evaluate both engineering education and registration in light of societal needs. It appeared as though the present system of volunteer accreditation of curricula and academic-oriented examination for registration was more acceptable to those attending the forum than further State intervention in either.

Information from this study indicated that changes in engineering education will evolve over a long period of time, and will probably occur as a result of increased representation of the practicing profession on the committees of the Engineers' Council for Professional Development. Changes in the State registration of engineers will probably not take place for many years, since the current practice of exempting the major portion of engineering practice from the Act will continue under pressure from the currently exempt groups. Also, since the registration process affects a small percentage of engineers, there will be little stimulus to bring engineering education and registration closer together, other than the current Board practice of accepting graduation from ECPD-accredited programs as equivalent to four of the six years of experience required for registration.

A clear definition of engineering practice would be one effective improvement in the current process of engineering education and registration. In this study, the parameters involved in engineering practice in a project environment were identified and defined in terms of "fields of understanding." This "fields" approach could be developed and employed in many situations and could become a basis for program review and evaluation by the Commission on Postsecondary Education. The Board of Registration could use this technique as a basis for the evaluation of experience profiles and criteria for the development of registration exams. Students could also employ this approach when planning their programs in order to take maximum advantage of the flexibility in the curriculum to achieve an awareness of the complexity of engineering practice.

IV. RECOMMENDATIONS

The hallmark of any profession is its relationship to the public health, welfare, safety and good. Thus, the education of professionals, the establishment of State minimum standards of competence, and the general practice of the profession must be interrelated if the public interest is to be served.

This study revealed that there has been great attention given to the development and implementation of engineering education programs to ensure high academic achievement. In addition, the engineering licensing act has been modified numerous times since its original enactment over 50 years ago, and the Legislature has given a wide latitude for policy-making to the Board of Registration for Professional Engineers. Finally, there is every indication that engineers are very concerned with maintaining their technical competence as they practice their profession.

The principal issue that has not been addressed, philosophically or structurally, is the interrelationship between engineering education, licensing requirements, and the practice of the profession in such a manner to guarantee that the public interest is served. As a result, the dedicated efforts in each of these three areas have not necessarily served the needs of engineers as professionals nor always addressed the evolving needs of society.

There are many recommendations provided through this report as they relate to specific areas of the study. The summary recommendations presented herein reflect the most salient elements of the project's research.

Recommendation 1

> Engineering educational programs must be evaluated against specific criteria of engineering practice, i.e., "fields of understanding."

Recommendation 2

> The registration of engineers, through which minimum standards of competence are established, must reflect relevant education and the practice of engineering in light of the "fields of understanding."

Recommendation 3

> A vehicle must be developed which will bring together educators, public policymakers, employers, professional societies, students and others for the continual evaluation and coordination of the

interrelationship between education, licensing and engineering practice.

Recommendation 4

Degree programs in the social sciences and humanities should be modified to incorporate overview courses in science and engineering to increase understanding of the technical considerations in meeting societal needs.

Recommendation 5

Full-time engineering practice should be a major consideration in the selection of engineering faculty members.

V. COMPREHENSIVE SUMMARY

In the Fall of 1975, the California Postsecondary Education Commission was awarded a grant by the National Science Foundation to conduct a study of the relationship between engineering education and registration relevant to the needs and wants of society. This study addresses the concern of whether future engineers will have the skills and competencies to employ technology to meet the demands of society while maintaining, as paramount, the protection of the public health, welfare, safety, and good.

The initial task was the development of a detailed program plan in each of the three areas of the study: societal needs and wants requiring technical involvement; California engineering education programs; and the registration of engineers in California. The factors affecting each area of the study were identified and analyzed to develop a series of detailed tasks to facilitate the compilation of relevant data. Because the scope of this project was limited, only those factors having the greatest impact in each of the three areas were emphasized in research efforts.

A. Societal Needs and Wants

Applied engineering technology has not only changed the face of the earth, it has affected its mores and institutions. It has yielded a power which is an intimate part of every aspect of living. Its responsiveness to society's need and demand for many products and activities to enhance living beyond the basic subsistence level must be considered in examining the practice of engineering as a profession under contemporary conditions.

1. Fields of Understanding

Societal needs and wants--classified into 14 areas--and projects exemplifying three of these (energy, environmental quality, and transportation) were selected for detailed examination to determine the types of knowledge they involved. The three projects were the development of the nuclear power plant at Diablo Canyon in California; the oil spill off the Santa Barbara coast in California; and the Bay Area Rapid Transit System. Fourteen discrete areas of knowledge were identified as being integrally involved in the projects. For presentation purposes, they are referred to as "Fields of Understanding" in this report. The "fields" do not necessarily relate to specific subjects or courses. Rather, they group like-courses into the following categories or "fields" which were subsequently used to analyze various aspects of engineering education and the Engineers' Registration Act in California: physical science (including mathematics); design/application; ethics; management science; law; behavioral science; humanities; engineering science; engineering technology; communication arts; economics; political science; life science; history.

2. Degrees of Understanding

It must be recognized that no one person could be expected to be competent in each of the fields. Ideally, expertise in each area is provided by the various members of a project team. Deans of accredited California engineering education programs and California employers of engineers were asked to rate each "field of understanding" according to the degree of understanding they felt a newly graduated engineer should possess. A learning scale with five degrees of understanding was developed: 0-none; 1-awareness; 2-sensitivity; 3-proficiency; and 4-expertise.

Responses to this rating scale showed a general agreement that the graduate should be proficient in the technical fields and sensitive or approaching sensitivity in many nontechnical fields; and never less than strongly aware in all nontechnical fields.

B. Engineering Education

1. Prior Studies

Eight major prior studies of engineering education and their recommendations were reviewed. The preliminary review identified those major elements in engineering education which, for the past twenty years, have been of concern to the engineering community. A number of these elements--accreditation, hiring, promotion, and tenure-selection criteria, curricula, and continuing education--were selected for further examination.

A more in-depth study of the recommendations categorized them according to "fields of understanding." This categorization revealed a marked similarity among recommendations made over the past twenty years. Related literature documented that since most recommendations lacked mechanisms for implementation, change had been gradual--evolutionary rather than revolutionary.

2. Accreditation

The history, organization and functioning of the Engineers' Council for Professional Development were examined. ECPD is a private organization which is responsible for the accreditation of engineering and engineering technology programs in the United States. As such, it can be the most instrumental mechanism for effecting changes in engineering education. ECPD is supported by funds from its member organizations, which include the National Council of Engineering Examiners (NCEE), the American Society for Engineering Education (ASEE) and numerous engineering technical societies. The accreditation standards used by ECPD are broad and are often supplemented by criteria for each discipline formulated by the technical society representing the particular discipline.

Two major criticisms are commonly made of ECPD by the engineering community: (1) failure to establish minimum credit-hour requirements, and (2) dominance of ECPD by educators. In response to the first criticism, ECPD has not attempted to establish a strict credit-hour requirement because there is no uniformity among the basic credit-hour systems used throughout the country. In view of this, ECPD takes the total number of units required by a specific institution for a baccalaureate degree and divides this amount by four to obtain what "one full year" constitutes in that particular program. Further subdivisions provide the necessary standards.

As to the second concern, ECPD has attempted, with only limited success, to increase the involvement of practicing engineers in the accreditation process. However, it is dependent upon its member societies to select individuals with varied backgrounds. Because the member societies often provide lists comprised principally of educators' names, the accreditation process remains dominated by educators.

3. Hiring, Promotional, and Tenure Selection Criteria

Usually, decisions affecting the composition of faculty are made by administrators in conjunction with committees comprised of tenured faculty. Therefore, faculty members as both evaluators and those being evaluated play an important role in this process. They have developed some insight into how hiring, promotional, and tenure selection practices affect engineering education. Consequently, faculty were surveyed to determine their opinions on these practices and their effect on engineering education.

Questionnaires were distributed to the engineering faculty through the deans of each accredited engineering education program in California. An average of 35 percent of the engineering faculty from each campus responded.

Three major background elements of faculty members were examined: (1) whether faculty were tenured, (2) where faculty received their education and what degree was earned, and (3) what experience faculty had in engineering practice. The data indicated that 74 percent of the respondents were tenured and that over 97 percent of the respondents had doctorate degrees. Further, these academic credentials were representative of a large number of different schools. However, a high percentage of the degrees were obtained from relatively few schools. Of the 64 schools identified, the top five accounting for 46 percent of the total doctorates awarded were Stanford, UC Berkeley, UCLA, CALTECH, and MIT. Stanford alone awarded 16 percent of these degrees. In response to the question on experience, most faculty responded that they had some experience in engineering practice. No attempt was made to differentiate industrial experience from faculty consulting activities.

Faculty were asked to rank nine possible hiring criteria in order of current importance at their school. The engineering faculty, from the University of California and from the private schools, ranked the hiring criteria almost identically. The doctorate degree was considered the most important criterion, followed by research, teaching experience and publications, in that order. Industrial experience was considered sixth in importance. In contrast, faculty from the California State University and Colleges ranked industrial experience as the most important hiring criterion, followed by the doctorate degree, teaching experience, publications and research, in that order.

When asked whether the promotional system accurately rewarded merit in teaching, research, and public service, 49 percent of the tenured faculty and 63 percent of nontenured faculty felt that teaching was rewarded. With respect to research, 76 percent of the tenured faculty and 55 percent of nontenured faculty felt that this was given proper recognition. Over half of both groups felt that public service was not accurately rewarded.

As to whether the review process encouraged faculty members to conduct research, which might be directly applied to solving societal problems, the overall faculty response was 70 percent "no." Tenured and nontenured faculty were in agreement on this.

4. Undergraduate Engineering Curricula

The required undergraduate curricula of four chemical, five civil, six electrical and six mechanical engineering programs from seven California schools were examined and categorized according to the "fields of understanding." It was found that required physical science and engineering science courses ranged from 43 percent to 79 percent (with an average of 57 percent) of the total minimum requirements for a bachelor of science degree. From 2 to 18 percent of the total minimum requirements were devoted to design/application. Seventy percent of the programs examined devoted less than 19 percent of the curricula requirements to this area. 32 percent of all the programs reviewed required a course in ethics, and 68 percent required a course in communication arts. The remaining "fields of understanding" were rarely covered by required courses.

The review also revealed a marked degree of program flexibility in the accredited engineering programs. From school to school, technical electives in accredited programs ranged from nearly 6 percent of the total required units at the University of Santa Clara to 20 percent at CALTECH. Nontechnical electives ranged from 1.5 percent at CPSU, San Luis Obispo to nearly 30 percent at the University of Santa Clara. Unrestricted electives ranged from approximately 1 percent at CSU, San Jose to 9 percent at UC, Berkeley. Civil engineering offered the highest degree of flexibility of the programs studied (technical electives, 15 percent; nontechnical electives, nearly 17 percent; and unrestricted electives, nearly 7 percent).

Depersonalized student transcripts from three schools with accredited programs, and one school without an accredited program, were reviewed to determine whether students were taking advantage of program flexibility to select classes providing exposure to all "fields of understanding." Only one of the 89 transcripts examined included a class in each "field of understanding." Of the transcripts, 5.7 percent included classes in 12 of the fields, 81 percent failed to include classes in at least four of the 13 fields, and 17 percent failed to include classes in at least 7 of the fields. A high percentage of students did not take a course in law, ethics, political science, engineering technology, life science, and management.

5. Continuing Education

The content of undergraduate programs is concentrated on fundamentals. Specialized engineering subject material must be obtained from graduate education or continuing education programs offered through (a) university extension programs, in conjunction with recognized schools of engineering; (b) government and industry providing in-plant training programs for employees; (c) newly formed continuing education units of professional and technical societies, offered as membership services; and (d) entrepreneurial organizations. It is estimated that approximately half of today's engineering graduates will not take continuing or graduate education in their working careers. They will, instead, be dependent upon their undergraduate education to provide long-range job performance and professional development. Hence, undergraduate education may have to be designed to meet total career needs.

6. Interviews

Employers, recent graduate engineers, students, and faculty were interviewed to obtain their impressions of engineering education and its relevance to their needs and the needs of the public. In general, industry representatives felt that the engineering graduate should come prepared to practice under the constraints of the competitive marketplace and should be concerned with a company's position in the market. There was a keen desire to see changes in the educational process which would better prepare the engineer for real-life conditions. There was a feeling that current methods, including the accrediting process, were not serving the needs of industry.

Students' greatest concern was for the lack of practical application of their engineering educations. They felt that courses were too subject-oriented and might better be taught by faculty who related theoretical practice to actual practice. They also felt that the practice of engineering must be sensitive to the safety and environmental needs of the public, and questioned whether the skills necessary to practice with that sensitivity were being provided.

Information from faculty interviews did not represent a consensus of opinion on any particular issue. Some faculty believed that exposure to engineering practice in the educational program was very important: others questioned whether such exposure was the responsibility of the educational institution. There was general agreement on a need for greater coordination within the total engineering community.

C. Engineering Registration

1. History

The collapse of the St. Francis Dam in Southern California prompted the mandatory registration of civil engineers in California. However, such registration has not been expanded; most engineering practice remains exempt from licensing requirements. Confusion exists over whether or not registration is necessary or can protect the public, and if so, how it can serve that purpose best.

2. Critical Analysis of the Act

The effect of the Professional Engineers Act is severely limited because the majority of engineers practicing in California are not registered and the majority of the registered engineers practice in areas exempt from the registration Act. In addition, its impact is hampered by provisions which dilute rather than strengthen the State's efforts to promote the public welfare. In the Act, little attention is paid to the role of formal education in providing the individual with not only engineering expertise, but also with the sensitivity to ensure the public's well-being. Most importantly, the basic premise of the Act is poorly defined, with little or no explanation as to how the various provisions will promote the public health, welfare, and safety. Basically, the effectiveness and therefore the necessity of the Act must be questioned. Considering the broad spectrum of engineering practice, the Act in its present form does not play a significant part in the protection of the public.

3. Examination Process

Qualified engineers may apply to be examined for registration as professional engineers. The examination process entails two eight-hour tests: the first, the Engineer in Training (EIT) exam; the second, the Registered Engineer exam. The former is designed to cover engineering principles;

the latter is more broad, covering areas of engineering practice that would normally be acquired by the applicant through both engineering experience and education.

Both State-prepared and national exams concentrate on or emphasize the following "fields of understanding": engineering science, physical science, design/application, and economics. It is possible for an applicant to pass either type of test by solving problems only in the science-oriented fields. Most critics agree that exam problems in the engineering science category on State-prepared registration exams are quite similar in content and difficulty to those found in the EIT exam. For the most part, the State-prepared exams reviewed in this study tested for only college-level knowledge and experience.

4. Grandfathering and Other Registration Alternatives

The granting of professional engineering licenses by the Board of Registration for Professional Engineers through grandfathering procedures requires that applicants demonstrate nine years of "qualifying experience," four years of which may be met by a degree from an accredited engineering program. There is no requirement for the applicant to successfully pass a qualifying examination, such as the EIT, as proof of minimum competence. With the exception of the long-established "practice act" disciplines of civil, mechanical, and electrical engineering, there has been little increase in the number of specialty licenses issued by examination since a large initial number were issued without examination during the grandfathering period. Annual growth rates in some disciplines have been less than one percent. The number of licenses granted are a result of individual examination and reciprocity, and are insignificant when compared with those granted through regularly scheduled written exams and grandfathering.

D. Forum on Engineering Education and Registration

Numerous recommendations for change in engineering education and registration requirements have been made over the past twenty years, but there has been no governmental mandate to accomplish many of them. The general question addressed throughout this phase of the study was how interested the various groups and entities in the engineering profession were in change. More specifically, how interested would these groups be if change were enforced through the State governmental process?

Two approaches to examine this subject area were possible. First, to eliminate all engineering licensing in the State; second, to modify existing law to require that all engineers in responsible charge in the State be registered to practice engineering. It was felt that the second proposal would stimulate the greatest response from all elements in the engineering community. Thus, a piece of legislation was drafted to incorporate all of the changes sought over many years by segments of the engineering community and others. The bill was not introduced, but rather, was prepared in "preprint" form so that it could be seen and circulated in the normal bill format. The text of the draft legislation is shown in Appendix I.

On July 26, 1976, Senator Albert S. Rodda, Chairman of the Senate Committee on Education of the California State Legislature, conducted a forum on the draft legislation (SB 17 Preprint). The bill proposed a complete reorganization of Chapter 7 of the Business and Professions Code (which concerns Professional Engineers). It also proposed to delete technical disciplinary titles and references; require the registration of all practicing engineers "in responsible charge"; reorganize the standing committees of the Board of Registration; add an advisory committee to the Board; add a code of ethics to the Chapter; and define the technical and nontechnical considerations of engineering education and practice.

The forum provided an opportunity to determine the feelings and positions of the concerned groups in two phases. The first, through written solicitation of analysis of the draft legislation; the second, through presentations made at the forum. The following groups were asked to participate:

> Engineering technical societies; National Council of Engineering Examiners; American Society for Engineering Education; Engineers' Council for Professional Development; Board of Registration for Professional Engineers; California Department of Consumer Affairs; conservation groups; industry; futurists; recent engineering graduates; legislative staff; engineering unions; engineering educators

1. Initial Review

The participating groups were asked how they felt about a possible requirement that engineers have an understanding of all the various considerations in engineering practice as presented in the "fields of understanding." The consensus was that engineers in "responsible charge" should have at least an awareness of all elements in the "fields."

The groups were also asked their opinion on the adequacy of engineering education in light of the "fields." The response was anomalous in light of data gathered through other tasks of this study. In essence, it was felt that current engineering educational programs adequately prepared engineers for practice, and that if additional education were needed, then it should be obtained through on-the-job training or from courses specifically pertaining to job requirements.

Another issue presented to the groups was whether the Board of Registration should review curricula. In the draft legislation, this proposal raised concerns in both educators and industry representatives alike. Some respondents said that an independent action by California in curricula review could jeopardize efforts to standardize engineering accreditation and registration examinations.

Inquiries were also made concerning universal mandatory registration. Of particular interest were responses from currently exempt corporations. While the purpose of registration to safeguard life, health, property, public welfare and good was not in question, respondents did debate the thesis that registration was necessary to accomplish public protection. Some felt that registration was necessary only in cases where the engineer offered services directly to the public and that no other means was necessary to assure the recipient that an engineer was competent. Some educators, and a few representatives of technical engineering societies, supported universal mandatory registration, but most industry respondents were opposed to the concept.

2. Forum Proceedings

The structure of the forum was similar to a legislative hearing. It was held in a hearing room in the State Legislature and was recorded verbatim. (A transcript has been retained in the project file.) Senator Rodda, assisted by members of the Senate and Assembly staff who deal with legislation in education and registration, chaired the forum. One practicing engineer, having past experience as a member of the Board of Registration for Professional Engineers, also assisted.

Panel representatives from engineering societies, industrial management, education administrators, engineering educators, practicing engineers, and engineering unions were assembled to present views on five major aspects of the proposed legislation: (1) justification for registration of engineers; (2) education requirements for registration; (3) qualifications for registration; (4) miscellaneous requirements and administrative provisions of the bill; and (5) industrial and public utilities exemptions.

The following issues were discussed during the forum:

- The parameters involved in the practice of engineering;
- The breadth of engineering practice;
- The relationship of engineering practice to the adequacy of engineering education (given existing needs);
- The nature and effectiveness of accreditation of engineering education programs;
- The need for and extent of engineering registration in California;
- The adequacy of the current engineering registration act;
- The justification for federal government, public utility and industrial exemptions;
- The adequacy of education-related registration requirements;
- The adequacy of disciplinary licensing and grandfathering;
- The question of whether an engineer employee, "attempting to be ethical," should be protected by the State from reprisals by the employer;
- The inclusion of a code of ethics in the registration act;
- The question of whether the Board of Registration should even make an attempt to enforce a code of ethics; and
- The question of whether the prospective benefits of the proposed changes would outweigh the potential costs.

The forum was highly successful in bringing strong feelings to the surface. Formal positions taken by many of those making presentations were diametrically opposed to positions taken in prior studies of engineering education and registration. With one exception, nearly all of the provisions of the draft legislation were opposed by at least one of those making a presentation. The consensus was that if such legislation which carried the threat of governmental intervention were ever introduced, it would be opposed by all of the groups represented.

Based only on testimony presented at the forum, the following interesting conclusions could be drawn:

- Engineering educational programs in California are providing all necessary industrial requirements and are sufficiently diversified to satisfy the breadth of marketplace needs.

- Current examination requirements, including grandfathering, adequately ensure competent engineering practice.

- There is no need for mandatory licensure of engineers, since industry is liable for any injury resulting from incompetency.

- Disciplinary licensing is better than nonspecialized registration.

- There is no need for the incorporation of a code of ethical practice as part of the registration act.

- A small segment of land surveying is the only type of engineering practice that is offered directly to a citizen. Therefore, this area is probably the only one that should be licensed in California. A public agency or private industry has the ability to determine competency without State intervention.

- The current educational system and registration practices adequately serve the public in the State of California. Where problems exist, they should be resolved through court action.

Most of these "findings" are incongruent with data directly obtained from the related sources.

E. Engineering Advisory Committee

Throughout this program, major attention was given to defining and establishing a mechanism to permit the evaluation of engineering education and registration as an ongoing process. One finding of this study was that an Engineering Advisory Committee could be established and implemented within the California Postsecondary Education Commission under existing statutes (State Education Code) and within the program objectives of the Commission's Five-Year Master Plan. (See Appendix J.)

The Engineering Advisory Committee would be composed of representatives of engineering education institutions, the Board of Registration for Professional Engineers, the practicing engineering profession, public policymakers, engineering students, and others. It would have, as one of its primary functions, the making of recommendations to the Commission on criteria for the evaluation of engineering education and licensing programs and thereby facilitate close coordination in their development in light of the changing needs of society.

VI. DETAILED DISCUSSION

A. Societal Needs/Wants

Before 1850, technology in the United States was the realm of the military engineer, who, motivated by nationalistic ideals and visions of great expansion, planned and supervised the early development of canals and railroads. The very nature of military engineering required that only one matter be taken into consideration--a successful technical solution to the problem at hand.

After 1850, a new type of engineer came into dominance, a civilian with a cosmopolitan outlook, interested in providing specialized services to the new institutions becoming established in this country. He provided a variety of services to municipal, state, and private corporations and became known as the "civil engineer" in contrast to the "military engineer."

Civilian engineering required that the engineer be aware of matters other than just technical solutions to a problem. The economics of a project, and the health and safety of the public in connection with the project, became additional concerns which often affected the technical solution.

With the rapid growth of technology since 1875 has come a growth in the number of concerns involved in the development of that technology, concerns which must be dealt with as part of each engineering project. For instance, energy production must be conducted in a manner which protects environmental quality, carefully manages natural resources, is safe, economical and acceptable to the public and the courts.

1. Fields of Understanding

As part of this study, some of the major societal needs/wants requiring technical input or solutions were identified and classified into 14 different areas: energy; natural resources management; recreation and entertainment; business; education; health care; advanced technology and space; transportation; environmental quality; communications; manufacturing; construction; agriculture; security and national defense.

Engineering projects in three areas were selected for review to determine the considerations and types of knowledge involved. In the area of transportation, the Bay Area Rapid Transit system was examined. Offshore oil drilling was chosen to demonstrate the concerns and needs of energy and environmental quality protection, and the development of a nuclear power plant was reviewed to illustrate the considerations involved in the development of alternative energy sources. A discussion of these three projects can be found in Appendix A.

From the review of the above listed projects, 14 types of knowledge, referred to in this study as "fields of understanding," were identified:

Physical Science (including mathematics): The precise description of existing phenomena often using mathematical models.

Engineering Science: The application of a knowledge of mathematical and natural sciences gained by study, experience, and practice to develop ways of utilizing materials and forces.

Design/Application: The process of applying various techniques and scientific principles for the purpose of defining a device, a process, or a system in sufficient detail to permit its physical realization.

Engineering Technology: The use of products, systems, processes, devices, mechanisms, and technical know-how associated with the practice of engineering.

Ethics: Standards of conduct.

Communication Arts: The study of effective language use.

Management Science: The study of methods of applying manpower, material, and other resources to produce goods and services.

Law: Any established practice which is potentially enforceable by judicial action.

Political Science: The study of the interaction of individuals and/or structured groups with other structured groups.

Behavioral Science: The study of the individual and social behavior of people.

Life Science: The science of living organisms.

Humanities: Sensitivity for and appreciation of aesthetics and art.

History: The study of man's heritage.

2. Degrees of Understanding

The "fields of understanding" are representative of many of the types of knowledge that must be considered in every engineering project. Typically, expertise in each of these fields is provided by project team members whose "degree of understanding" will vary according to their function in the project. To account for this varying "degree of understanding," a learning scale of five "degrees of understanding" was developed:

0 - None: Having little or no knowledge of a subject area.

1 - Awareness: Having sufficient knowledge of a subject area to recognize problems in that area and the type of talent needed to solve them.

2 - Sensitivity: Having sufficient knowledge of of a subject area to recognize and solve problems in that area and having the ability to make some preliminary judgments concerning solutions and approaches.

3 - Proficiency: Having sufficient knowledge of a subject area to recognize problems in that area and develop solutions to them.

4 - Expertise: Having sufficient knowledge of a subject area to develop new approaches to solutions.

3. Survey of Engineering Deans and Engineering Employers

Employers of engineers and deans of those California engineering education programs accredited by the Engineers' Council for Professional Development (ECPD) were surveyed to determine their opinions on the "degree of understanding" recent engineering graduates should generally have in each "field." The results of these two surveys are presented in the following two sections.

a. Deans of Accredited Engineering Education Programs

Of the 20 deans surveyed, a response rate of 50 percent was received. The deans were asked to "rate" the "fields of understanding" (using the numerical values assigned to the five "degrees" of the learning scale) according to their relative importance in engineering education.

On the average, the deans rated engineering science and design/application highest, 3.6 and 3.5, respectively: 60 percent of the deans felt that an engineering graduate should have expertise in engineering science, while the remaining 40 percent believed a recent graduate should have proficiency in this area. Fifty percent rated design/application at the expertise level and the remaining 50 percent believed proficiency in this area was necessary.

Three other "fields" were rated in the proficiency range: physical science, 3.0; engineering technology, 2.8; and communication arts, 2.6. In the remaining "fields," the deans' average rate was for a lesser "degree of understanding." The average rating given any one "field" was never less than 1.4, i.e., awareness approaching sensitivity. Further details on the responses are found in Table 1 (following).

b. Employers of Engineers

A wide variety of companies and several State and local government agencies responded to the questionnaire, including producers of high technology and consumer products, construction companies, and companies engaged in research and development. Using the numerical values assigned to the five "degrees" of the learning scale, there was some disagreement among respondents over the "degree of understanding" that recent engineering graduates should have of the engineering science, engineering technology, and management "fields." Much of this disagreement could be a function of the limited response received from some of the groups.

On the average, the respondents rated engineering technology, 3.0; design/application, 2.8; and engineering science, 2.8 as the "fields" requiring the greatest "degree of understanding," indicating that the graduate engineer should be proficient in each

TABLE 1

RATING OF FIELDS OF UNDERSTANDING BY ENGINEERING DEANS

("Degree" Frequency Distribution and Mean of Responses for Each "Field" and Deans' Survey)

FIELDS OF UNDERSTANDING	PERCENT RESPONDING					
	0-None	1-Awareness	2-Sensitivity	3-Proficiency	4-Expertise	Mean Response
Physical Science				100		3.0
Engineering Science				40	60	3.6
Design/ Application				50	50	3.5
Engineering Technology			40	40	20	2.8
Ethics		10	60	20	10	2.3
Communication Arts			40	60		2.6
Systems Management 1/		10	40	50		2.2
Business/ Administration		30	60	10		1.8
Economics		30	70			1.7
Law		60	40			1.4
Political Science		50	50			1.4
Behavioral Science		30	70			1.5
Life Science		60	40			1.7
Humanities/ History 2/		30	70			1.4

1/ "Systems Management" and "Business Administration" were later combined to form one "field," "Management."
2/ "Humanities/History" were later separated into two fields, "Humanities" and "History."

of these three "fields." Those "fields" in which employers felt a lesser degree of understanding was necessary were communication arts, 2.4; physical science, 2.3; ethics, 2.2; and systems management, 2.2. The consensus was that the engineer should be "sensitive" in these "fields." Respondents believed that in the remaining "fields," the engineer should never be less than aware of these concerns.

More detailed information on the responses from employers is presented in Table 2 (following), and in Appendix G, Industrial Survey. Table 2 presents the average response of each type of employer to each "field," as well as the mean of all responses.

c. Comparison of Responses Rating the "Fields of Understanding"

A comparison of the results from both deans and employers showed substantial agreement on the "degrees of understanding" in most "fields," but a difference in emphasis and attitude between the two groups for a few "fields."

The greatest disagreement centered on the "degree of understanding" necessary in physical science, engineering science, and design/application. Although both groups rated these "fields" as the most important, the deans rated each "field" 0.8 degrees higher than the corresponding rates given by the employers. The deans rated the "fields" as requiring proficiency to expertise, while employers rated them one "degree" lower, i.e., requiring strong sensitivity to proficiency.

The two groups demonstrated close agreement in their rating of the remaining "fields," i.e., that an engineer should possess at least an awareness of each "field of understanding." As one would expect, the consensus was that the graduate engineer should be far more knowledgeable in the technical "fields" than in the nontechnical "fields."

d. General Observations

For the first 25 years following World War II, this country concentrated its efforts on expanding industrial technology and developing massive weapons systems and sophisticated aerospace hardware. Gradually, into the 1970s, a transition toward employing technology to deal with the problems and needs/wants of society occurred.

TABLE 2

RATING OF FIELDS OF UNDERSTANDING BY ENGINEERING EMPLOYERS

(Average Response of Each Group for Each "Field" and Average Response for All Groups Per "Field")

FIELDS OF UNDERSTANDING	TYPE OF EMPLOYER OF ENGINEERS					
	High Technology	Consumer Products	Construction	Research & Development	State & Local Gov't.	Mean of All Responses
Physical Science	2.4	2.4	2.0	2.2	2.7	2.3
Engineering Science	2.8	3.1	2.7	2.8	2.0	2.8
Design/ Application	3.3	2.8	2.0	3.0	2.3	2.8
Engineering Technology	3.0	2.6	3.0	3.0	2.0	3.0
Ethics	2.4	2.0	2.3	2.4	1.7	2.2
Communication Arts	2.4	2.8	2.3	2.2	3.0	2.4
Systems Management 1/	2.4	2.2	2.3	2.2	1.7	2.2
Business Administration	1.8	2.2	2.0	1.4	1.0	1.8
Economics	1.3	1.6	1.0	1.6	1.7	1.4
Law	1.6	1.1	1.0	1.0	1.7	1.2
Political Science	1.6	1.0	.7	1.2	1.7	1.3
Behavioral Science	1.7	1.8	1.3	1.4	1.3	1.6
Life Science	1.3	1.1	1.3	.4	2.0	1.5
Humanities/ History 2/	1.3	1.2	1.0	1.0	2.0	1.2
# of Responses	8	8	3	5	3	27

1/ "Systems Management" and "Business Administration" were later combined to form one "field," "Management."

2/ "Humanities/History" were later separated into two fields, "Humanities" and "History."

Public policymakers have directed technology toward serving society, while placing a great many restraints on the manner in which the delivery system can provide its services. The essential part of the technology delivery system is the engineering project. The project members must assess the problem, define the parameters, and provide an acceptable technical solution. In today's engineering environment, recognition of the "fields of understanding" and appropriate tradeoffs between the "fields" is critical to a successful engineering project.

The identification and definition of the "fields" and "degrees" of understanding was an important first step in the study of the relationship between engineering education and registration. It is now recognized that the practice of engineering is composed of both technical and nontechnical considerations, and these considerations provide the framework within which the relationship of engineering practice, registration, and education may be viewed.

B. Engineering Education

Engineering education in California is provided through the "four segments" of postsecondary education: the University of California, the California State University and Colleges, the independent colleges and universities, and the California Community Colleges. A previous study, Project E-E (refer to 1-h of this section), determined that over 70 institutions in California offer degrees in engineering and/or science. The University of California has nine campuses, five of which have ECPD-accredited engineering programs. Twelve of the nineteen State University campuses offer ECPD-accredited engineering programs and seven independent colleges and universities offer ECPD-accredited engineering programs. Also, numerous engineering-related associate arts degree programs, providing strong support for further study, are offered at many of the Community Colleges.

Numerous elements involved in this postsecondary system have a role in determining the quality and content of engineering education programs. A preliminary review of prior studies of engineering education was made to determine which elements should be selected for further investigation as part of this study. The areas chosen for further review were recommendations of previous studies of engineering education; accreditation; hiring, promotion, and tenure selection practices; attitudes of engineering educators, students and employers of engineers; the content of undergraduate education; continuing education; and the development of an advisory committee system (see Sections V-E, Comprehensive Summary, and VII). A discussion of each of these areas follows. (For reader reference, the pages upon which the quotes appeared in the original documents are noted.)

1. Prior Studies

Many studies in the past 50 years have attempted to answer major questions as to what the content of a basic engineering degree program should be. Since the mid-1950s, there has been a downward shift in the credit hour requirements in engineering baccalaureate degree programs from about 150 to 128 semester credit hours. Much of the technology-oriented program content--surveying, heat treating, machine shop, foundry--has been eliminated. Efforts have been made to include more courses in the humanities to provide engineering students with greater exposure to the nontechnical concerns of engineering practice, and the fields of basic science, mathematics, and computer science have received increased emphasis.

Eight prior studies were reviewed to determine their effect upon engineering education:

Report on Evaluation of Engineering Education (The Grinter Report), American Society for Engineering Education, 1955;

General Education in Engineering: Report of the Committee for the Humanistic-Social Research Project, ASEE, 1955;

An Engineering Master Plan Study for the University of California, The Engineering Advisory Council, 1965;

The Preliminary Goals Report, ASEE, 1965, and The Final Goals Report, ASEE, 1968;

A Study of a Profession and Professional Education, Allen B. Rosenstein, 1968;

Liberal Learning for the Engineer: Report of the Humanistic-Social Research Project, ASEE, 1968;

Future Directions for Engineering Education: System Response to a Changing World, a report by the Center for Policy Alternatives prepared for the School of Engineering of the Massachusetts Institute of Technology, ASEE, 1975;

Project E-E: Energy and Engineering Education, Professional Engineering and Research Consultants, 1975.

The findings of each study were examined, and the recommendations made were categorized according to the "fields of understanding" and other categories. This information is found in Table 3 immediately following this section. Two of the studies, General Education in Engineering and Liberal Learning for the Engineer, were not included in the categorization scheme because of their limited scope. Literature concerning engineering education was then reviewed to determine the impact of these studies.

The following is a review of each study:

a. Report on the Evaluation of Engineering Education

The Committee on Evaluation of Engineering Education of the American Society for Engineering Education (ASEE) was appointed by the society's president in May, 1952, upon the recommendation of the 1951 Committee on Adequacy and Standards of Engineering Education and the Engineers' Council for Professional Development and ASEE committees. The Committee was asked to develop standards to aid ECPD in "bringing engineering accreditation in consonance with future responsibilities of engineers." (p. 3)

The Committee's report (commonly known as the Grinter Report) stressed the need for more mathematics and science in engineering curricula, with emphasis on "education directed toward the creative and practical phases of design, involving analysis, synthesis, development, and engineering research as the most distinctive feature of engineering curricula." (Page 14.) The report also noted the importance of orienting engineering education toward the obligation of the profession to society, but it did not propose that this obligation be realized through a substantial reordering of nontechnical content in engineering education.

Since the Grinter Report was published, basic principles have been given increased emphasis in engineering programs. This may be largely due to increased federal funding for basic research in the late 1950s, and a concentrated effort to increase the number of graduate degree engineers with a basic research orientation 1/. However, emphasis on the creative and practical phases of design have been reduced.

b. General Education in Engineering: Report of the Committee for the Humanistic-Social Research Project

This project was a by-product of the Grinter Report. Its purpose was "to consolidate and make available the experience of engineering schools during the past ten years in developing workable programs of study in the humanities and social sciences; and to make recommendations looking to the future strengthening of this portion of engineering education." (Page 627, Journal of Engineering Education, April 1956.)

Competent observers conducted over a thousand interviews of engineering educators and made follow-up reports. These interviews indicated that engineering education programs were extremely diverse, and the data obtained from them were not readily reducible to tabular form.

> It was observed . . . "that engineering educators throughout the country are in nearly unanimous agreement that their students would profit--as professional men, as citizens, and as individuals--from a fuller acquaintance with the resources of the humanistic and social sciences; that a sizable number of these same educators are honestly fearful that attempts to incorporate into already overcrowded curricula substantial programs of humanistic-social studies may either jeopardize the quality of the technical education, or lead to superficiality in the treatment of the humanities and social sciences; but that some thirty or more of our leading engineering schools have demonstrated such fears to be groundless by developing carefully planned programs that provide a sound introduction to the humanities and social sciences while simultaneously reinforcing the student's engineering training." (p. 623)

Relying upon the professional judgment of many engineering educators, the study discussed the selection and development of an engineering faculty, curricular content as related to the objectives of engineering education, the evolution of engineering curricula, special factors that influence undergraduate educational achievement, and graduate study in engineering.

The report concluded that the most common cause of unsuccessful engineering-designed liberal arts programs was unilateral planning by engineering faculty. Often the liberal arts faculty were not included in the early planning stages of such programs, causing resentment which precluded their later cooperation. At times, their resentment grew into "overt opposition." To eliminate this situation, the study stressed the importance of joint planning and cooperation between engineering and liberal arts faculty in the development and administration of liberal arts programs for engineering students. (p. 666)

c. <u>An Engineering Master Plan Study for the University of California</u>

This study was conducted by the Engineering Advisory Council in response to concerns expressed by many engineers, i.e., whether parallel practice- and research-oriented professional graduate programs should be developed; whether more content should be included in undergraduate education; whether the quality of undergraduate instruction can be maintained in an atmosphere dominated, at many schools, by graduate study and research; and whether faculty should be added to stimulate greater faculty attention to teaching and to continuing education, and to enlarge the professionally qualified segments of the faculties as compared with the research-oriented segments.

The Council concluded that engineers should be broadly educated:

> "Because the engineer must please people with his works, he must understand, as much as his time permits, not only the sciences, but also the current laws, rules, customs and procedures of his society. Because he has a major social responsibility, he must eventually deal in aesthetics, philosophies, mores, folkways, and many emotional and seemingly irrational aspects of human behavior. The scientist, on the other hand, can seldom predict with accuracy the social consequences of his undertakings. He must spend more time at the frontier of knowledge in his special field and less on the social, economic, and political implication of his discoveries.
>
> "In both engineering and science, new information is being developed at a rapid rate. During the next decade, there will be high rates of change in many of our political and social institutions, as well as in our technologies and our business and physical environments. It thus appears

that two very desirable educational goals are impossible of accomplishment: (1) A student cannot be equipped to know all there is about everything applicable to engineering practice; there is too much to know. (2) He cannot even be equipped for the duration of his lifetime; too much will change." (p. 26)

In effect, the study supported the need for engineers to have at least some knowledge of the "fields of understanding." It also made numerous observations concerning faculty:

"That the single most important requirement for an excellent engineering program is an outstanding faculty. (p. 121)

"That 'the faculty must excel in teaching and must have collective excellence in the activities for which students are being trained. A proper balance of faculty competence is important, not only for teaching and student guidance, but also for educational policy making.' (p. 121)

"That 'the programs of instruction in engineering must be designed for undergraduates, for both professionally and academically oriented graduate students, and for continuing education programs. The University maintains strong faculties in support of the undergraduate and academic graduate programs. However, the composition of the present faculties, and the associated evaluation and reward system will not adequately support the expanded professional graduate or continuing education programs.' (p. 121)

"That 'the University's formal statement of its expectations as to faculty performance is adequate for the evaluation of engineering faculty members provided its interpretation can be changed to place greater emphasis on quality of teaching and on forms of creative achievement other than research.' (p. 121)

"That in practice promotional policies have been 'interpreted to give recognition in the area of creative work only to research as

> documented by publications. Thus, only faculty members whose creative activity is in research are satisfactorily evaluated at present. The faculty members whose creative work is not in the area recognized as research are disadvantaged. Those working in more than one creative area often have difficulty, too, even when one of the areas is research. The excellence of teaching is not weighted strongly enough. A result has been the evolution of a research-dominated education program, albeit one of high quality. Undergraduate and professional graduate instruction and continuing education have been handicapped.'" (p. 132)

Based on these observations and others, the study concluded that teaching should be a main faculty duty; that some professors should have continuing involvement with engineering design and development in industry and government during summers and on leaves; that some professors should give substantial attention to continuing education; that the University should give major attention to the maintenance of a competitive system of faculty remuneration; and that a task force of department chairmen and Engineering Advisory Council members should be formed to investigate the evaluation of teaching and creative achievement in tenure selection and promotion practices.

d. The Preliminary and Final Goals Reports

In 1961, the ECPD requested the ASEE to conduct a study of the goals of engineering education, financed by a $300,000 National Science Foundation grant. Two reports were issued as a result of this study. Both outlined the growing dichotomy between research-oriented and practice-oriented activities and concluded that a two-stem approach to engineering education should be developed, one emphasizing practice; the other, research. The reports also recommended that engineering students should be given greater exposure to the humanities and social sciences. The Preliminary Report recommended ". . . that during the next five years the accrediting activity of ECPD be gradually shifted from the bachelor's degree to the master's degree, or in other words, that the first professional degree be considered the master's degree, and the bachelor's degree be considered an introductory degree." (p. 36)

The recommendation was rewritten in the Final Report to read:

". . . it is recommended that the engineering profession and engineering educators recognize the inevitability of increased graduate level education in the future and take whatever steps are necessary to provide the opportunity for at least one year of graduate study for the majority of those who will complete their undergraduate education during the coming decade . . . . That during the next decade basic engineering education be extended to include at least one year of graduate level education leading to the master's degree." (pp. 13-14)

e. A Study of a Profession and Professional Education

As part of the Educational Development Program of the Engineering Department of the University of California at Los Angeles, the study began as one of engineering education with an emphasis on the design of undergraduate and graduate education programs. It evolved into a study of the professions in general, but focused on the engineering profession. In explaining why the study was conducted, Mr. Rosenstein, the principal investigator, wrote:

"The 'crisis of the profession' which precipitated our study has roots both inside and outside the university. It reflects massive changes in the professions, in the university, in technology and in society. The problems of professional education are a consequence of the accelerating socio-technical changes that have been affecting and transforming every profession and every major university during the past several decades." (p. x)

In his discussion of the "crisis of the profession," Mr. Rosenstein noted the declining position of the United States as an exporter of technology and capital goods; then discussed the relationship of the nation's competitive posture and interests to activities of our professional schools. He cited several examples that suggested such a relationship, but concluded that the exact nature of the relationship was yet to be determined.

Rosenstein also questioned whether research alone could solve many of society's problems. As evidence, he cited the lack of a positive correlation between Nobel Prizes received in medicine and the quality of our nation's medical services.

He also observed that:

> "The pressures upon the personnel of the professional colleges have become overpowering. The flight from teaching is well-documented, and the effects upon both undergraduate and graduate programs have been accumulating. It is easier to teach a mathematics or a science course than a professional course with open-ended problems. It is easier to concentrate in a specialized scientific area than to undertake the solution of substantial professional problems with a slower paper production rate. The young assistant professor has little choice. Faced with the perils of "publish or perish," only the foolhardy will assume a professional stance.
>
> "Professors, like all other living organisms, tend to replicate themselves. One cannot expect a young professor who has gone directly from his Ph.D. to teaching without any professional experience to produce anything other than a Ph.D. with little understanding of the profession in which he has little desire to practice. The inbreeding consequences of the past two decades have influenced the professional curriculum. In engineering, for example, the undergraduate mathematics and science courses have received a long-overdue renovation and modernization. On the other hand, the older, empirically-based engineering subjects have been discarded and too often have not been replaced with a modern professional stem." (p. II, 7-8)

Based on these observations and conclusions, Rosenstein recommended that professional education should be evaluated on a regular basis. He developed a method of curricular design and recommended that the professional schools teach courses in applied humanities, and for the general campus, offer courses on the professions and society. In the area of engineering education, he emphasized the importance and need for teaching more design/applications.

f. Liberal Learning for the Engineer

This study, conducted by the Humanistic-Social Research Project Committee of ASEE in response to charges that the engineering students' education was inadequate and irrelevant, was designed:

> ". . . to formulate goals for the humanities and social sciences which are relevant to the changing character of society and the changing role of the engineer in society; to examine the resources available and the changing emphases and directions within the humanities and social sciences as they affect planning, staffing, and teaching of courses and programs for engineering students; to gather information concerning changes which have taken place in the humanistic-social education of engineering students within the last decade and to identify trends, situations, programs, and courses which appear to further selected goals; and to draw up guidelines for teachers, administrators, and policy makers in order to assist them in achieving their desired goals in specific institutional situations." (p. 6)

The following statement summarizes the findings of the study:

> ". . . there is little sign as yet that either new programs, or the new-found status of humanists and social scientists, is even beginning to meet the challenge of change in our technological culture and in the role of the engineer within it. Most revisions of program appear to be matters of minor adjustment rather than major overhaul. Very few involve liberal attempts to give the student a sense of the overall picture--the interactions and interrelations within the context in which he will live as a person and work as a professional man. Nor does one find much awareness of the importance to the whole enterprise of involving the engineering student in the life of the campus, both its culture and its controversy." (p. 12)

The study concluded that it was not possible to formulate a fully developed program which could be offered as a general solution to the problem of humanistic and social content in engineering education, but did develop some general recommendations: ". . . that developmental and contextual objectives should be emphasized and their implications should be thoroughly explored; and that the humanities and social sciences should be treated not as a separate stem, but as an integral part of a liberal engineering education." The study also recommended that " a qualified humanist or social scientist should be invited to join each accrediting team, and be asked to study the humanistic-social part of the program." The suggestion was not, however, adopted by the Engineers' Council for Professional Development.

g. <u>Future Directions for Engineering Education: System Response to a Changing World</u>

In 1972, the MIT School of Engineering supported a study of engineering education conducted by the MIT Center for Policy Alternatives. The study was initiated "to examine the engineering education system in a changing world" (p. 3). A committee composed of engineering educators, employers of engineers and several nonengineers analyzed the information gathered by the Center and drew upon their experience to draft the report.

The committee made numerous observations, some of which are summarized below:

"During the last twenty years, military and space programs stimulated demand for engineering scientists. Future demand for engineers will probably be in the traditional and more slowly expanding sectors. However, demand for new power plants will result in considerable demand for engineers with a design orientation. (p. 39).

"Just as social, economic, legal, and political considerations now must be considered more fully in work for the federal government, industries are faced with the growing importance of new requirements arising from changing demands of the market or of the society through the political process. Consumers are demanding improved product performance. Safety and consumer regulations have become more pervasive and restrictive. Environmental considerations determine the design and use of products and affect the technology and location of production plants. The rising costs of fuel and mineral resources influence engineering decisions and create opportunities for new engineering work in the development of more efficient technology. The engineering of social systems (medical, educational, and governmental systems) requires greater consideration of human values and attitudes and the characteristics of societal institutions. These changing emphases are not yet generally reflected by changes in engineering education. (p. 39).

"Engineering training is being used more often as a foundation for graduate study in other fields, such as business and public administration, law and medicine. (p. 40)

"Work and careers of engineers change significantly during their lifetimes. These changes are caused by their own growth, the requirements of their employers, changes in the technology they use in their work, the changing market, and changes in national goals and societal attitudes.

"At present, there are few programs which provide for retraining and relocation, little evidence that it can be done effectively, and little financial support available. Also, it has not been established that present engineering education prepares the student with the attitudes or skills to take advantage of the opportunities of a changing career. (p. 41).

"A decade of protest and turmoil has left engineering campuses and students only slightly changed. As before, the engineering student is comparatively pragmatic, self-directed, not people-oriented, and desirous of unambiguous situations and structured work. Existing engineering education patterns, centered on analysis, problem sets, and abstract symbol manipulation, may reinforce such characteristics rather than people-oriented traits and skills.

"If, as we believe, the art of engineering requires skill in the use of intuitive processes, in dealing with uncertainty and ambiguity, in problem definition and solution, then it is no wonder that design is hard to teach engineering undergraduates, especially in the upper years. This is in sharp contrast to fields such as architecture where creative design ability is expected and nurtured at all stages of the educational process.

"There is considerable evidence that many relatively flexible, less analytical students leave engineering by either changing majors during the undergraduate years or by changing fields after graduation. Other students change to less prescribed curricula than are offered by traditional engineering curricula in search of flexibility and wider options for the future. These "dropouts" from engineering may be the very people who could best deal with the ambiguities of the greater number of engineering problems." (p. 42)

Based upon findings such as these, the committee concluded that design and clinical experience should be integral parts of engineering education; that more schools ought to offer "bachelor of engineering" degree programs for students planning graduate study in professions other than engineering; that more effective counseling methods should be developed; and that schools should prepare for a possible period of little or no growth.

h. Project E-E: Energy and Engineering Education

Project E-E was conducted by Professional Engineering and Research Consultants for the California Assembly Committee on Education. Its purpose was to identify energy related research projects being conducted by institutions of higher education in California, and to examine engineering and science curricula as it relates to the training of engineers and scientists to cope with the broad implications of the energy problem.

Data gathered in visitations made to several campuses of the University of California, the California State University and Colleges System, and independent colleges indicated:

- that courses which increase the engineer's awareness of the interaction of the physical sciences with the biological, social, political, economic, and environmental sciences should be required;

- that "parallel ladders" should be developed to recognize research, teaching, and public service;

- that professional experience should be one of the criteria for employment as a member of the engineering faculty;

- that the current emphasis upon basic principles should be expanded to cover an appreciation of engineering technology;

- that undergraduate programs should be oriented in a direction permitting students the option of emphasizing either research or practice;

- that the California Postsecondary Education Commission should establish a mechanism for the continual evaluation of the relevance of engineering and scientific education; and

- that an investigation should be undertaken to determine the relationship between engineering licensure in the State of California and engineering curricula.

i. Summary

A basic concern in the eight studies which were reviewed was the impact of changing technology and societal needs on engineering education. The lack of practice-oriented programs; inadequate social and humanistic content; insufficient credit hour requirements for a professional degree; and inadequate faculty evaluation practices were the major problems identified by the studies. Numerous recommendations were made to alleviate the problems, but very little evidence exists indicating that the recommendations have been implemented.

As indicated in Table 3 following, there was a high degree of similarity in the recommendations of most of the studies; that is, that courses be more effectively taught in most of the "fields of understanding." Other recommendations proposed that new accreditation criteria be adopted by ECPD; that articulation between colleges and universities be improved; that curricula flexibility and diversity be encouraged; that both research- and practice-oriented programs be offered; that undergraduate education continue to offer the bachelor of science degree, yet base the curricula on the assumption that students will obtain a master's degree; that engineering students be provided with practical engineering experience; that faculty be exposed to engineering practice; and that teaching positions be made available to practicing engineers.

The similarity of recommendations may indicate that changes made in engineering education programs have not been adequate, and/or that there is a need for engineering education to continuously change to meet the changing demands for engineering skills.

j. Authors of Previous Studies

The principal authors of four previous studies, and others closely involved, were contacted to obtain their opinions on the impact of the following four studies: the Evaluation of Engineering Education (the "Grinter Report"), the Master Plan Study, the Final Goals Report, and A Study of a Profession and Professional Education.

Responses to three questions were solicited:

- Do you feel that the recommendations are still valid in light of the engineering environment of 1976?

- Have any of the recommendations been implemented?

- Which recommendations should be implemented on a high priority basis?

(1) Evaluation of Engineering Education

L. E. Grinter, then Chairman of the Committee responsible for this report, replied that he believed the report ". . . opened the curricula of engineering schools to greater emphasis upon science and its applications. . . . Hence, . . . I believe the Report's first recommendation has been widely implemented." In regard to the other recommendations, Dr. Grinter was "less satisfied." "Engineering education has actually lost ground in the attention it has given to humanistic and social studies."

(2) Engineering Master Plan Study

Replies were received from R. L. Johnson, who chaired the task force which conducted the study, and from Robert Bromberg, then current Chairman of the Engineering Advisory Council. Both respondents felt that while lacking some detail and statistics, the logic behind the recommendations was sound, and the recommendations in essence remained valid. Both believed that many of the recommendations have been implemented, "some directly and others in spirit."

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TABLE 3

CATEGORIZATION OF RECOMMENDATIONS
OF PRIOR STUDIES

-RECOMMENDATIONS-	The Grinter Report (1955)	Engineering Master Plan Study (1965)	Preliminary Goals (1965)	Final Goals (1968)	Rosenstein (1968)	Future Directions for Engineering Education (1975)	Project E-E (1975)
GENERAL:							
Curricula Diversity/Flexibility	X	X	X	X			
New Teaching Methods	X	X	X	X			
Accreditation Standards	X		X	X			
Education-Licensing Relationship							X
FIELDS OF UNDERSTANDING:							
Physical Science	X	X	X	X	X	X	X
Life Sciences		X	X	X	X	X	X
Engineering Science	X	X	X	X	X	X	X
Design/Application	X	X	X	X	X	X	X
Communication Arts	X	X	X	X	X	X	X
Behavioral Science	X	X	X	X	X	X	X
Humanities/History	X	X	X	X	X	X	X
Political Science	X	X	X	X		X	X
Economics	X	X	X	X		X	X
Management	X			X		X	X
Law						X	X
Ethics	X			X	X		X
UNDERGRADUATE EDUCATION:							
Improve Articulation		X	X	X		X	
Masters in Engineering Directed		X		X			
Reduce Work Load of Students			X	X			
Provide Practical Experience			X			X	
Extend Curriculum to more than Four (4) Years	X						
GRADUATE EDUCATION:							
First Professional Degree		X	X	X			
Provide Practical Experience		X					
Improve Industry-University Collaboration		X					

TABLE 3 (cont'd.)

CATEGORIZATION OF RECOMMENDATIONS OF PRIOR STUDIES

-RECOMMENDATIONS-	The Grinter Report (1955)	Engineering Master Plan Study (1965)	Preliminary Goals (1965)	Final Goals (1968)	Rosenstein (1968)	Future Directions for Engineering Education (1975)	Project E-E (1975)
FACULTY:							
Competitive Salary Levels	X						
Reasonable Teaching Loads							
Improve Recruiting Practices	X		X				
Exposure to Eng. Practices	X	X	X			X	
Teaching Positions for Practicing P.E.'s		X	X				
Placing Emphasis on Teaching		X					
Improved Student-Faculty Relationships		X				X	
Evaluation	X	X				X	
RESEARCH AND DEVELOPMENT:							
Research and Development		X			X		
General Relevance		X			X		
Support of Teaching		X					
University-Industry-Government		X					
CONTINUING EDUCATION:							
On-Campus		X		X			
Off-Campus		X		X			
Degree Recognition		X					X
Industry-University Collaboration		X					

(3) Final Goals Report

Eric A. Walker, who chaired the ASEE Goals Committee, and J. M. Pettit, the Director of the Graduate Phase of the study, replied that the recommendations were still valid and that the engineering community in both educational and accreditation activities was working to implement the activities. Dr. Walker's interesting comments:

"However, I would point out that there are still two difficulties. First, there is too little interaction between the practicing engineer in industry and the professors of engineering, with the result that engineering education is not as responsible to the needs of engineers as it should be. By practicing engineers, I mean those who are actually engaged in putting science to work.

"My other complaint is that too many schools have adopted the report as being a guidebook and have not been selective in what they do. The report stresses diversity in engineering education, but too many schools are trying to do everything. They are giving instruction in all branches of engineering and at all levels, from the associate degree to the doctorate. There are few, if any, colleges and universities that can be first-class in all fields. I believe colleges should be selective, pick out a few things in which they can excel and forget about the others."

(4) A Study of a Profession and Professional Education

The principal investigator of this study, Allen B. Rosenstein, replied that, "The recommendations seem more valid than ever in light of the engineering environment of 1976." He estimated that 13 of the 38 recommendations ". . . are in the process of being implemented to some degree in some institutions." Many of the recommendations being implemented are the same as those which were considered high priority items. He added that:

"We are in the process of rewriting the Study to include recommendations for (1) a continuing partnership between the public sector, private sector, professions and professional schools for the improvement of the nation's quality of life and maintenance of the nation's competitive position in world markets; (2) restructuring the University; (3) means for measuring educational needs and institutionalizing the change process in higher education; (4) common undergraduate professional stems; and (5) societal assessment as a regular part of undergraduate education."

(5) Summary

Contrary to the opinions of many observers, the principal authors of these four studies agreed that there had been implementation to some degree of some of the recommendations. By no means was the degree of implementation always satisfactory, nor were the number of recommendations acted upon sufficient.

Contrary opinions among critics and authors on the matter of whether or not recommendations had been implemented seemed to be over conflicting definitions of what constituted change. Where most critics were looking for obvious and immediate implementation, the principal authors recognized evolutionary change, the gradual adoption of the spirit of the recommendation.

2. Accreditation

The Engineers' Council for Professional Development (ECPD) is one of the single most effective organizations in guiding the curricula of engineering programs in the educational institutions of the United States. It is the nationally recognized accrediting agency for engineering programs. This section examines the creation and development of ECPD and its accreditation process and guidelines, and analyzes the extent of the organization's impact on engineering education.

a. History

In 1928, the Committee on the Economic Status of the Engineer, appointed by the American Society of Mechanical Engineers (ASME), issued a report which emphasized the need to improve the status of engineering by establishing a clear distinction between the engineer and the nonengineer. The report suggested that an educational program beginning with high school students would provide engineers and the public with an understanding and conception of engineering as a profession. In response to the Committee's report, ASME requested that other technical societies join with it in a "conference of certification of the engineering effort."

During this same period, the National Council of State Boards of Engineering Examiners (NCSBEE) 2/ invited other national engineering societies to aid in the establishment of a "National Bureau of Engineering Registration."

> The plan was to provide unified certification: (a) for registration by the State Boards, (b) for admission to membership in the engineering societies, and (c) for the conferring of professional degrees by the engineering schools. 3/

These efforts became united in the Conference on Certification into the Engineering Profession, which was attended by representatives of NCSBEE, American Society of Mechanical Engineers (ASME), the American Society of Civil Engineers (ASCE), the American Institute of Electrical Engineers (AIEE), the American Institute of Mining Metallurgical and Petroleum Engineers (AIME), the American Institute of Chemical Engineers (AIChE), and the Society for Promotion of Engineering Education (SPEE). 4/

In February of 1932, the conference membership appointed a planning committee consisting of representatives from each society attending the conference. This committee met in March of 1932 and developed a comprehensive program entitled, "A Plan for Joint Action in the Development of the Engineer." The report containing this program was adopted with only minor changes by the conference members in April, 1932. It was then proposed that the plan be put into effect by calling the first meeting of the Engineers' Council for Professional Development, whose "governing objective is to be the enhancement of the status of the Engineer." 5/

b. Organization

ECPD has been in existence as a private organization for over 40 years. It presently is comprised of 15 "participating" and "member" bodies. As defined in ECPD's Constitution and Rules of Procedure, "member bodies must . . . have objectives and programs which can effectively support those of ECPD, whereas participating bodies must . . . have objectives and programs which actively support those of ECPD . . . and be . . . actively engaged in the dissemination of technical knowledge, and have a demonstrated interest and capability in the accreditation process . . . ." There is currently one member body, the National Institute of Ceramic Engineers (NICE), and 14 participating bodies in ECPD:

AIAA, ASCE, SAE, ANS, NCEE, AIIE, ASME, AIMW, IEEE, AIChE, ASEE, SME, ASAE, NSPE

Applications for membership must be approved by the Board of Directors of ECPD. To become a member body, applications must be approved by the governing boards of at least two-thirds of the member bodies; to become a participating body, applications must be approved by at least two-thirds of the participating bodies.

ECPD is governed by a Board of Directors which enacts policy and manages the organization. Dues income of the participating bodies determines how many "representative directors" each may appoint to the Board. If this income is less than $700,000, the participating body can appoint one director to the Board; if it is greater than $700,000 and less than $1,200,000, it may appoint three directors. The Board of Directors must abide by the Rules of Procedure.

In addition to its policy-making responsibilities, the Board of Directors determines the dues each member shall pay to support the annual operating budget of ECPD. Each member body must pay $1,000. The annual assessment for each member body consists of two parts. The first part is a fixed amount equal to that paid by the member bodies. The second part is in proportion to the annual dues income (excluding student dues) of each participating body. The minimum annual assessment for each participating body is $2,000.

As a participating body, NCEE is entitled to representation on the Board of Directors of ECPD. Thus, as a result of their membership in NCEE, the state boards of registration have a voice in ECPD's policy-making process. In addition, boards of registration may send observers on ECPD accreditation visits to colleges and universities.

The accreditation guidelines can be found in ECPD's Annual Report. Present guidelines are fairly broad and do not include a minimum credit hour requirement for a bachelor of science degree. Because there is no uniformity across the country in the basic credit units for a degree, ECPD has not attempted to set up a strict unit requirement for bachelor of science engineering degree programs. Instead, ECPD accepts four full academic years as the time necessary for completing a basic level baccalaureate program in engineering. Across the nation, these four years could mean anything from 40 to 500 credit hours, depending upon the credit-hour system used by the institution. As a result of the use of different credit-hour systems, ECPD takes the total number of units required by the institution for a baccalaureate degree, then divides by four to obtain what "one full year" means in a particular program. Further subdivisions then provide the necessary standard.

The Engineering Education and Accreditation Committee of ECPD is responsible for the formulation of accreditation guidelines. Members of the committee are appointed by the president of ECPD, subject to approval by the participating body holding curricular responsibility in the disciplinary field that the appointee is representing. Membership on the committee is by formula, and is structured so that those disciplines having a larger number of programs also have a larger number of representatives than those having a smaller number of programs.

Persons are appointed to the committee in accordance with Sections 10 and 11 of ECPD's bylaws. Appointments to the committee are primarily based upon previous experience on accreditation visits and knowledge of the particular discipline assigned. Thus, persons usually become active in ECPD's accreditation process by participating on an ad hoc visiting team. Appointment as an ad hoc visitor indicates that the person is well-versed in a given discipline and considered capable of passing judgment on the quality of educational programs in that discipline. Successful service as an ad hoc visitor on several accreditation visits makes a person an eligible candidate for vice chairman of a region. Successful work in this capacity can then qualify a person for a regional chairmanship. Further evidence of leadership and understanding of accreditation can then enable this person to be nominated as an officer of the Engineering Education and Accreditation Committee.

Since the individual disciplinary programs, rather than the entire engineering college, school, or department are accredited, an institution must petition to have a specific program evaluated for accreditation. After making application, an institution receives a detailed questionnaire from ECPD. The data submitted by the institution in response to the questionnaire, and the supplemental report on an on-site visit by an ECPD accrediting team, are used to evaluate the program for accreditation.

There are several steps in the selection process for visiting members. Each participating body submits a list of members who they feel are qualified to participate in accreditation activities to ECPD. Once an institution has applied for accreditation, a team chairman selects those individuals from the official list who he feels are most qualified, as a result of their preparation and expertise, to evaluate that particular program. This second list, usually containing the names of several persons who could competently evaluate the program, is then sent to the institution for approval. The judgment of the visiting team must not only be acceptable to ECPD, but also to the institution being evaluated for accreditation. Consequently, the institution seeking accreditation can eliminate from the second list anyone they consider unsuitable. (According to ECPD, there are many cases where a university has had dealings with an individual on a consultant basis, or in some other capacity, that would create a conflict of interest.) Nevertheless, since the ECPD accreditation team chairman selects the list of names from which the institution must choose, the determination of who will participate on the visiting team ultimately remains the responsibility of ECPD.

Prior to the visit, each member of the visiting committee is provided with a dossier of information, supplied by the institution, which explains the total campus education effort. The team members review this material and subsequently verify this information and qualitatively assess such factors as intellectual atmosphere, staff morale, and caliber of the student body during their visitation. The team must then project the potential competency of the graduates two years, four years, and six years into the future. There must be a subjective analysis of what will be required two years, four years, and six years hence in the practice of that particular engineering discipline. Once this process is completed, the accrediting team has a debriefing session with the members of the institution to help assess the weaknesses and strengths noted by the team.

Many practicing engineers have criticized the dominance of ECPD's accreditation efforts by engineering educators. Some have even suggested that educators evaluating other educators is "incestuous," and that engineering educators do not understand the problems of engineering companies and consequently are not capable of giving the engineering student an understanding of the problems that confront most practicing engineers. Others, however, have argued that most practicing engineers are not qualified to evaluate engineering education programs because they do not understand the problems that confront most educators or have insight into the basic requirements of the field of education. Unfortunately, interest in the educational process among practicing engineers is generally minor, and very few experienced engineers have taken advantage of the available opportunities to assist the educational process. Consequently, the accreditation process has remained dominated by educators even though an equal balance of representation by practitioners and educators is sought by ECPD.

ECPD relies upon member societies to nominate individuals with a variety of different backgrounds to participate in its accreditation activities. There is no requirement that the practicing profession and education be equally represented on the ad hoc visiting teams. The responsibility of the participating bodies is simply to provide ECPD with the names of members they feel are qualified to participate in accreditation activities. The Executive Director of ECPD has stated:

> "Though the 50/50 distribution has been mentioned as a possible ideal situation, it is not necessarily the ultimate goal. It is known that the ratio of educators to practicing engineers within any given discipline shows less than two percent as educators; however, not all practicing engineers understand the requirements of the educational process. It is true that there is a preponderance of educators over practicing engineers in previous years. The past few years have shown a concerted effort on the part of ECPD team chairmen to select as close as possible a 50/50 mix of educators and practicing engineers for the visiting teams. The success of this venture will depend upon the successful performance of industrial people versus that of educators and the awareness and cooperation of the disciplinary societies in providing ECPD with a balanced mixture of the educators and industrial people for the visitors lists. In some fields this last year (1975), the balance of practitioners to educators was 40/60." 6/

Like the ad hoc visiting committees, the Engineering Education and Accreditation Committee is also dominated by educators. Currently 22 of its 27 members are educators. According to ECPD, as more industrial people participate in accreditation visits, there will be more of them eligible for consideration for committee positions. ECPD expects that within the next few years the 50/50 representation may occur in some disciplines.

In addition to accrediting engineering Bachelor of Science programs, ECPD also accredits associate and baccalaureate degree programs in engineering technology. Accreditation of these programs is the responsibility of ECPD's Engineering Technology Committee. This committee became a standing committee on October 5, 1964. Since that time, it has established a basis for accrediting technical institute type programs, now designated as programs in engineering technology. The policies, methods of evaluation, criteria and procedures established by the Engineering Technology Committee to evaluate these programs are included in ECPD's annual publication. They parallel those established by the Engineering Education and Accreditation Committee.

ECPD has distinguished between engineering and engineering technology in its definition of engineering technology. According to ECPD,

> "Engineering technology is part of a continuum extending from the craftsman to the engineer. Located nearest the engineer, it requires the application of scientific and engineering principles in support of engineering activities. The support is given whether or not the engineering technologist or engineering technician is working under the immediate supervision of the engineer. The term "engineering technician" is applied to the graduates of the associate degree programs. Graduates of the baccalaureate programs are termed "engineering technologists." 7/

ECPD-accredited programs in engineering technology include those offered by institutes, community colleges, colleges of technology, polytechnic colleges, divisions of colleges and universities, and proprietary schools.

Although companies often employ graduates of these programs as engineers, they are not fully accepted or recognized by many practicing engineers as being equivalent to graduates of Bachelor of Science in engineering programs. Additionally, many state engineering registration boards do not recognize this four-year degree as satisfactorily meeting the educational requirements of state licensure. In California, the State Board of Registration does not view engineering technology education programs as equivalent to engineering education programs. An applicant for registration may obtain four years of experience credit toward the six-year requirement by completing an ECPD-accredited engineering Bachelor of Science program. However, applicants can only obtain two years of credit for experience by completing an ECPD-accredited engineering technology baccalaureate program.

c. Summary

ECPD is a private organization supported by funds from its member organizations. These include NCEE and numerous engineering technical societies. One of the organization's principal functions is to accredit engineering and engineering technology education programs. The accreditation standards used are broad and often supplemented by criteria formulated by engineering technical societies representing particular disciplines. The accreditation guidelines do not include minimum credit-hour requirements.

ECPD is the single most effective mechanism for initiating changes in engineering education. It has attempted to increase the involvement of practicing engineers in the accreditation process. However, the organization is dependent upon its member societies who usually nominate educators as their representatives (although an effort is made to select individuals with varied backgrounds).

3. Hiring, Promotion, and Tenure Evaluation

Significant attention has been given to the structure of the curricula for engineering education programs in past studies. (See Appendix C.) However, one of the greatest influencing factors in the entire educational delivery system is the faculty, and faculty "set" or profile which plays a major role in the direction of both course content and presentation. Set is established by previous experience, habits, bias, education, and degree level, and the unique emphasis which each institution exercises over its total educational program.

A survey among the faculty of the major engineering schools in California was conducted to determine their attitude on some of the major issues involved in hiring, promotion, and tenure. Some of the principal issues investigated were the academic degree level of the faculty, the emphasis the faculty and institutions placed on degrees, engineering practice experience, teaching, and basic research. Responses on tenure, hiring, and promotional policies were also compiled. A detailed presentation of this survey and the findings are presented in Appendix B.

The survey indicated that a high percentage of faculty members possess doctorate degrees. It also indicated that there is a difference in emphasis placed upon teaching, experience, and research by the different institutions.

a. Faculty Education Background

Over 97 percent of the responding faculty indicated that they possessed doctorate degrees and that they felt this was important. Interestingly, almost 50 percent of these degrees were granted by five educational institutions in the United States. Of these institutions, Stanford University ranked highest with 16 percent of all the degrees granted.

b. Faculty Engineering Practice Experience

According to the survey, 98 percent of the engineering faculty had some engineering practice experience, reporting an average of 13.2 years each. The University of California faculty reported having an average of 14.3 years; California State University and private colleges and universities reported 13.1 and 12.2 years, respectively.

These figures may be somewhat misleading, since faculty members were inconsistent in their responses. It was apparent that some faculty members counted part-time consulting activities, with their academic responsibilities, on a full-time equivalency basis. For example, a faculty member with 14 years of academic experience, including some consulting activity, might have indicated 14 years of engineering practice experience.

c. Hiring Practices

Faculty hiring is done through a review process involving tenured faculty and school administration. Administrators usually make decisions based upon recommendations made by committee members who are usually tenured.

Faculty members were asked to rank, in order of importance to their schools, nine possible hiring criteria. Respondents from the independent colleges and universities, and the University of California, indicated that the doctorate degree was the single most important criterion. Research was second in importance. Respondents from the California State University and Colleges ranked engineering experience the highest and the doctorate second. The majority of all the respondents ranked teaching as third in importance followed by publications. By no means were these rankings unanimous, and variation existed between schools in the same system.

d. Tenure Evaluation and Promotional Review

It was the opinion of 63 percent of the surveyed faculty that in the review process the emphasis placed upon research, teaching, and public service was influenced by the composition of the review committees. It was felt that the review process gave priority to teaching and research and did not recognize the importance of public service. The data in Appendix B shows a split in attitude on these issues. Opinion as to the value of involving practicing engineers on review committees and on the issue of student involvement in the process was also split. Non-tenured faculty were most favorable to the involvement of practicing engineers, and 83 percent of both tenured and non-tenured respondents felt that engineering faculty were adequately represented.

In exploring the issue of basic research versus applied research, a majority of the faculty respondents felt that the review process favored the former rather than the latter.

Engineering professors were asked to rank research, teaching, and public service by the degree of emphasis that each was given in their departments in promotional and hiring practices. The results of this inquiry showed the basic differences in the three segments of higher education. Respondents from the University of California strongly indicated (86%) that the ranking order was research, teaching and public service, contrasting the ranking given by the respondents from the California State University and Colleges and private schools. Public service, research, and teaching were ranked in that order of emphasis by 59% of the CSUC faculty, and 68% of the faculty from the private schools ranked teaching first, with research and public service following.

e. Attitude Toward Tenure

The attitude of faculty members toward tenure was evaluated on the basis of the benefits and detriments they felt were associated with the system. Most often academic freedom, or freedom of expression without threat of reprisal, was sited as the primary benefit. The principal detriment of the tenure system was identified as its tendency to support and retain nonproductive faculty members. (See Appendix B for related responses.)

Tenure is an emotional subject and can polarize members of a faculty. The faculty tenure system is paralleled in both private and public sectors. While these systems were created to give employees job security, complaints about them concern similar issues. The basic concern of the hiring, promotional and tenure systems is whether or not they provide incentives which encourage innovativeness and creativity to enable faculty to relate their specific subject areas to engineering as a real-life experience. A faculty oriented in this manner will best serve the needs of the students, the practicing profession, and society as a whole.

4. Undergraduate Engineering Curricula

a. Required Curricula

Periodic concern by the profession and others over the relationship of undergraduate degree programs to the practice of engineering have resulted in numerous studies. This section discusses the curricula content of several of the technical majors programs of seven engineering schools in California. The "fields of understanding," which contain the interrelated parameters of engineering practice, were used as a basis for curricula examination in the following schools which were selected to provide a cross section of California Bachelor of Science Engineering programs. 8/ Selection criteria included size, geographic location, type of school, accreditation status, and program orientation. 9/

University of California, Berkeley (UCB)
University of California, Davis (UCD)
California State University, San Jose (CSUSJ)
California Polytechnic State University, San Luis Obispo (CSUSLO)
California Institute of Technology (CALTECH)
University of Santa Clara
West Coast University

Time and financial constraints of the project did not permit the examination of two-year engineering related programs offered by the Community College system. Future studies should evaluate this system and its effect on students who have received an associate arts degree and have transferred to a four-year college or university to complete the bachelor of science degree in engineering.

ECPD lists (p. 27, ECPD 43rd Annual Report) 27 engineering program disciplines in California. These are:

Aeronautical Engineering
Aeronautics
Aeronautics and Astronautics
Aerospace Engineering
Agricultural Engineering
Architectural Engineering
Ceramic Engineering
Chemical Engineering
Civil Engineering
Computer Engineering
Electrical Engineering
Electrical and Computer Engineering
Electronic Engineering
Engineering
Engineering Materials
Engineering Science
Environmental Engineering
Industrial Engineering
Industrial and Systems Engineering
Industrial Engineering and Operations Research
Mechanical Engineering
Metallurgical Engineering
Metallurgy
Naval Architecture
Ocean Engineering
Petroleum Engineering
Sanitary Engineering

To provide an overview of engineering program content, four chemical, five civil, six electrical, and six mechanical engineering programs were examined. The course descriptions found in the 1974-75 catalog of each school were used to classify required courses. "Specific course requirements" 10/ were categorized according to the "fields of understanding." Elective course requirements were classified as "technical," "nontechnical," or "unrestricted." 11/

Laboratory classes, examining only physical phenomena, were classified as physical science or engineering science courses. However, if such a course had a design or applications component, it was placed in the design/application category.

The data indicated that four different credit-hour systems were used: the quarter system was used at UCB, UCD, and CSUSLO; the semester system was used at CSUSJ and West Coast University; the unit system was used at the University of Santa Clara (one unit per course; 44 units to graduate); and the unit system based on each hour per week spent working on a course (one unit per one hour of course work) at CALTECH (516 units were required for a BS in engineering).

Cumulative results from the investigation of the seven institutions and four disciplines studied are summarized below. A more complete summary of the findings can be found in Tables 4, 5, 6, and 7 immediately following.

(1) Technical Course Requirements

- Required physical and engineering science courses ranged from 43 to 79 percent (average 57 percent) of the total minimum requirements for a bachelor of science degree.

- Design/application was the next most significant area of concentration. Courses in this category ranged from 2 to 18 percent of the total minimum requirements. Seventy percent of the programs examined devoted less than 10 percent of their curricula requirements to design/application courses. (Note: This 10 percent figure may be misleadingly high. If a course had a design or applications component, no matter how small, it was classified as design/application.) Few, if any, courses encompassing the other "fields of understanding" were required, but were available at the student's discretion.

	UCB	UCD	CSUSJ	CSUSLO	CALTECH	U OF SANTA CLARA	WEST COAST UNIVERSITY
FIELDS OF UNDERSTANDING	%	%	%	%	%	%	%
Physical Science	28.5	24	39	25		27	36
Engineering Science	36	31	27	30.5		16	20
Design/Application	2	13	8	6.5		16	18
Engineering Technology	0	2	2	3		0	2
Ethics	0	2	1	1		0	0
Communication Arts	0	4	4.5	3		0	2
Management	0	0	0	0		2	4
Economics	0	0	0	1.5		0	3
Law	0	0	0	0		0	0
Political Science	0	0	0	1.5		0	3
Behavioral Science	0	0	0	1.5		0	6
Life Sciences	0	0	0	1.5		0	0
Humanities	0	0	0	5		0	6
History	0	0	0	2.5		0	0
Total Req'd. Courses Within Fields %	66.5	76	81.5	82.5		61	100
Technical Electives %	11	8	13	10		0	0
Nontechnical Electives %	15	13	4.5	1.5		30	0
Courses Req'd. Not Within Fields %	0	0	1	1.5		0	0
Unrestricted Electives %	7.5	3	0	4.5		9	0
TOTAL %	100	100	100	100		100	100
Total Minimum No. of Units Req'd./Bachelor of Science	180	180	131	200		44	135

TABLE 4

CURRICULUM EVALUATION
MECHANICAL ENGINEERING REQUIREMENTS
(From 1974-75 Catalogs)

FIELDS OF UNDERSTANDING	UCB %	UCD %	CSUSJ %	CSUSLO %	CALTECH %	U OF SANTA CLARA %	WEST COAST UNIVERSITY %
Physical Science	32	27	42.5	23		25	40
Engineering Science	37	26	29	30		18	16
Design/Application	3	2	9	10.5		5	18
Engineering Technology	0	2	2	2		0	2
Ethics	0	2	1	1		0	0
Communication Arts	0	4	5	3		0	2
Management	0	0	0	0		0	4
Economics	0	0	0	1.5		0	3
Law	0	0	0	0		0	0
Political Science	0	0	0	1.5		0	3
Behavioral Science	0	0	0	1.5		0	6
Life Sciences	0	0	0	1.5		0	0
Humanities	0	0	0	5		0	6
History	0	0	0	2.5		0	0
Total Req'd. Courses Within Fields %	72	63	87.5	83		48	100
Technical Electives %	0	21	5	9.5		11	0
Nontechnical Electives %	15	13	5	1.5		30	0
Courses Req'd. Not Within Fields %	0	0	1.5	1.5		0	0
Unrestricted Electives %	13	3	1	4.5		11	0
TOTAL %	100	100	100	100		100	100
Total Minimum No. of Units Req'd./Bachelor of Science	180	180	127	200		44	135

TABLE 5

CURRICULUM EVALUATION
ELECTRICAL ENGINEERING REQUIREMENTS
(From 1974-75 Catalogs)

FIELDS OF UNDERSTANDING	UCB	UCD	CSUSJ	CSUSLO	CALTECH 2/	U OF SANTA CLARA	WEST COAST UNIVERSITY
	%	%	%	%	%	%	%
Physical Science	26	27	39	NOT EVALUATED	32	25	36
Engineering Science	24	24.5	29		0	23	18
Design/Application	6	4	9		0	11	16
Engineering Technology	0	2	2		0	0	2
Ethics	1	0	0		0	0	0
Communication Arts	0	4.5	5		1	0	2
Management	5	0	2.5		0	0	8
Economics	0	0	0		0	0	3
Law	0	0	1.5		0	0	0
Political Science	0	0	0		0	0	3
Behavioral Science	0	0	0		0	0	6
Life Sciences	0	0	0		0	0	0
Humanities	0	0	0		0	0	6
History	0	0	0		0	0	0
Total Req'd. Courses Within Fields %	62	62	86		33	59	100
Technical Electives %	11	20	8		30	6	0
Nontechnical Electives %	15	14	5		21	29	0
Courses Req'd. Not Within Fields %	0	0	1		2	0	0
Unrestricted Electives %	12	4	0		14	4	0
TOTAL %	100	100	100		100	100	100
Total Minimum No. of Units Req'd./Bachelor of Science	180	180	131 1/		516	44	135

TABLE 6

CURRICULUM EVALUATION
CIVIL ENGINEERING REQUIREMENTS
(From 1974-75 Catalogs)

1/ The total listed in the catalog is 134-138. To obtain this total, C.E. 112 was counted twice. The actual total is thus 131-135, if C.E. 112 is counted (cont'd.

only once.

2/ The CALTECH engineering and applied science option is examined here. Bachelor of Science degrees are granted in engineering and applied science, but are not offered in specific disciplines other than chemical engineering. Students may, however, choose to specialize in any of the following areas: aeronautics, applied mechanics, communications and control, computer science, electron device physics, electronic circuits, environmental engineering science, fluids engineering and jet propulsion, mechanical behavior of materials, mechanical design, physical metallurgy, structural and soil mechanics, structures and properties of alloys. (A Master's degree is offered and recommended in chemical, civil, electrical and mechanical engineering.)

FIELDS OF UNDERSTANDING	UCB %	UCD %	CSUSJ %	CSUSLO %	CALTECH %	U OF SANTA CLARA %	WEST COAST UNIVERSITY %
Physical Science	41	42	50	DOES NOT HAVE A CHEMICAL ENGINEERING DEPARTMENT	46	DOES NOT HAVE A CHEMICAL ENGINEERING DEPARTMENT	DOES NOT HAVE A CHEMICAL ENGINEERING DEPARTMENT
Engineering Science	21	26	29		12		
Design/Application	4	5	6		10		
Engineering Technology	0	0	2		0		
Ethics	0	0	0		0		
Communication Arts	3	4	5		0		
Management	0	0	0		0		
Economics	0	0	0		2		
Law	0	0	0		0		
Political Science	0	0	0		0		
Behavioral Science	0	0	0		0		
Life Sciences	0	0	0		0		
Humanities	0	0	0		0		
History	0	0	0		0		
Total Req'd. Courses Within Fields %	69	78	92		69		
Technical Electives %	13 1/	10	0		10		
Nontechnical Electives %	13	12	5		19		
Courses Req'd. Not Within Fields %	0	0	1.5		2		
Unrestricted Electives %	5 1/	0	1.5		0		
TOTAL %	100	100	100		100		
Total Minimum No. of Units Req'd./Bachelor of Science	183 2/	183	132		526		

TABLE 7

CURRICULUM EVALUATION
CHEMICAL ENGINEERING REQUIREMENTS
(From 1974-75 Catalogs)

1/ A student could choose to take 24 units of technical electives and nine units of unrestricted electives.

2/ The minimum units requirement found on page 46 of the 1974-75 UCB general catalog is 180 units. The requirements found in the 1974-75 UCB College of Engineering catalog total 183 units.

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(2) Ethics

Although ethics was a required component in only 32 percent of all the programs reviewed, it never constituted more than 2 percent of the total unit requirements (usually one course). The following programs required such courses:

1. One out of four chemical engineering programs;
2. Three out of six electrical engineering programs;
3. One out of five civil engineering programs; and
4. Three out of six mechanical engineering programs.

(3) Communication Arts

Sixty-eight percent of the engineering programs required a course in communication arts, but never constituted more than 5 percent of the total unit requirements.

(4) Program Flexibility

Program flexibility varied substantially:

1. The number of technical electives engineering students were required to take ranged from 0 - 21 percent.
2. The number of nontechnical electives engineering students were required to take ranged from 0 - 30 percent.
3. The number of unrestricted electives engineering students were required to take ranged from 0 - 13 percent.

- Possible design/application content varied as a function of the number of technical and unrestricted electives required and the number of such courses offered.
- Humanistic and social content varied as a function of the number of nontechnical and unrestricted electives required. Thus, this content varied from 11 to 36 percent of total

program content depending upon the program's flexibility. (The average was slightly less than 20 percent.)

(5) Life Science

Only one school (out of the seven schools examined) required a course in life sciences.

(6) Unit Requirements

Most engineering education programs required the equivalent of 180 quarter units or 130 semester credit hours. California State University, San Luis Obispo, was the most notable exception, requiring 200 quarter units for a Bachelor of Science in engineering.

(7) Summary

Bachelor of science degree course requirements varied substantially from discipline to discipline and institution to institution. The greatest proportion of required courses were usually in the engineering and physical sciences. Only a very small percentage of the total course requirements were devoted to design/application and communication arts. Moreover, very few courses were required in the remaining "fields of understanding." (For example, most programs did not require a course in ethics.) But, by carefully selecting electives, students could acquire an exposure to, and awareness of, most of the "fields of understanding." The extent of this exposure would, however, be limited by the credit-hour requirements for a bachelor of science degree.

b. Elective Curricula

The review of required curricula revealed that program flexibility varied substantially from campus to campus and discipline to discipline. Even so, the flexibility provided on most campuses was such that the student could obtain classes in most of the "fields of understanding," if he chose to do so. To determine whether students were actually choosing elective classes that would provide some exposure to the "fields of understanding," depersonalized transcripts 12/ of engineering students were examined.

An initial sampling of depersonalized transcripts was obtained from the University of California, Davis, to determine the feasibility of reviewing them, and to ascertain the degree of emphasis placed upon each "field of understanding" in engineering education. Although the complete transcripts of students who had transferred from one institution to another were difficult to obtain, the results of this preliminary survey indicated the feasibility of transcript review and analysis.

Subsequently, transcripts were requested from the six other institutions whose catalogs had previously been examined. These institutions were:

University of California, Berkeley (UCB)
California Polytechnic State University, San Luis Obispo (CSUSLO)
California State University, San Jose (CSUSJ)
Santa Clara University
California Institute of Technology (CALTECH)
West Coast University

UCB, CSUSLO, Santa Clara University and West Coast University sent the requested transcripts.

Transcripts of students who had not transferred into a specific institution, but who attended for the full four-year program, were also examined. 13/

Utilizing course descriptions found in each school's catalog, the courses listed on the individual transcripts were classified according to the "fields of understanding." Where doubt existed as to how a course should be classified, the course description was "liberally interpreted" to maximize the indicated breadth of the student's education.

This analysis produced some interesting results. Engineering students were not exposed to many of the "fields of understanding" involved in engineering projects unless professors discussed concepts from the nontechnical "fields of understanding" in classes taken by them. (See Figure 4.) However, discussions with engineering students indicated that nontechnical concepts were rarely discussed in technical classes. (A summary of student interviews is presented later in this chapter.)

Several observations can be made from Figure 4, immediately following, which represents the breadth of the educational experience for those students whose transcripts were reviewed in this study. Only one of the 89 transcripts examined included a class in each "field of understanding." Eighty-one percent of the students did not take a class in at least four of the 13 "fields," and 16 percent of the students did not take a class in at least seven of the "fields."

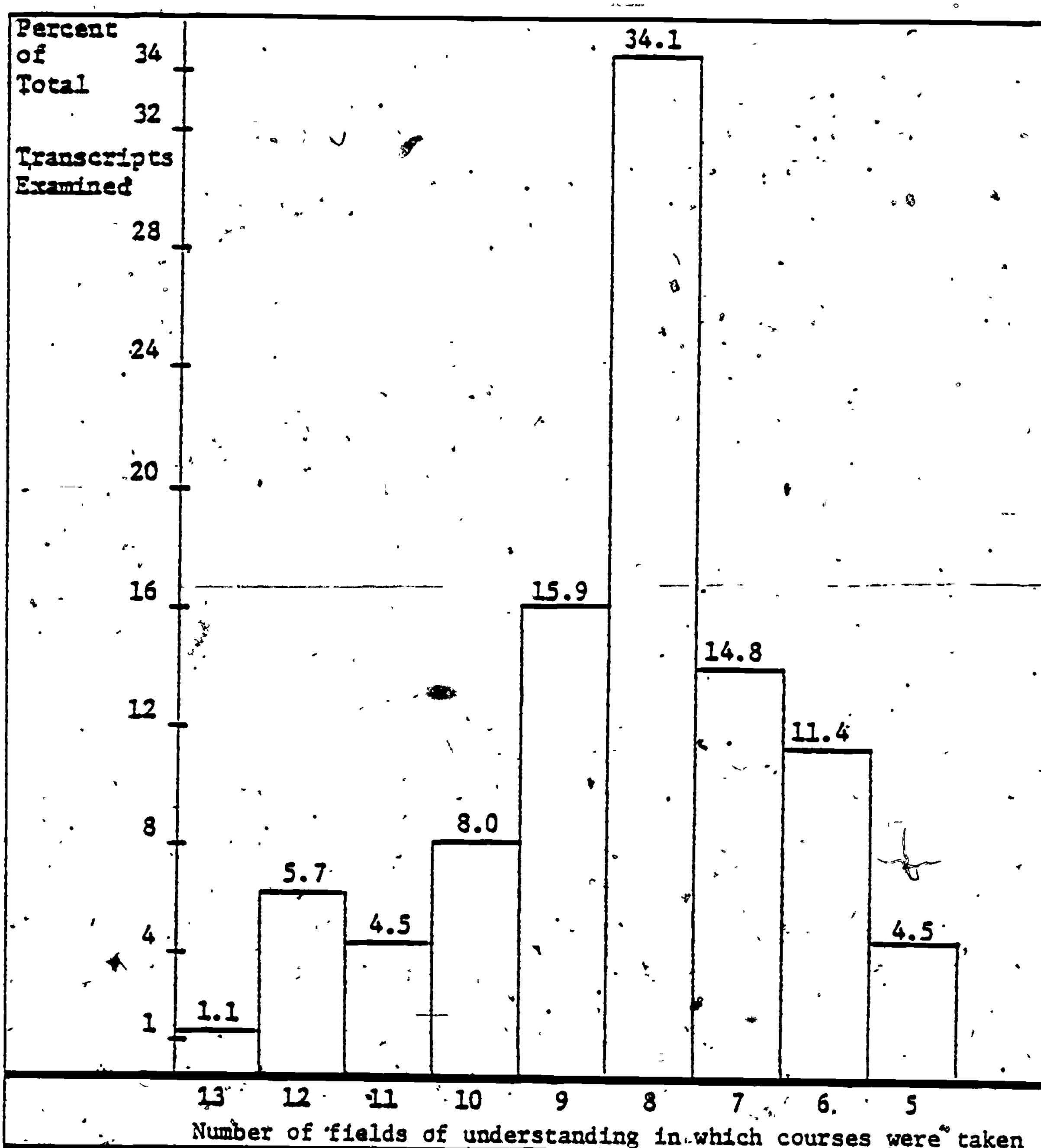
The emphasis placed on each "field of understanding" is summarized in Table 8. All numbers found in this chart are expressed as percentages. The number above each diagonal is the mean percentage indicating the average emphasis placed upon a "field." The number below each diagonal indicates the range. The first number is the lowest percentage of classes taken in the field; the second is the highest taken in the "field" for that group of transcripts. If the two numbers are the same, each student in that group had the same number of courses in that "field of understanding."

When this analysis was conducted, humanities and history were considered one field. Consequently, only thirteen fields are listed in Table 7. These "fields" were subsequently separated.

The bottom category, "interdisciplinary studies," refers to courses which integrated two or more "fields of understanding." If a student had taken a substantial number of these courses, his exposure to the "fields" may be broader than indicated by the figures corresponding to the thirteen "fields."

Unlike the other colleges and universities listed in this table, West Coast University has no engineering program accredited by ECPD in their 43rd Annual Report. Additionally, it has a fixed curriculum--all courses are required; there are no electives. Averages of all schools are shown both with and without the figures from West Coast. As can be seen, the results were not significantly changed when the transcripts from West Coast University were examined separately.

Those students receiving a bachelor of science degree from an ECPD-accredited education program took classes mainly in the physical sciences, engineering sciences and in design/application. On the average, 62 percent of their curricula was devoted to physical and engineering sciences, while design/application courses



CURRICULUM EVALUATION FROM DEGREES GRANTED
FREQUENCY DISTRIBUTION OF 89 TRANSCRIPTS EXAMINED

Fig. 4

	ECPD ACCREDITED											NOT ACCREDITED BY ECPD		ALL
	UC BERKELEY				CSULB	U. OF SANTA CLARA						WEST COAST		
	n=6	n=6	n=10	n=7	n=11	n=9	n=10	n=11		**	**	n=6	n=13	
	Mechanical	Electrical	Civil	Chemical	Mechanical	Mechanical	Electrical	Civil	Mean	Low Range Figure	High Range Figure			Composite Mean
Physical Science	35 / 30-40	43 / 31-62	37 / 30-51	51 / 41-70	27 / 24-34	28 / 24-37	30 / 27-36	25 / 20-28	34.5	20	62	55 / 51-59	55 / 46-65	38.6
Engineering Science	33 / 25-38	23 / 18-33	24 / 20-31	25 / 16-39	35 / 32-39	22 / 17-31	28 / 25-32	26 / 21-30	27.0	16	39	22 / 21-24	23 / 19-25	26.1
Design/Application	7 / 4-14	11 / 7-18	11 / 5-14	9 / 7-10	10 / 8-14	17 / 15-22	13 / 9-16	13 / 9-14	11.4	4	22	3 / 2-3	1** / 0-6	9.5
Engineering Technology	2 / 0-4	0 / 0-0	2 / 0-4	0 / 0-0	4 / 3-6	0 / 0-1	1 / 0-2	3 / 2-5	1.5	0	6	1 / 0-2	0 / 0-0	1.3
Ethics	0 / 0-0	0 / 0-0	.5 / .5-.5	0 / 0-0	1 / 1-3	0 / 0-0	0 / 0-0	0 / 0-0	.2	0	3	0 / 0-0	0 / 0-0	.1
Communication Arts	3 / 0-5	2 / 0-5	3 / 0-8	5 / 2-9	3 / 3-6	3 / 0-17	3 / 2-7	4 / 0-11	3.2	0	17	2 / 0-4	4 / 2-8	3.2
Management	0 / 0-3	1 / 0-5	11 / 0-12	1 / 0-3	1 / 0-4	3 / 2-4	3 / 0-9	2 / 0-7	2.8	0	12	0 / 0-0	0 / 0-0	2.2
Economics	3 / 0-10	6 / 0-10	1 / 0-5	2 / 0-3	1 / 1-3	3 / 2-4	3 / 0-9	4 / 0-7	2.9	0	10	3 / 3-3	3 / 0-4	2.9
Law	0 / 0-3	0 / 0-0	0 / 0-0	0 / 0-0	0 / 0-1	0 / 0-0	0 / 0-2	0 / 0-0	0	0	3	0 / 0-0	0 / 0-2	0
Political Science	1 / 0-3	2 / 0-5	2 / 0-3	1 / 0-5	1 / 1-3	0 / 0-0	0 / 0-2	0 / 0-0	.9	0	5	3 / 1-3	2 / 0-3	1.2
Behavioral Science	0 / 0-3	3 / 0-5	1 / 0-5	1 / 0-3	2 / 1-3	2 / 0-7	2 / 0-5	2 / 0-5	1.6	0	7	6 / 6-6	5 / 2-6	2.4
Life Sciences	3 / 0-9	2 / 0-10	0 / 0-2	2 / 0-6	1 / 0-1	0 / 0-0	1 / 0-7	0 / 0-5	1.1	0	10	0 / 0-0	0 / 0-4	.9
Humanities/History	7 / 3-12	4 / 0-10	7 / 2-11	5 / 3-12	7 / 7-8	14 / 9-24	13 / 9-20	11 / 9-14	8.5	0	24	3 / 3-4	3 / 0-8	7.4
Interdisciplinary Studies	5 / 0-9	2 / 0-7	5 / 0-10	1 / 0-3	2 / 1-4	4 / 0-7	1 / 0-2	4 / 2-9	3.0	0	10	2 / 0-3	2 / 0-3	2.8

TABLE 8

PERCENTAGE AND RANGE OF CURRICULA IN EACH PROGRAM DEVOTED TO EACH "FIELD OF UNDERSTANDING"

NOTE: All figures are percentages of the total curricula. Figures above the diagonal are averages; figures below the diagonal indicate the range.

averaged 11 percent of the curricula. The percentage of students who took a class in the other ten fields are summarized below:

Law	17%	Management	53%
Life Sciences	23%	Behavioral Science	67%
Ethics	27%	Communication Arts	82%
Political Science	39%	Economics	82%
Engineering Technology	44%	Design/Application	90%

A high percentage of students did not take a course in law, ethics, political science, engineering technology or management, although these classes were usually available.

c. Summary

Engineering education is faced with a dilemma. How can it best provide the basic principles of engineering and science, together with some exposure to the humanities, within a fixed period of time (that is established for reasons other than educational purpose) and yet prepare engineers for the "macro" nature of engineering practice in the field?

Results of this study indicated that, first, young engineers are given a strong basic foundation in mathematics, science, and engineering science. Second, although universities have many other courses available in the non-science/non-technical areas, statistically, engineering students do not take these courses. Third, engineering education presented in subject-form rather than project-form, provided little stimulus for the student to tie the various courses together in the manner that constitutes engineering practice in the field. Fourth, this study indicated that the hiring, promotion, and tenure processes tended to favor basic research rather than applied scientific endeavors and finally, many faculty members lack the industrial practice necessary to relate first-line experiences to their students as part of their regular course content.

Under these present circumstances, it is highly unlikely that engineering students will be exposed to fields such as law, life sciences, ethics, political science, and management. Yet, these fields can be paramount in the practice of engineering under the present social constraints of public policy. Every manufactured product must now be examined from a liability standpoint (law). Every civil engineering project must begin with the analysis of the effect of the project on the existing and projected natural life systems. The professional responsibility of an engineer to society with a hypersensitivity to the protection of health, safety, welfare, and good are concepts of a professional code of ethics, but few engineering students are either aware of such a code, nor sensitized as to professional responsibility. Finally, the integration of basic scientific information, materials, processes, manpower, resources, and finance into a project is keystone to engineering practice, and yet this field, "management," is rarely a part of the engineering student's educational experience.

Many learned individuals in the education element of the engineering profession state that there is an intended role-separation between engineering education and engineering practice, that primary responsibility of engineering education is to provide the basics in science, mathematics, and engineering science. Some also state that the university need not teach engineering technology at all. According to the scenario, technology becomes quickly outdated; however, the basics remain the same. The current assumption is that engineering technology and the nontechnical fields of engineering practice will be picked up through engineering experience and continuing education.

The following section presents an overview of the subject of continuing education as it relates to the overall engineering educational experience of engineers.

5. Graduate and Continuing Education

For the one hundred years prior to World War II, engineering developed through an evolutionary process. With a college background and with experience attained through engineering practice, an engineer was able to perform reasonably well for the duration of a normal career. From about 1870 on, advanced degrees were given, but only a small fraction of engineers was involved in graduate or continuing education up to the time of World War II. The revolutionary pace of development in the ensuing years gave rise to the concept of "the half-life of an engineering education" (about 10 years, perhaps less). Part-time master's degree programs were developed at almost all urban engineering schools, and hordes of engineers employed in advanced technological industry pursued advanced degrees in conjunction with their company employment (generally on a cooperative basis allowing about 24 hours of work per week) together with sufficient graduate study to yield the M.S. degree in two calendar years. (This is the formula of the Hughes Aircraft Company, the national leader in development of part-time graduate study for its employees.)

Graduate study, from about 1945-65, was frequently a means of bringing the engineering graduate (often several years out of school) up-to-date in his field. Then the concept of continuing education was conceived, and the Continuing Engineering Studies Division of the American Society for Engineering Education was established. A delineation of terms was essayed, which still provides the basic guidance of today:

> Graduate education upgrading requires academic admission, and takes place where and when graduate faculty see fit to teach, generally on campus and in daytime programs.
>
> Continuing education is updating, is open to all engineers desiring the information, and takes place where and when students can be gathered, commonly in off-campus centers and often in-plant. Teachers, as the best qualified to teach current and advanced practice, are frequently drawn from the ranks of industry and practicing professionals. Continuing education also includes diversifying, as when the civil engineer engaged in the electric power field learns more about the electrical and mechanical sides of the power industry, and broadening, as when the engineer gains management skills as well as cultural enrichment.

The engineer's needs for continuing education vary considerably during a normal career. It is often said that for the first ten years, he needs more technical information and problem-solving methods; for the next ten years, he needs leadership training, business economics, etc.; for the next ten years, he needs upper management skills dealing with labor unions, etc.; and for the next ten years, he wants more in-depth philosophy, literature, music and art.

While it is accepted that a formal college education is a basic prerequisite to the professional practice of engineering, by no means is there a concurrence on how continuing education is best acquired or how uniformly it is needed. For the engineer who plods along at the same job year after year, lacking aspiration to move up the ladder, there is no motivation for an aggressive formal program of continuing education. The engineer at the other end of the spectrum, the dynamic self-starter, continuously on the go and into new things, is always one step ahead of formal continuing education and is thought of as best making it available to others. For the great majority of engineers between these extremes, however, graduate and continuing education represent critical opportunities for personal advancement and renewal.

a. Graduate Education

Graduate education is more precisely documented and controlled than is continuing education. Annual publications of the Engineering Manpower Commission of the Engineering Joint Council and the ASEE provide statistical summaries of enrollments and degrees granted at all levels of engineering education, from engineering technology programs up to the Doctorate and Doctorate of Engineering. The national output of M.S. degrees in engineering is roughly one-half of the B.S. output. A large number of graduate students, as noted above, are sponsored by their employers on a part-time basis, with all fees and books covered, as well as cooperative time allowed to pursue the study. Employers have testified that this investment in education is good business when compared with the alternative of recruiting M.S. graduates at higher salaries, who are subject to conventional attrition losses.

Engineers working for smaller companies, and in locations distant from universities, have a more limited opportunity to pursue formal graduate study. It is sometimes stated that for a company in advanced technology to be successful, there must be the opportunity for engineering employees to pursue graduate study, even if totally on their own time and expense.

It is safe to say, however, that approximately half of today's engineering graduates will not be taking significant amounts of graduate study in their working careers. This proportion is of considerable impact in light of the extent to which the content of the undergraduate program has concentrated on fundamentals at the expense of specialized engineering subject material. No matter what the philosophy of the engineering education studies of the '50s and '60s, at least half of the B.S. engineering population is not taking material formerly included in the undergraduate curriculum.

b. Formal Continuing Education

Continuing education is offered by (a) university extension programs, in conjunction with recognized schools of engineering; (b) government and industry providing in-plant training programs for employees; (c) newly formed continuing education units of professional and technical societies, offered as membership services; and (d) entrepreneurial organizations. All except (b) of the above generally publicize their programs.

Some of the best continuing education programs for engineers are given without examination, grades, or other opportunity to evaluate the student's progress or comprehension. These are primarily the short courses, given in periods of from three to ten days. The fees are high, on the order of $100 per day, and it is generally considered that if a company sponsors that kind of expense, the student will find something useful in the course.

(1) The Continuing Education Unit

The Continuing Education Unit (CEU) is a device, now gaining wide acceptance, which will greatly enhance the opportunity of measuring the involvement of the American engineering community in continuing education. The CEU is given for ten hours of participation in an organized continuing education experience under responsible sponsorship, capable direction and qualified instruction. It is envisioned that there will eventually be one national data bank in which each engineer will have a CEU account. For whatever purpose, census, studies, or qualification for renewal of professional license, etc., it will be possible to know the continuing education involvement for any individual or group of individuals, for any period of time. With the growing antipathy toward release of personal record information, however, it may well be that the national data bank idea could serve no more than a personal purpose for the individual. In any event, industry regards the CEU skeptically as it does not inherently represent an evaluation of the individual's involvement in the program. As one training director has put it, "there is much less in the CEU than meets the eye."

(2) Continued Education Participation

Lacking information, the extent to which practicing engineers participate in continuing education can only be surmised. The American Society of Civil Engineers is currently undertaking a comprehensive study of its membership to determine the extent of participation in continuing education programs. Other organizations are conducting similar studies from time to time, but professional society membership represents only about one half of the United States engineering population and is not representative. In fact, some 0.6 million who call themselves engineers are not members of any engineering society, yet they comprise approximately half of the engineering population in the United States. It is almost certain that this same half has but scant engagement in continuing education programs, perhaps because continuing education is seldom a requirement for job retention or advancement. Furthermore, attempts to specify continuing education as a requirement for renewal of engineering registration have met strong opposition from the profession.

It is increasingly understood that advancement in engineering employment, especially in the public sector, does not relate to continuing or graduate education or other formal qualifications. Rather, it relates to demonstrated competence on the job which is even more difficult to evaluate than performance in a continuing education program. Perhaps in five to eight years, graduate and continuing education will again become critical factors for advancement and/or for continuance of employment in a competitive society. In private practice, where competition is a way of life, education now has that importance.

(3) Summary

Graduate and continuing education are reaching an estimated half of the engineering population. This same half are probably members of engineering societies and probably constitute more than half of the graduates with B.S. in engineering degrees. These engineers, also, are presumably in leadership positions.

The remaining half, a cadre of perhaps a half million or more engineers, are simply not participating formally in continuing or graduate education. Some may follow personal study programs in reading and literature but are in fact dependent upon their undergraduate engineering education to provide for their long-range job performance and professional development.

It is imperative, therefore, that this undergraduate education be designed to meet total career needs.

6. Interviews

Many of the elements which determine the overall quality of engineering education have been examined previously in this section. Throughout the study, students, faculty and employers of engineers were interviewed to obtain their impressions of engineering education and its relevance to their needs and the needs of society. The interviews were designed to examine curricula, tenure, course content, accreditation and continuing education. The opinions and observations gathered are presented in the following section.

a. Employers of Engineers

The manufacturing industry represents nearly 50 percent of the engineering job market, and its need for graduate engineers varies widely in terms of quantity, type, discipline, and the nature of assignment. What is industry's attitude toward engineering education? Does industry consider current engineering education adequate to meet its needs? Should engineering education be sensitive to the industrial need for engineering graduates to have broad flexibility to enter into any type of practice? What type of capability, orientation or understanding should graduates possess for immediate productivity to an employer? How important is the institution from which the engineer graduates, or the grade point average he has maintained during his education process?

An assessment of the position of industry on the issues of engineering education is complicated by the fact that the needs of industry vary not only from industry to industry, but also from time to time within a single company. Employee responses may also reflect a position different from formal company policy.

In Appendix G, the results of an industrial survey questionnaire are presented. An unstructured interview technique was used to permit freedom of discussion with industrial leaders and representatives of companies which produce a broad range of products. Data was also obtained from conference presentations on engineering education.

Representatives from four major high technology companies in the State of California (McDonald Douglas, Hughes Aircraft, Litton Industries, and Aerojet Liquid Rocket Company) were interviewed. McDonald Douglas is principally involved in the development of aircraft, both military and commercial. The division of Hughes Aircraft interviewed concentrates its efforts in the electronics field. Litton Industries is involved in commercial products, as well as systems for the federal government, and Aerojet Liquid Rocket Company is involved in a broad range of advanced technology systems ranging from space propulsion to isotope-powered artificial heart pump research.

The presentation of these findings should not be construed to represent a concensus of industry in general, although there was a high degree of agreement among the individuals interviewed on many of the issues.

(1) Industrial Considerations

The industrial environment and the demands of the competitive marketplace establish the needs of industry for certain elements in engineering education. Some of these elements were identified as follows:

(a) Since many engineering projects have far-reaching implications or even global consequences, companies need engineers who can deal with problems on a "macro" level.

(b) Since most engineering problems are multidisciplinary rather than unidisciplinary, future engineers will need to have a greater understanding and insight into more engineering disciplines.

(c) Industry needs engineers with well-rounded systems capability who can perform within a set of industrial and environmental constraints.

(d) Since the answer to many engineering problems involves the trade off of many parameters, engineers must be able to conceptualize and innovate under nonprecise problem conditions.

(e) Since industry undergoes constant change in response to technology and market requirements, engineers must have great adaptability.

(f) To have an appreciation for the problems of their employers, graduate engineers should understand business administration.

(g) High technology industry is particularly concerned with the technical half-life of the engineer.

(h) A graduate engineer should be exposed to all of the "fields of understanding" as part of his undergraduate program.

(2) Positive Points of Bachelor's Degree Education

(a) Newly trained engineers have well developed skills in the use of the digital computer.

(b) Industry has the general impression that new graduates are very bright.

(c) Graduates seem to have good mathematical analytical capability.

(3) Deficiencies in Bachelor's Degree Education

Based upon those industrial needs which they perceived, interviewees expressed concern as to deficiencies in the B.S. degree program:

(a) Graduate engineers are too subject oriented; the demands of industry require greater project orientation.

(b) Undergraduate programs place too much emphasis on basic principles, giving little attention to the application of these principles in the industrial environment under the constraints of the real marketplace.

(c) Frequently, the graduate engineer has been exposed to more mathematics than he will ever use in practice.

(d) Graduate engineers are deficient in the communication arts; they lack the training to apply reading and writing skills in the industrial work place.

(e) The educational process trains the engineer to solve problems with precise answers; actual practice deals with problems that are not precise.

(f) Current graduates are unable to identify alternative solutions to problems with varying constraints.

(g) Engineering faculty are compelled to pursue basic research in order to publish. More emphasis should be placed upon teaching with a practice orientation.

(h) Some industrialists feel that the ECPD requirements for the accreditation of engineering programs are too loose; that there should be an increase in required courses that focus on the practice of engineering in the real world.

(i) Present engineering education programs produce too many engineers who are narrow and unaware of the world around them.

(j) Computer orientation in engineering education has caused new engineers to lack interest in design.

Because of these deficiencies in engineering education, industry must put new graduates into analytical and support functions. It takes about two years in these positions before a new graduate is "aboard" and productive for the employer.

(4) Engineering Technology Degrees

The new degree in engineering, the Bachelor of Science in Engineering Technology, has created interest and concern throughout the engineering community. The degree was initiated by educational institutions to provide alternatives for the engineering student who was not oriented toward the strong mathematical and basic science approach required for the regular bachelor of science in engineering degree. As learned from interviews, industry apparently uses the engineering technology graduate as an engineer. Industrialists feel these graduates are more attuned to the "real-life" practice of engineering than is the basic science-oriented engineering graduate.

(5) Continuing Education

One of the companies whose management was interviewed has an extensive continuing education program conducted at the company facility. Primarily, it is technically oriented to meet the needs of employees in coping with the changing technology of their jobs in the electronics field. Courses in management development are also taught. The company's commitment to this program is extensive.

Other interviewees felt that continuing education was a personal responsibility of the employee, that a company does not have the responsibility for "upgrading" engineers. Nonetheless, most companies did provide some support and stimulus for their engineers to become involved in programs related to their job assignments.

As mentioned under "Deficiencies in Bachelor's Degree Education," one industry representative felt that engineering graduates probably have more mathematics than the majority of them will ever use. He suggested that it may be better to spend more time in the undergraduate program on engineering practice and allow the engineer to pick up the extra math (if needed) through continuing education.

(6) Industry Recommendations

The industrial representatives interviewed recommended a number of changes in the undergraduate degree program for engineers:

(a) Opportunities should be developed by universities and industry to permit representatives from industry to lecture to undergraduate engineering students as part of their formal programs.

(b) Educational institutions and the practicing profession should increase counseling efforts to better orient the student toward engineering practice.

(c) The federal government should use its financial influence to effect change in engineering curriculum toward practice orientation in the same manner that it used its influence to effect change toward basic science in the late 1950s.

(d) Engineering university faculty should be periodically required to spend time in industrial practice. This experience would provide a better understanding of the requirements of engineering practice which they could then transfer to students as part of regular course material.

(e) Engineering educational institutions should develop general courses to expose engineering students to some of the broader nontechnical concerns of engineering practice.

(f) Industry, educational institutions, and the State should develop a method to bring industry and the educational institutions together to resolve some of the problems and concerns industry has with engineering education.

(g) The undergraduate program should be increased to five years with a full year devoted to non-technical engineering subjects.

(h) The engineering profession should reevaluate the methods used to educate young engineers and train engineering professors.

(i) Some of the needs of industry in education can be incorporated into present courses, but educational institutions should develop a problem- or project-oriented undergraduate program.

(j) The practicing profession, through the engineering societies, needs to develop a system for "real-time" feedback from the industry to the educational institutions. Present methods are ineffective. Industry must also reexamine the way it is using engineers. Are engineers being overtrained for the demands that industry is making of them, or is industry underemploying the engineers?

(k) One industry representative felt that the need for change was so great that short of governmental mandate, public policymakers should bring more pressure on educational institutions.

(7) <u>Summary</u>

In general, industry felt that the engineering graduate should come prepared to practice under the constraints of the competitive marketplace; that he should have concern for a company's position in the market; and that changes in the educational programs were needed to better prepare the engineer for real life conditions. There was also the feeling that current methods, including the accrediting process, were not serving the needs of industry.

b. <u>Discussions with Recent Graduates</u>

Several recently graduated engineers who had been in engineering practice for from one to three years were interviewed to assess their feelings on the quality of education they received. They made the following general reflections, based upon the demands they felt industry made of them:

(1) More insight into engineering practice should be provided during basic engineering education. Some insight was obtained through involvement in intern programs working in research with faculty members. However, few engineering students had this opportunity.

(2) Awareness of the engineering job market should be increased.

(3) There should be greater opportunity to obtain the necessary communication skills.

(4) Class scheduling should allow for courses in sociology and psychology.

(5) The professors should be less subject oriented, though it was recognized that there was a limit to what could be done in the amount of time allowed for the B.S. degree program.

(6) The engineering graduate should at least be "exposed" to all of the "fields of understanding" in the undergraduate program.

(7) Courses in engineering design and engineering practice were very important as part of the B.S. degree program. Also, engineering technology should be an integral part of the undergraduate program. This was not the case in many schools.

(8) A college education should not only educate for a job, but should also prepare the individual for an understanding of life ahead..

Summary

Recently graduated engineers were dissatisfied with the lack of counseling and training for the "real life" situation they encountered and the lack of training for the practical application of their knowledge.

c. Discussions with Current Students

Course prerequisites, grade point averages and general interest in mathematics and physical science are a few of the factors that establish the profile of that group of high school students who enter postsecondary engineering education programs. Social and economic factors, summer or part-time employment, and extracurricular activities also affect the student profile and influence a student's choice of courses.

Interviews and discussions, arranged with faculty assistance, were held with engineering students at the campuses of UCD, UCLA, and CSUSLO. The participants were generally students who were active in campus activities and student chapters of engineering technical societies. In the opinion of faculty, many of the participants were outstanding students in their respective disciplines. Some nonengineering students also attended the discussions, which were as unstructured as possible to permit free expression.

(1) Comments on Faculty

Primarily, students criticized faculty for the lack of application and real life relevance of their courses. Two separate observations contributed to their concern: (1) the tendency toward specialization, and (2) the lack of practice orientation.

First, students commented that faculty frequently guided students toward highly specialized areas, which became more accentuated through the master's and doctorate programs. As specialization increased, job market opportunities decreased, along with a more limited demand for engineering services.

Second, students expressed concern for the lack of practice orientation in faculty presentations. Noting that the "practical experience" of many professors was limited to research, students commented that few were able to communicate the relationship of the theory taught in the classroom to the practicality of everyday engineering practice.

(2) Comments on Curricula

While students believed that engineers should be broadly educated, they noted that it would be impossible for an individual to be thoroughly knowledgeable in all "fields of understanding" involved in engineering projects. However, students did believe that exposure to all "fields" was desirable, and that additional knowledge in each could be developed later as required. One student commented that awareness was developed more by talking with people outside the classroom, and through outside reading and participation in extracurricular activities, than in the classroom.

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Many students believed that their engineering educations were too theoretical. They expressed a desire for an opportunity to take more design/application courses. They also believed that liberal arts courses failed to provide an understanding of the nontechnical aspects of engineering projects. They felt that the average engineering student was not developing proper communication skills, in spite of required liberal arts courses in these areas.

In general, both engineering and nonengineering students agreed that too few classes were designed for the nonmajor, and that existing classes were seldom adequate. Nonengineering students found "overview" classes to be useless; the content was usually similar to technical information found in the newspaper. The nonmajor could seldom relate the content of these classes to his field of interest.

(3) Comments on Community Colleges

Students who had transferred from Community College systems to four-year schools criticized the Community Colleges for failing to prepare them for the engineering programs they ultimately enrolled in. Many transferees were "shocked" by the amount of studying required to do well in four-year programs.

(4) Comments on Work Experience

Students recognized the value of work experience, but despite the availability of internship programs, meaningful summer employment with engineering firms was difficult to find.

(5) Relevance of Engineering Education to the Job Market

Engineering students generally felt that as graduates of engineering programs, they were "fit only for research on the campus." They felt that their lack of practical experience left them "unfit for the real world."

(6) Summary

Students' greatest concern was the lack of practical application of their engineering educations. They felt that courses were too subject oriented and would be better taught by faculty who could relate theoretical practice to actual practice.

Students also believed that engineering practice must be sensitive to the safety and environmental needs of society, and they questioned whether their educations were adequately equipping them to practice that belief.

Researchers have pointed out that the attitudes of the engineer change throughout his career. If engineering education were designed to meet the students' attitudes in later life, these same students would be critical of their educational experience. Interviews conducted with practicing engineers, recently (within five years) graduated from the same institutions as those in which the student interviews were conducted, expressed opinions quite similar to those expressed by the current students. This may be because the students interviewed were a very select group possessing a higher state of awareness than the average engineering student.

What is the best balance of basic principles and practical application in an engineering curriculum? What should be required in terms of nontechnical courses, and how much technology and laboratory exposure should the student receive? Can all of these concerns be molded into a four-year baccalaureate program within the budget constraints placed upon all engineering programs? Similar questions have been raised for many years. Student awareness of these issues accentuates the need for increased consideration of these matters.

d. Discussions with Faculty

In order to examine the importance of faculty attitude and orientation in determining the quality and content of engineering education programs, unstructured discussions with faculty members were conducted at several campuses. A summary of the candid comments is presented below, with the notation that many of the opinions expressed paralleled data on these subjects obtained from other sources.

(1) Relevance of Engineering Education to Engineering Practice

A majority of the interviewed faculty members felt that it was necessary for educational institutions and industry to share in the training of engineers. It was generally believed that to achieve a balance, engineering faculty should teach basic fundamentals and industry should teach technology. However, the latter was qualified in that some applications must be taught in formal engineering education programs.

Many individuals asked that if "engineers were not treated as professionals, why train them as such?" This statement stemmed from the belief that the professions are self-governing while engineers are not; that it is more important to prepare students to work within a corporate structure, something students are not presently prepared for.

Many educators also supported the belief that engineering curricula were more research-oriented than design-oriented; that too many specialized engineering subjects (for which there is little job demand) were being taught; and that a shortage of professors qualified to teach design of sophisticated engineering systems existed. In some advanced degree programs, the United States has trained engineers in specialities for which no job market exists, and therefore, has become a technology importer.

Some faculty members believed that to increase the relevancy of engineering education to engineering practice, programs should be taught using a "project" rather than "subject" orientation. Further, engineering departments could be organized along problem or project lines, rather than technical disciplines.

Another commonly expressed opinion was that, in general, engineering faculty were too basic-science-oriented, interested in doing obscure research for the purpose of publishing technical papers. In contrast, faculty should be encouraged to do more practical research, and educational institutions should find some method of attracting practicing engineers to the faculty. It was also suggested that replacement of the tenure system for engineering faculty with a five-year contract system would aid in obtaining a more representative faculty profile.

Since public policymakers place greater emphasis on the social, legal, safety, and environmental concerns of engineering practice, faculty were asked their opinion on whether these areas were properly reviewed in curriculum. Some members expressed concern that very little was presented in the engineering curriculum on these matters. One example of this is the toxicity problem in chemical engineering. Students are told, "don't sniff that," but are not sensitized to the problem of toxic effluent discharged into the atmosphere or water.

(2) Credit-Hour Requirements

According to the interviewed engineering faculty members, credit-hour requirements for a bachelor of science degree in engineering were reduced from the early 1950 requirements in response to university economic and administrative pressure. In turn, engineering administrators stated that there was a nationwide movement to reduce the requirements, partly in response to the "Goals Study" and partly because of competition for students between the schools of both engineering and science. Departments compressed content into a smaller number of credit hours and included additional humanities and social science classes in the curriculum for a four-year degree in engineering.

When the credit-hour requirements were reduced, the design- and application-oriented (technology) courses were also reduced. One faculty member commented, "When the 'crunch' comes, where do you assign your priorities? One must stick with the basics, providing students with a strong background so they can later assimilate the more applied material." He added that if engineering students were taught more technology instead of fundamentals, they would be obsolete in ten years.

Consequently, as a result of the credit-hour reduction, faculty members have primarily emphasized fundamentals, with only a limited number of design and applications courses. Individuals stated that if resources were available, they would increase the design component of engineering programs. Such increases would also require an increase in quarter units from 180 to 194 for a bachelor of science degree in engineering. Faculty members were not in agreement on this issue. Many supported retention of the 180 quarter-unit requirement and the encouragement of students to obtain a master's degree.

(3) Engineering Courses for the Nontechnical Students

Many interviewed engineering professors believed that engineering departments have done quite well by introducing humanities and social sciences into engineering curricula. They commented that they did not find a counterpart effort in other academic disciplines for nonengineering majors taking technical courses. They felt that engineering educators might "be falling down" by failing to teach more nonengineers something about engineering. Engineers often face "curious restraints," because people fail to keep what an engineer can reasonably be expected to do well in perspective. The opinion was that if more nonengineers, especially those who later became policymakers, were taught more technical concepts, engineers might be faced with fewer unreasonable constraints.

Engineering administrators noted that the teaching of nonengineers was made more difficult by budget constraints. They felt that care should be taken in providing resources to teach "service courses" which might not result in a stable workload. Given the present situation, engineering departments could be in the position of misallocating teaching resources if the interest in service courses declined.

(4) Relevance of Engineering Education to Engineering Registration

Faculty representatives disagreed considerably on the function of engineering registration. Some believed that graduates from accredited engineering programs should be automatically licensed, while others viewed registration as the perpetuation of "guildism" and saw no need for it at all.

Some faculty maintained that licensing instilled the engineer with a sense of responsibility to the public and increased pride in his profession. Others disagreed, and supported the position that the engineering product, rather than the process, should be licensed. Engineers, they felt, were rarely professional. They were usually salaried employees, "a captive group of corporate interests." It was felt that it was unreasonable to hold engineers liable for their work unless they were given more decision-making power in the corporate structure.

In general, faculty members believed that they were doing a satisfactory job of producing responsible engineers. At the base ~~of~~ this statement was the question of how responsible an engineer can be. As a rule, engineers do not make the decision to perform a mission; they only carry out the technical requirements to satisfy the mission.

(5) Summary

Results from previous studies correlate with the findings in this study in that the relevancy of engineering education to the total concept of engineering practice was the major issue. The basic concern was whether engineering education should prepare an individual for practice in the "real world," or should it be limited to basic instruction in a disciplinary field of applied science. In general, interviewed faculty members agreed on the need for greater coordination among the engineering community to adequately prepare engineering students to enter a diverse job market with the competence necessary to deal with technology and the impact it has on most aspects of modern life.

The "Professional Schools Concept" has been proposed as one technique for greater control of engineering education by the practicing profession. Under this concept, the school of engineering at any institution would be highly independent, similar to the schools of law and medicine. The proponents of this concept believe that such a system would be beneficial, since requirements could be established for faculty to have extensive experience in the practice of engineering. Critics of the system feel that it would be detrimental to the engineering profession; that there are certain advantages in belonging to the overall campus administration rather than fending alone for funding and facilities as a separate entity.

Since some degree of flexibility already exists in engineering programs, and since educational programs are accredited by a private organization that is heavily influenced by representatives from engineering education, changes in curricula may be long in coming. Significant changes are occurring in the composition of ECPD which are guiding accreditation toward placing more emphasis on relevance and practice orientation. It is likely that the accreditation process will be the principal forcing function for change. However, the general interest in sensitizing engineering education to engineering practice will require a concerted effort from every sector of the profession.

7. General Observations

An early philosophy of the purpose of higher education was to "seek out truth, document it, and put it on the shelf." History has recorded the conflict between those who would impose political direction and controls on institutions of higher learning and those who would preserve academic freedom. But today, many disciplines in higher education are devoted not only to intellectual enlightenment and truth, but also to the preparation of individuals to provide services to meet the needs of society as a whole. A significant portion of higher education is a combination of education and training, particularly in the professions.

Unlike the early history of higher education, a significant portion of postsecondary education currently receives financial assistance from public funds. Given this, does the public have a right to expect institutions to educate and train competent professionals? Is it the responsibility of educational programs to meet societal needs? How should this be done? Does relevancy mean anti-intellectualism? Is relevancy in conflict with academic freedom?

The "Goals Study" recommended that parallel options be developed in engineering curricula. One option would lead to a career in basic research (most likely to be conducted in an educational institution) and the second option would train the individual toward the practice of engineering in the free marketplace. There was no indication from the research conducted in this study that this recommendation has been strongly adopted in any of the engineering education programs reviewed. In most of the curricula reviewed, there was adequate flexibility for a student to obtain a degree and be exposed to most or all of the "fields of understanding." However, the review also showed that the majority of engineering graduates had not been exposed to many of the nontechnical parameters which have become paramount in the practice of engineering.

C. Engineering Registration

1. History of Registration of Engineers in California

The history of registration or licensure of professionals can be traced back to the days of Roger, King of Normandy, who in 1140 A.D. required that doctors be examined and certified by their peers. Some stories date the beginning of the registration of professionals at 3,000 years ago, when the Code of Laws of Hammurabi were practiced. In that time, if a house collapsed and the owner was killed, the builder was put to death; if the son of the owner was killed also, the builder's son would also be put to death. Historically, safety of the public has been the chief impetus for codes regulating the practice of professionals.

In the United States, the history of the registration of professional engineers dates from 1907 when the Wyoming Legislature enacted a law requiring registration of all engineers and land surveyors in the state, thereby becoming the first state to give legal recognition to the engineering profession. In 1923 and 1925, the California Legislature attempted to regulate the practice of professional engineering. Interest in licensing was the result of the advocation of a "model law" in 1911 by the American Society of Civil Engineers and later by the Council of State Boards of Engineering Examiners in 1920 (which subsequently became the National Council of Engineering Examiners [NCEE]). Then and now, the purpose of the "model law" was to promote and secure uniform engineering registration laws in the United States.

In both 1923 and 1925, legislation was introduced to the California Legislature to regulate the practice of professional engineering through a Professional Engineers' Registration Board. However, because of debate among the engineering factions in the State on the major provisions of such legislation, it was not enacted. In 1928, the collapse of the St. Francis Dam in Southern California, which killed 450 persons and caused property losses in the millions of dollars, united all factions behind the need for legislation to regulate the design, construction, and maintenance of all dams, with the exception of those owned by the federal government. During this same period, the California Engineers' Registration Association was formed to secure the enactment of a law requiring the registration of professional engineers. Consequently, California enacted its first engineering registration legislation, effective on August 14, 1929. It required the registration of all civil engineers, but excluded other engineering disciplines at their request.

The original act of 1929, known as the Civil Engineers Act, was "to safeguard life, health, and property." However, during the early years of the Act, most of the activity involved procedural matters. Many amendments were needed involving technical and operational procedures of the State Board of Registration for Civil Engineers created as part of the 1929 law. Also, the Board was forced to focus its primary attention on the controversy between structural engineers and architects over the professional overlap in the design of buildings.

In 1947, eighteen years after the enactment of the Civil Engineers Act, the California Legislature established a State Board of Registration for Civil and Professional Engineers in the Department of Professional and Vocational Standards.

The registration and certification of professional engineers was expanded to include chemical, electrical, mechanical, and petroleum engineering. However, the 1947 action only licensed the titles, not the practice, of the respective disciplines.

Since 1947, the Act has been amended 74 times, seventy since 1951 when the law was amended to create the Civil and Professional Engineers Act, which is the basis for the current law. Among the major legislative changes were the enactment of legislation in 1959 to include one public member on the Board, and a 1972 amendment adding negligence in practice to existing causes for reproval, suspension, or revocation of the certificate of a registered professional engineer. Other amendments to the Act over the years have dealt with: whether the names of retired or deceased partners of an engineering firm should be allowed to remain a part of the firm's name; registration procedures; filing fees; applicant qualifiactions; Board terms and membership; examination schedules; inclusion of engineering technical disciplines; Board name change; signers of plans, specifications, reports or documents; and the extent of Board powers. The major purpose of the current Act, like the 1929 law, is "for the protection of the public health and safety."

By 1976, there were three public member positions and eight professional engineers on the Board. In this year, the California Legislature enacted legislation to change the makeup of many licensing and regulation boards under the Department of Consumer Affairs (formerly the Department of Professional and Vocational Standards). This legislation was in response to criticism that many of the regulatory bodies were dominated by members of the professions they regulated. The new law placed public members in the majority on all but the ten boards regulating the healing arts and the Board of Accountancy. As of January 1, 1977, the Board of Registration for Professional Engineers had six public members, four engineers, and one land surveyor.

Prior to 1974, the California Legislature had to pass a new piece of legislation for each new technical discipline to be added to the engineering registration act. In 1974, the Legislature passed a law authorizing the Board to approve any further engineering disciplines as necessary for the "protection of the public health and safety." The Board thus gained the authority to recognize new disciplines and establish "grandfathering" periods for them. Since 1974, the Board has recognized nine of the seventeen technical disciplines in which engineers are currently being registered. The seventeen are: civil, mechanical, chemical, electrical, petroleum, structural, industrial, metallurgical, agricultural, quality, control system, fire protection, traffic, safety, corrosion, nuclear, and manufacturing. The Board approved two additional technical disciplines, aerospace and ceramic, but there have been no engineers licensed in these fields as a result of actions taken by the Department of Consumer Affairs. The Department did not approve budgetary adjustments to permit the grandfathering of engineers into these fields.

California's Registration Act is complicated by "title" and "practice" concepts found in the Act. In three fields of engineering, i.e., civil, electrical, and mechanical, individuals who are not exempt must be licensed to practice. Under "title" provisions in the California Act, the Board may identify additional titles of engineering for licensing. Registration in these areas merely allows individuals to use the registered engineer's title, "professional engineer."

The California Act exempts individuals in industry, public utilities, and the federal government. The majority of the practicing engineers in California are exempt from registration. It is estimated that there are some 210,000 technical engineers in California of which approximately 52,000 are registrants. The Board of Registration estimates that this number will increase to approximately 70,000 when all of the qualified applicants in the new categories have been grandfathered.

a. Summary

Registration of engineering practice in California originally was prompted by the disaster of the collapse of the St. Francis Dam. Civil engineers, those engineers who design such dams, became subject to mandatory registration. Since that time, other disasters in fields of engineering practice not covered by mandatory registration have occurred, but mandatory registration for the respective engineering disciplines has not been enacted. This history has placed the future of registration in California in a considerable dilemma. How does registration, as currently practiced, relate to the protection of the public? What segment of the public is protected by registration? Should all engineers be registered? Should only those working with structures and public works projects be registered? Should there be a different approach to registration for different types and areas of engineering practice?

Not only is registration under reevaluation in California, but also throughout the nation. Various state legislatures have passed "sunset laws," which automatically eliminate licensing boards unless they can prove that their continued existence is required to protect the public. These laws also require periodical reevaluation of any remaining boards.

The history of engineering registration in California shows that while the stated purpose of the initial and subsequent registration acts was for the protection of the public, much confusion exists as to how or if registration is serving that purpose. Those who support state registration of engineers will have to prove that licensure is more effective than any other approach in protecting the public. They will also have to show that the licensing process is not discriminatory, that it is not a restraint of trade, and that it is not perpetuating guildism. The recent history of registration of engineering practice in California shows a decided shift toward consumer control. Whether this shift will result in mandatory registration or the abolition of registration remains to be seen.

2. Critical Analysis of the Act

Chapter 7 of Division 3 of the Business and Professions Code of the State of California relates to the Professional Engineers Act, created for the protection of the public health and safety. Yet, if approximately 75 percent of the engineers engaged in engineering work in the State of California are exempt from registration under the Act as employees of industry, public utilities and the federal government, what is the impact of the Act in the areas of public health, welfare, and safety? Is the public being given full protection under the Act? The history of registration in California has revealed that aside from changes necessary to keep the law current, virtually at no time--until 1976--was the Act in any way amended to strengthen its primary purpose to protect the public. As the Act is currently written, how strongly does it guarantee the public health and safety?

The basic Act today consists of seven articles: Article 1, General Provisions; Article 2, Administration; Article 2.3, Professional Engineers Review Committees; Article 3, Application of Chapter; Article 4, Registration; Article 5, Disciplinary Proceedings; Article 6, Offenses Against the Chapter; and Article 7, Revenue. In the analysis of the Act presented in the following pages, the provisions of the Act were evaluated and categorized as they relate to the powers of the Board, public health and safety, education, discipline, and general administration of engineering licensing.

a. Powers of the Board

Prior to action in 1976 by the California Legislature, Section 6711 of the Act provided for the appointment, by the Governor, of three public members, seven members of various engineering technical disciplines, and one land surveyor to serve on the Board of Registration for Professional Engineers. Before the change in the law, nearly two-thirds of the Board members were from professions which the Board was empowered to license and monitor.

Section 6711, newly amended, states that four members of the Board shall be registered; one member shall be licensed under the Land Surveyors' Act; and six shall be public members who are not registered under this Act or licensed under the Land Surveyors' Act. The new law also requires that one of the public members of the Board shall be a person possessing expertise in one or more significant portions of the Board's regulated activities.

The requirement of 12 years' active experience for the nonpublic members of the Board remains the same as before, as does the age (30 years) and residency (five years in California immediately preceding appointment requirements).

In addition to public members having the majority vote, civil engineers will no longer dominate the engineering profession's representation on the Board. This changes a tradition of dominance dating back to the 1929 Act. Currently, three civil engineers are guaranteed positions on the Board. Under the new law, one civil engineer, one electrical engineer, one mechanical engineer, one structural engineer 14/, and one land surveyor will serve as Board members. Three additional public members of the Board will, as vacancies occur, replace two of the civil engineering members and the one chemical engineering member presently on the Board. As further vacancies occur, the Governor will appoint professional members so that the proper combination required by the new law is achieved.

In spite of strong consumer representation on the Board, decisions on engineering licensing, discipline, and accreditation could be heavily influenced by the four engineering members of future boards. To fulfill the mandate of the amending legislation, the public members must have the ability to best reflect the safety and health concerns of the public at large as applied to the fields of engineering and land surveying.

Ostensibly, there will have to be other changes in the Act as a result of placing public members in the majority on the Board. If changes are not made, certain exclusive decision-making powers may still reside with the engineers on the Board regardless of the public members' qualifications. Sections 6726 and 6726.2 do not permit public members to serve on committees to assist the Board in investigating claims of violations of any provision under the Act. Also, Section 6728 does not specifically prescribe the participation of public members on review committees, although the powers of review committees do not differ from the powers of the Board.

b. Engineering Registration and Educational Requirements

Grandfathering, a method of registration without examination, accounts for the greatest percentage of registered professional engineers in the State, nearly two-thirds of the licensed engineers.

The second greatest number of engineers are registered by examination which requires evidence of six years or more of experience in engineering work satisfactory to the Board. Other common ways of becoming registered as a professional engineer in California are through reciprocity, and individual examination. Further, by its own rules and regulations, the Board permits registration in a specialty established by it. By this method, which allows a period of time for interested engineers to meet the Code requirements, past work experience is considered but not necessarily education or tested competence.

Before 1968, there was little mention of formal academic training in the Act as a prerequisite to the practice of engineering, to obtain a license as a professional engineer, or to ensure that each engineering discipline approved for licensure had a corresponding curriculum in an institution of higher education. In 1968, the Governor signed a bill into law which amended Section 6700 to read:

> "The Board may not approve an engineering discipline which is not covered by curriculum leading to first degrees in engineering in an accredited university or college in the United States recognized on the effective date of the amendments made to this section at the 1968 Regular Session of the Legislature by the Engineers' Council for Professional Development."

This amendment was deleted in 1971 by the passage of another law. It is interesting to note that within two years, 1973-1975, eleven new disciplines were recognized by the Board, only three of which had a corresponding accredited educational program at an institution of higher education in California. Additionally, some engineering disciplines approved before 1968 lack any reference to education as a prerequisite for licensing as, for example, structural engineering. (Section 404, Title 16)

Institutional education, though not required by the Board to secure an engineering license, may satisfy four of the six years of the experience requirement for securing a license, as provided in Section 6751 of the Act. A 1971 measure amended Section 6753 of the Act to read that postgraduate work in the school of engineering or the teaching of engineering <u>may</u> (in place of previous wording, <u>shall</u>) be considered by the Board as engineering experience not in excess of one year.

c. <u>Disciplinary Provisions</u>

Section 6775 of the Act, which delineates those actions by a licensee subject to disciplinary action, applies most directly to ensuring public health and safety. Historically, it was not until 1972 that negligence in the practice of engineering was added to this section. Prior to this amendment, the personal morality of the licensee as a private citizen, rather than as a professional, was subject to disciplinary action.

In 1975, the Legislature deleted several provisions from the Act, particularly those in Section 6775, which permitted the Board to impose disciplinary action upon a professional engineer convicted of a crime involving moral turpitude. The amendment also deleted any reference to the moral character of the engineer, whether it be in reference to disciplinary action, as a prerequisite to issuance of a new certificate of registration, or as required for renewal of an expired license. The amendment clearly removed the authority to judge an engineer's private life, against his professional service and performance, from the jurisdiction of the Board.

Critics have argued that the Act may permit less than scrupulous engineers to be licensed under the sanction of the representatives of the people of the State of California. These critics maintain that good moral character is a pervasive trait, not confined to the hours following a day's work. Public health, safety and welfare depend not only on the quality of work done by an engineer, but also on the moral character of the business practices of an engineering firm. Price fixing, arbitrary charging of high costs, and collusion are all manifestations of bad faith or lack of good moral character which, under the present Act, can occur without any liability being assessed against the engineer for such activities.

According to this argument then, the elimination of "good moral character" may have inadvertently resulted in the public sanction of engineering activity which is contrary to the public's welfare. One faces the problem, as identified in Goldfarb v. Virginia Bar Association, where the State has condoned otherwise illicit business practices and bad faith stemming from the lack of a good moral character.

The following three questions are raised:

- Are the provisions of Section 6775 adequate to ensure public health and safety?

- Has the State sanctioned illicit business practices or other manifestations of bad faith or lack of good moral character contrary to the public's welfare and the laws applicable to private enterprise?

- Has the Board utilized Section 6775 in order to protect the public's interest or has there been a general reluctance among professional engineers, as in some other professions, to prosecute a fellow professional?

d. General Administration

Perhaps the most perplexing provisions of the Act are found in the changing descriptions of the general administrative duties the Board and its Executive Secretary must execute. Keeping in mind that the Board and its administrative staff are empowered to protect the public's health, safety, and welfare, the administrative duties appear to have little relationship to that primary duty.

Beginning with Section 6738(2) and continuing to Section 6379 through Section 6746, various exceptions to the licensing requirement are allotted to individuals working as engineers. As an example, Section 6738(2) permits nonlicensed individuals to prepare engineering plans, specifications and reports under the supervision of a licensed civil engineer. However, the Board has no means of investigating whether the licensed civil engineer has directly supervised nonlicensed individuals, who may or may not be engineers themselves, as required by this Section of the Act, or whether approval by a licensed civil engineer of a nonlicensed individual's work has been a cursory or careful procedure. This exemption, when first added to the Act in 1957, limited work by nonlicensed engineers or nonengineers to the preparation of plans for one/two level dwellings and farm/ranch buildings.

In 1959, this limitation was dropped, permitting non-licensed engineers to work on all engineering plans, specifications and reports.

Section 6795 delineates the license renewal procedures for professional engineers. However, it does not provide an explanation as to what type of review or standards are to be utilized in order to determine whether the safety practices and professional competency record of an engineer applying for licensure renewal satisfactorily warrants such renewal. The Section does empower the Board to establish the renewal qualifications for each discipline. However, it is not mandatory for the Board to do so, and as mentioned above, no general requirements, standards or qualifications are provided in the Act.

e. Public Health and Safety

Perhaps the least defined subject in the entire Act is the premise upon which the Act is based, protection of the public's health and safety. Carefully worded definitions of the various engineering disciplines, procedures for paying fees, and exemptions to the licensing requirement are set forth in the Act and in the Rules and Regulations of the Board, but there is little delineation of the meaning of public health and safety or the means by which the Board will ensure the purpose of the Act.

Historically, 74 amendments to the Act have been made since 1951, with only one having any direct reference to the public's health and safety. In contrast, at least three amendments to the Act have been passed through the years dealing with the right of continued use of a retired or deceased partner's name in a firm's name or in its professional advertising. At least five amendments have been passed since 1947 dealing with fees, but the majority of the amendments have been principally concerned with the membership and composition of the Board and with the coverage of additional engineering disciplines under the Act.

Section 6703.1, delineating the responsibilities of a licensed engineer in the supervision of the construction of engineering structures, excludes engineers from the responsibility of observing the construction process, site conditions, operations, equipment, personnel or the maintenance of a safe place to work or any safety in, on, or about the site of work. It is unclear why protection of public health and safety would exclude on-site engineering evaluation of the construction processes.

The only language in the Act which appears to associate the actions of the Board and the provisions of the Act for the public's health and safety is Section 6730. It states that in order to safeguard life, health, etc., a person intending to practice engineering shall submit evidence that he is qualified to practice the particular technical discipline he is seeking registration in.

Section 6751 establishes the general criteria upon which an applicant will be judged qualified to practice. However, these criteria, and the present make-up of the exam (as described in Section 6755), do not specifically account for knowledge of areas of public health and safety. What is lacking in this portion of the Act is a description of those areas of knowledge, other than those falling within strict engineering curriculum, upon which the individual should be evaluated and tested to ensure that he has not only expertise in engineering, but also has a broad awareness of the effects of his actions on the public's health, safety, welfare, and property.

The problem arising from inadequate definitions for public health and welfare are exemplified in Section 6793.3 of the Act. This Section delineates four criteria for reapplication for licensure. Only one mentions the public interest, ". . . or otherwise establishes to the satisfaction of the Board that, with due regard for the public interest, he is qualified to practice the branch of engineering in which he again seeks to be certified . . .." How the Board will make such a determination in the public's interest is left unexplained.

f. Summary

That the majority of practicing engineers in California are not registered, and that the majority of the registered engineers practice in areas exempt from the Act, severely limits the effect of the Professional Engineers Act. In addition, the impact the Act may have on the public health, safety, and welfare is hampered by provisions which dilute rather than strengthen the State's efforts to promote the public welfare.

The powers of the Board are virtually discretionary, as the Act provides it with no detailed standards or guidelines against which to regulate its activities.

The Act pays little attention to the role of formal education in providing not only engineering expertise, but also the sensitivity to ensure the public's well-being. Although experience may be more valuable than institutionalized education in developing the technical skills needed to practice in the profession, it has not been established that such experience also develops the necessary skills and sensitivities needed to promote the public health and safety.

Those who support registration for engineers point out that the Board rarely sits in judgment of malpractice events and this, they assert, demonstrates how effective licensure is, since registered engineers are rarely negligent in the practice of engineering. Critics of this line of thought point out that most registration applies to the fields of stationary structures and public works which are also controlled by various building codes.

Most importantly, the basic premise of the Act is poorly defined, with little or no explanation throughout the Act as to how the various provisions will promote the public health, welfare, and safety. Therefore, the basic effectiveness and necessity of the Act must be questioned. It is not clear how the Act plays a significant part in the protection of the public.

3. Examination Process

The intent of the Professional Engineers Act is to place the primary emphasis for qualification for engineering registration on the written examination process. However, this process is only the second most common way of becoming a registered professional engineer. Statistics show that "grandfathering" accounts for the greatest number of registered professional engineers in the State. (Grandfathering and other registration alternatives to the examination process are discussed in Section 4, following. Also see Appendix H, Grandfathering Procedure for Licensing.) Nevertheless, the examination process is the means by which 42 percent of the engineers presently registered in this State qualified and is the means by which future engineers will be registered following the expiration of the "grandfathering" period for current and future Board-approved technical disciplines.

The purpose of the examinations is to establish minimum qualifications for persons registering as professional engineers. How do the examinations relate to California engineering education programs? More importantly, how do the examinations relate to the "fields of understanding" developed earlier in this study? The previous chapter on engineering education examined the content of engineering curricula and the relationship of this content to the concerns which engineers must deal with in engineering practice. The question now is whether registration examinations test not only for competence in engineering, but also for sensitivity to the nontechnical parameters of engineering practice which relate to the public health, safety, and welfare.

The testing process consists of two separate examinations. The first, the engineer-in-training (EIT) exam, covers engineering fundamentals. Presently, the Board uses a national exam prepared and graded by the National Council of Engineering Examiners (NCEE). The second test, the registration exam, is also prepared by NCEE in most cases. This exam can be taken only after the applicant has passed the EIT exam and acquired six years of related experience in engineering practice. A bachelor of science degree from a Board-approved engineering or related science program satisfies four of the six years of engineering experience.

Information presented in this section was obtained first by identifying current trends in the Board's examination practices. This was followed by a review of professional engineering written examinations, prepared and administered by the Board between 1967 and 1974, to determine the extent to which the applicants were examined in both technical and nontechnical parameters of engineering practice ("fields of understanding"). Lengthy interviews with Board staff members were held to review certain aspects of the examination process to determine the background of the Board's use of national examinations; to develop information about the intent and the value of the EIT; and to obtain statistical data on the current status of engineering registration. In addition, correspondence with the Excecutive Director of NCEE provided information on the preparation and content of national exams.

a. National Exams

The EIT exam has been administered as a national exam since 1971. California began using the national exams for the registration test in the Fall of 1974. Essentially, the Board's policy is to use each NCEE exam unless it is felt that the content does not meet the "needs" of the State. For some disciplines that are presently examined under the California Act, there are no prepared NCEE exams. These include such categories as fire protection, corrosion, safety, control systems, and quality. NCEE does prepare exams in manufacturing, traffic, agricultural, and nuclear engineering. The land surveyors and the structural engineers' exams are presently prepared by the California Board.

The operational procedures of the Board and staff have been changed by the shift toward the use of national examinations in recent years. The Board has neither access to the grading procedures nor direct access to the preparation of the national exams. On an annual basis, the Board determines if national exams will be used, but prepares a State exam for each discipline for use if an NCEE exam is rejected.

The Board compiles engineering exams from questions prepared by Board and staff members, or by paid expert examiners. Staff members edit the questions, prepare the instructions, and oversee the typing and final preparation of the exam. The final draft of each exam, according to Board staff, is referred to the appropriate committee of the Board for approval prior to its possible use.

According to the Executive Director of NCEE:

> "National examinations are prepared by seeking question material from all available sources in the engineering profession, primarily from registered engineers (but not exclusively), from engineers in industry, private practice, government at all levels and, of course, engineers in education. The question material is reviewed carefully by our Uniform Examinations Committee, either rejected or accepted, and then put into the best possible form for use on examinations."

Board staff stated that since pass/fail percentages are higher on the national exams than on state exams, it statistically appears as though the Board now passes more applicants than it would with Board-prepared exams. For example, about 15 percent of examinees normally pass the California civil engineer's exam, but nationwide statistics show about 85 to 90 percent of the examinees passing. This has caused considerable debate among Board members as to the advisability of continuing with this NCEE exam; nevertheless, they have elected to continue its use. Several factors may account for the difference between the national statistics and the California findings. Any individual with the appropriate experience may take the California examinations to become licensed. However, in many other states served by NCEE, one must be a graduate from an ECPD-accredited engineering degree program to be accepted for examination. Many non-degreed engineers apply for California engineering registration for professional recognition, and the failure rate on the California exams could be a manifestation of the lack of academic preparation for the academically oriented exams.

In contrast to the EIT, the national professional exams are not all multiple choice. Grading of professional test problems is based on the applicant's approach to a problem. Partial credit is given for problems partially solved. Some critics feel that the standard grading system used by the NCEE and the granting of partial credit is much more lenient than the system formerly used by the California exam graders.

b. <u>Examination in "Fields of Understanding"</u>

Board-prepared exams in all disciplines dating from August, 1967, through November, 1974, were reviewed to determine the extent to which an applicant's knowledge was tested in various "fields of understanding." The exam files were fairly complete during this period, except that only four exams were available in the industrial engineer category. Prior to 1967, exam fields were not readily accessible.

Each exam problem was reviewed and a personal evaluation of the intent of each particular problem was made. The intent was categorized according to the relevant "field(s) of understanding."

(1) Physical Science
(2) Engineering Science
(3) Design/Application
(4) Engineering Technology
(5) Ethics
(6) Communication Arts
(7) Management Science
(8) Economics
(9) Law
(10) Political Science
(11) Behavioral Science
(12) Life Science
(13) Humanities
(14) History

The results of this analysis were subjective and to some extent dependent upon the knowledge of the person reviewing the problem. Additional guideline definitions within some "fields of understanding" were developed for objectivity and were useful in making differentiations among exam problems in the fields of science, economics and design. Following are these guideline definitions:

- Physical Science: Examination problems differentiated from engineering science, economics and design in that the problems are confined to the application of known cause-and-effect relationships and formulas which yield a predictable result.

- Engineering Science: The solving of well-defined problems and systems with the intent of determining magnitude of the function and closely approximating a known result. The use of assumptions is required to define certain unknowns within the system.

- Economics: Examination problems which are primarily intended to reflect an understanding of the application of economic evaluations; now primarily intended for the selection of an optimum system or an optimum answer.

- Design/Application: Examination problems requiring judgment and experience to develop the concepts of a proposed system to be applied in a particular situation. The end result is not necessarily a previously known solution. A degree of innovativeness is required.

No special differentiation was made between numeric and verbal-type problems (or essay-type solutions), since scoring on the exams was for specific content, not presentation. Problems were scored on the basis of the analysis of the problem and the approach to the answer; not on how the answer was written. However, where essay-type answers were required, the problem was considered to give exercise in category six, communication arts. This was particularly true in the metallurgical engineer exam, because it was required that the answer be presented in a logical format relying upon the use of verbal expression rather than numeric analysis only.

The review included over 1,500 problems for a total point-value of about 15,000 (averaging around 10 points per problem). The results are best expressed as a composite tabulation of the assigned problem-point values in each field of understanding for all of the exams within each discipline.

In the examinations for civil, electrical, and mechanical engineering, there were many more problem-points available than problems which the examinee was required to answer. The examinee could pick and choose roughly one-third of the problems, except in rare circumstances when a problem was required. Therefore, of 2,705 points for questions asked in nine exams in civil engineering, 900 points were required to pass--roughly one-third. Furthermore, in civil engineering, 60 percent of the problem-points available were in the engineering science "field of understanding," so it was possible for an applicant to pass the exam by correctly working problems only in the area of engineering science. (A passing score would be 70 percent of one-third of the total problem-points available.) A summary of results by discipline is presented statistically in Table 9. Figure 5 graphically presents the cumulative results for all disciplines.

The combined summary of all disciplines produced the following results:

Field of Understanding	Percentage of Total Examination Points Within "Field"
Engineering Science	67%
Design/Application	13
Physical Science	9
Economics	7
All other "fields" combined	4
	100%

The engineering science field predominated with 67 percent of all exam problem-points in this field. The next most highly tested category was the field of design/application with 13 percent of all problem-points; and third, the category of physical science contained nine percent of all problem-points. In other words, 89 percent of all problem-points are in the fields of pure science--physical science, engineering science and design/application. The fourth category, containing seven percent, was the field of economics, which in the exams was essentially engineering economics. The data indicate that the California-prepared exams had no question in engineering technology, humanities, or history.

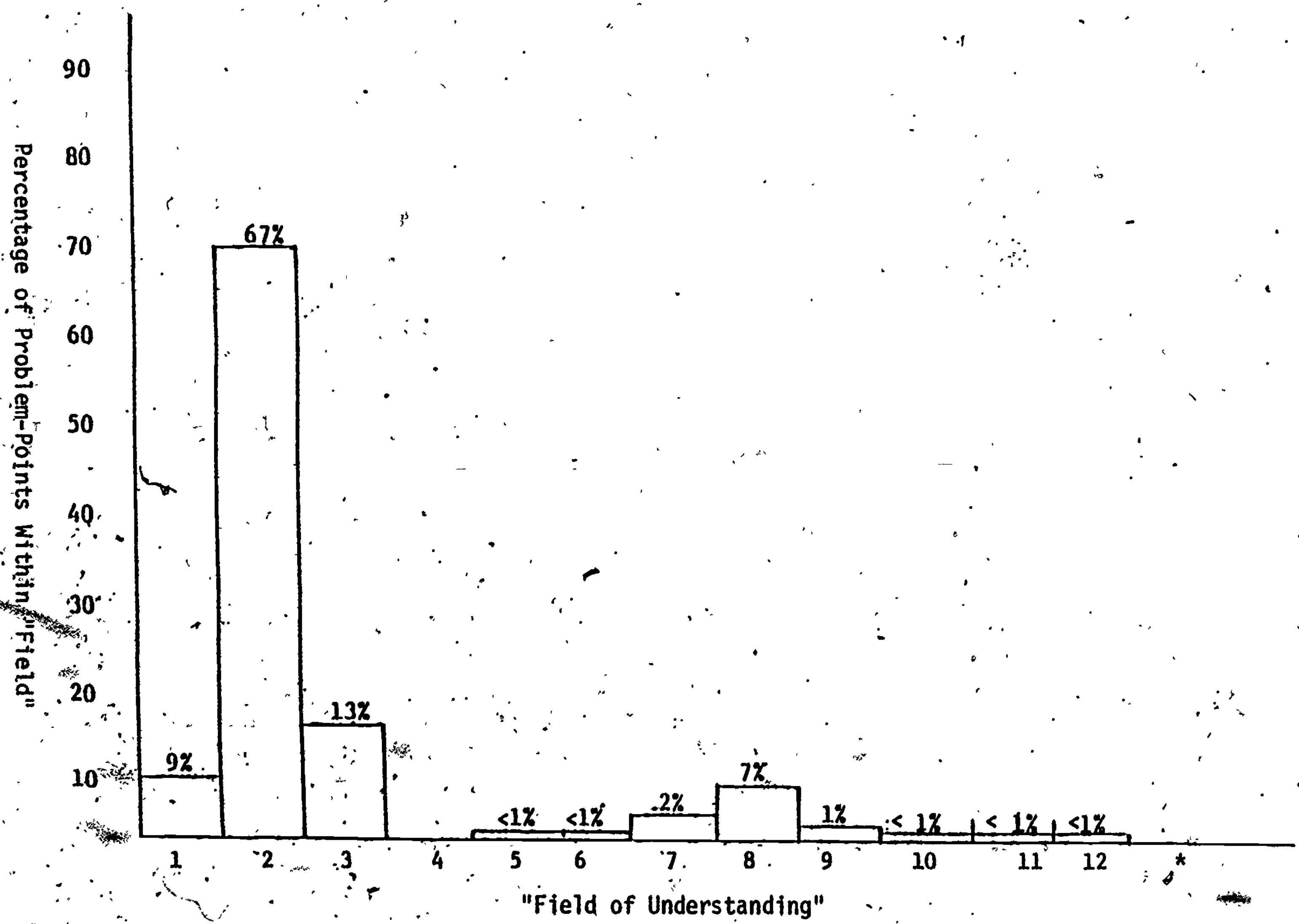
Exams within the discipline of industrial engineering exhibited the greatest diversity in terms of testing applicants in various "fields of understanding." This diversity was not significantly large, but it was greater than in other disciplines.

Discipline	Number of Exams Reviewed	"Field of Understanding" 1	2	3	4	5	6	7	8	9	10	11	12 *	Total Problem-Points Available	Problem-Points Required of Applicant
Civil	9	57.5 2%	1634.5 60%	702.0 26%		12.5 < 1%		50.0 2%	225.0 8%	17.5 < 1%	6.0 < 1%			2705	900
Electrical	10	280.0 11%	1685.0 65%	405.0 16%				20.0 1%	190.0 7%	20.0 1%				2600	1000
Chemical	7	390.0 31%	540.0 43%	190.0 15%				25.0 2%	85.0 7%	20.0 2%				1250	720
Industrial	4	279.0 31%	101.0 11%	80.0 9%				165.0 19%	145.0 16%	15.0 2%	10.0 < 1%	105.0 12%	5.0 < 1%	905	400
Metallurgical	9		2100.0 97%				75.0 3%							2175	900
Petroleum	8		753.0 84%	38.0 4%					101.0 11%	11.0 1%				903	803
Mechanical	9	380.0 9%	3082.5 71%	477.5 11%				40.0 1%	342.5 8%	45.0 1%				4367.5	900
TOTALS		138[illegible].5 9%	9896.0 67%	1892.5 13%		12.5 < 1%	75.0 < 3%	300.0 2%	1088.5 7%	128.5 1%	16.0 < 1%	105.0 < 12%	5.0 < 1%	14905.5	5623

TABLE 9

STATISTICAL SUMMARY OF EXAMINATION ANALYSIS
(California-Prepared Exams)

* The fields of Humanities (13) and History(14) were not included on any exams.



PERCENTAGE DISTRIBUTION OF EXAMINATION PROBLEM-POINTS WITHIN "FIELDS OF UNDERSTANDING"
SUMMARY OF ALL DISCIPLINES
(California-Prepared Exams)

Fig. 5

* The fields of Humanities (13) and History (14) were not included on any exams.

The staff of NCEE performed a similar analysis of "fields of understanding." The results are shown in Table 10. This analysis indicated which "field of understanding" was included to some extent in first, the fundamentals exam (FE), and second, the principles and practice of engineering exam (PP).

Virtually the only difference between the fundamentals exam and the principles and practice exam in "fields" tested was the addition of design/application to the principles and practice exam. As with the state-prepared exams, the "fields" receiving the most attention in the national exams were physical science, engineering science, design/application and economics. According to the NCEE staff reports, the national exams test competence in the "field" of engineering technology as well.

c. Summary

Except for certain special engineering disciplines for which no national examination is prepared, the Board of Registration has converted to the use of tests prepared by the National Council of Engineering Examiners (NCEE). This practice began with the EIT in 1971, and was extended to other engineering disciplines in 1974. The Board exercises some control over the quality of the exams (since it may elect to use a state-prepared exam in each discipline) if it is determined that the national exam does not meet the "needs" of the State. Thus far, a greater number of applicants have been granted professional licenses through the national examination process than have been granted licenses through the state-prepared examination process.

On both state-prepared and national exams, engineering science, physical science, design/application and economics have received the greatest emphasis. An applicant may pass both types of tests by solving problems only in the science-oriented fields. Most critics agree that exam problems classified in the engineering science category on state-prepared registration exams are quite similar in content and difficulty to those found in the EIT exam. For the most part then, the state-prepared exams reviewed in this study tested for only college-level knowledge and experience.

If the intent of the examination process is to require that the applicant demonstrate practical skill acquired through experience after college-level training, this goal is only minimally achieved. If one of the goals of the examination process is to require the applicant to

Fields of Understanding	Included in FE Exam	Included in PP Exam	Not Included In Either Exam
Physical Science	X	X	
Engineering Science	X	X	
Design/Application		X	
Engineering Technology	X	X	
Ethics			X
Communication Arts			X
Management Science			X
Economics	X	X	
Law			X
Political Science			X
Behavioral Science			X
Life Sciences			X
Humanities			X
History			X

TABLE 10

NCEE EXAMINATIONS CONTENT

demonstrate sensitivity to those matters which are involved in the public health and safety, the review of the exams did not indicate that this was being accomplished.

4. Grandfathering and Other Registration Alternatives

The written examination process is only one of four methods available to applicants seeking registration as professional engineers in the State of California. The other three methods are grandfathering, experience and reciprocity.

What relationship, if any, do these three alternatives have to engineering education? In what manner do they guarantee the public health, welfare, and safety?

An evaluation of grandfathering was made using statistics obtained through the staff of the Board of Registration. The total number of licenses issued from 1948 through 1975 in all disciplines was used in the evaluation. Statistics were not available on the number of persons granted licensure some 28 years ago who have since become professionally inactive. Detailed statistical evaluation of the status and origin of active licenses was beyond the scope of this study. However, it is believed that such detailed analysis would not produce results significantly different from those presented in the following pages.

Statistics were not available from the Board on the number of registrants who received licenses by means of experience through the interview process, or by the registration method of reciprocity.

a. Grandfathering

Grandfathering is the process of opening a new category of professional licensing to all those who can reasonably demonstrate to the Board, by evidence of nine years or more of qualifying experience, that they are entitled to use the title of the new discipline.

Prior to 1974, each new technical specialty registered by the Board required the passage of a separate piece of legislation to permit grandfathering. In 1974, the California Legislature enacted a measure granting the Board the power to approve new disciplines and establish related grandfathering periods for them. Consequently, groups wishing to establish a new technical discipline title for registration may petition the Board with their request. Should the Board deny the petition, these groups still have the right to present their petition to the

Legislature and request legislation on the particular discipline title.

After the Board was given the power to approve new disciplines (effective January 1, 1975), nine new categories were approved for registration: agriculture, control systems, corrosion, fire protection, manufacturing, nuclear, quality, safety, and traffic. The categories of aerospace and ceramic engineering were also approved by the Board, but the grandfathering period was not to begin until April, 1977, at the very earliest, because of budgetary restraints imposed by the Department of Consumer Affairs.

The primary criterion upon which the Board makes a determination to admit a new "title" discipline is whether or not that group is substantially covered within an area of existing licensing. For example, the Board refused to establish the discipline of air pollution engineering under the Act because it felt that this discipline was substantially a specialty, or subdiscipline, of civil or mechanical engineering.

Since it is a matter of accommodation in California not to legislate a person out of his occupation, the grandfathering process currently permits applicants in new disciplines a one- to three-year period in which to qualify. Appendix H is an information bulletin issued by the Board concerning registration as a professional engineer during the initial grandfathering period for a new category.

When a new technical discipline is approved by either the Legislature or the Board, interested persons file an application for registration, together with references and a work record. If the experience and references are found acceptable by those who review the application and by the Board, then the applicant is granted official recognition by the State as a registered professional engineer and may call himself by that title. This process differs from the examination process in that three additional years of qualifying experience are required, but an examination is not.

Prior to the recent admittance of the nine new specialty categories, the previously established disciplines were: civil, mechanical, electrical, industrial, chemical, structural, metallurgical, consulting, petroleum, and photogrammetric. (The statistics for land surveyors are also included in the following figures.) As of 1976, there were approximately 53,000 registrants in these disciplines. Of that total, approximately 22,000, or 42 percent, were qualified by examination; approximately 31,000, or 58 percent, were admitted by the grandfathering procedure.

The Board estimates that 19,600 applicants will be accepted for registration in the nine new disciplines currently in their grandfathering period before that period expires. If these estimates are realized, the number of grandfathered engineers in California will increase to approximately 69 percent of the total (using current figures).

Except for civil, mechanical, and electrical disciplines, which are practice acts, experience has shown that after the initial influx of grandfather applications, the interest in registration through the examination process is very small. For example, 1,500 applicants for metallurgical engineer were grandfathered in 1966. Over the next nine years, 1975, only 117 new licenses were added by examination (less than a one percent increase per year). In 1969, 3,700 applicants for industrial engineer were grandfathered. By 1975, only 167 new licenses were added by examination, also less than a one percent per year increase. Table 11 presents a summary of license activity experienced after the initial grandfathering period was closed. This same trend was identified in the State of Virginia and in the District of Columbia by Richard P. Hawkins, P.E., in an article appearing in the December, 1969, edition of the Consulting Engineer magazine. Hawkins wrote that once the first grandfathered group was admitted, ". . . little interest would be shown by anyone in that branch and the number of applicants usually would fall to zero and remain there."

b. Experience as a Registration Alternative

Under the rules and regulations of the Board, and at the discretion of the Board, individual examinations for registration can be performed either orally or by written examination, or in combination. Since most applicants seeking a license through regular examination attend a scheduled written examination in a group situation, the individual examination is considered a third and separate method of becoming registered. A passing score is a grade of 70 percent.

The examination applicant must meet one or more of the following requirements: (1) he must be 45 years of age, or older, as of the date of the application, a graduate of an approved engineering curriculum, and must submit satisfactory evidence to the Board that he has had 25

Discipline	Year "Grandfathered"	Number of Registrants Grandfathered 1968[1]	Number of Licenses Acquired Through Examination Process 1968	1969	1970	1971	1972	Total Registrants February 1976	Percentage Increase After 1st Year	Average Annual Increase
Civil	1947	5,555	--	--	--	--	--	19,799	356%	13%
Mechanical[4]	1948	10,576	241	127	261	163	383	13,336	26	1
Electrical[4]	1948	5,000	108	55	101	50	99	6,667	33	1
Industrial	1969-71	3,700	--	--	39	14	14	3,867	5	< 1
Chemical	1948	2,000	38	15	24	17	22	2,441	22	< 1
Petroleum	1948	800	8	4	3	6	2	885	11	< 1
Metallurgical	1966	1,500	10	4	6	6	11	1,617	8	< 1
Photogrammetrist[2]	--	102	--	--	--	--	--	102	0	0
Consulting[2]	--	129	--	--	--	--	--	129	0	0
Structural[3]	--	-0-	--	--	--	--	--	1,523	--	--
Land Surveyor[3]	--	-0-	--	--	--	--	--	1,967	--	--

1. Data for years prior to 1968 not available.
2. Category closed after initial "grandfathering."
3. Grandfathering was never granted--all registrations by exam or reciprocity.
4. Two exams given in even-numbered years--only one exam given in alternate years.

TABLE 11

CALIFORNIA LICENSE ACTIVITY AFTER INITIAL "GRANDFATHER" PERIOD
(By Discipline)

years or more of qualifying experience; or (2) he must be 50 years of age, or older, as of the date of the application, a graduate of an engineering curriculum with a bachelor of science degree or equivalent, and must submit satisfactory evidence to the Board that he has had 30 years or more of qualifying experience.

c. Reciprocity As a Registration Alternative

Individual examinations are also provided to applicants through reciprocity. This can be considered a fourth common means of becoming registered as an engineer.

The Board rules and regulations state that the applicant must hold valid registration as a professional engineer in another state in the same discipline in which he applies, and such registration or licensure must have been obtained by passing written examinations with comparable standards to the examinations required in California.

d. Summary

The granting of professional engineering licenses by the Board through grandfathering procedures requires that the applicants demonstrate nine years of "qualifying experience," four years of which may be met by a degree from an accredited engineering program. There is no requirement for the applicant to successfully pass a qualifying examination, such as the EIT or professional examination, as proof of minimum competence.

With the exception of the long-established "practice act" disciplines of civil, mechanical, and electrical engineering, there has been little growth in the number of specialty licenses issued by examination after an initial large number have been licensed without examination during the grandfathering period. Annual growth rates in some disciplines have been less than one percent.

Individual examination and reciprocity methods of registration are insignificant in number compared with those engineers registered through the scheduled written examinations and grandfathering methods.

5. General Observations

It is difficult to determine just what effect the entire registration procedure has on the health, welfare, and safety of California citizens. Only three engineering disciplines (civil, mechanical, and electrical) are covered under practice registration. All other disciplines recognized under the Act are registration of title only. In addition, in the fields of electrical and mechanical engineering (two of the three practice disciplines), and in virtually all of the discipline title areas, the majority of engineers practice in organizations that are exempt from the Act.

The differentiation between the licensed practice and the licensed title, the existence of the exemptions, and the lack of specific enforceable requirements in the Act are all aspects which raise many questions as to the purpose of the registration process. One clearly recognized benefit is that those persons who desire registration usually conduct a self-analysis and review engineering principles in preparation for examination. Some proponents of registration also maintain that there is a psychological change that occurs when an engineer becomes registered; that registration causes the engineer to become more aware of his responsibilities to society. However, these factors are subjective and intangible.

One matter which should be investigated is the requirement for future engineering curriculum development in California to satisfy the education requirements of many of the newly approved disciplinary titles for which there are currently no existing ECPD approved curricula in the California educational system. Presently, the Board accepts graduation from accredited programs in other disciplines.

The only justification for State registration is to ensure the protection of the public. For engineering registration to be effective in this area, the Act must become an enforceable piece of legislation, perhaps limiting the practice of engineering to those who have been registered by the State, regardless of area of practice. The other alternative would be to follow the "sunset" law as adopted by some states and automatically eliminate registration in engineering and in any other field where the Board cannot demonstrate that the process is necessary to protect the public.

D. Forum on Engineering Education and Registration

As reflected in the discussions in Appendix A, the needs and wants of society dictate the purpose for and direction of engineering projects. Decisions made in such projects involve tradeoffs between many technical and nontechnical considerations inherent in providing technology for public use. In order to assure the protection of the public to some degree, the State of California registers engineers in one or more of nineteen different technical disciplines. The relationship between this State registration and engineering education is discussed in the body of this report, but in summary, for an accredited degree in engineering, the State grants experience equivalence toward the six years' engineering experience required to become registered as a professional engineer.

Given the above, what is the degree of coordination in California between engineering education and engineering registration? Given the above degree of coordination, does the licensure of engineers effectively safeguard public health, welfare, safety, and good? These questions are of current concern to policy makers not only in California, but throughout the nation.

On July 26, 1976, Senator Albert S. Rodda, Chairman of the Senate Committee on Education of the California State Legislature, conducted a forum which focused on a piece of draft legislation (preprint Senate Bill 17, analysis following) that completely revised the Engineering Registration Act in California. (A copy of the draft legislation can be found in Appendix I.) The issues discussed included the following:

- The "parameters" involved in the practice of engineering;
- The breadth of engineering practice;
- The relationship of engineering practice to the adequacy of engineering education (given existing needs);
- The nature and effectiveness of accreditation of engineering education programs;
- The need for and extent of engineering registration in California;
- The adequacy of the current engineering registration act;
- The justification for federal government, public utility, and industrial exemptions;
- The adequacy of education related registration requirements;
- The adequacy of disciplinary licensing and "grandfathering";
- The question of whether an engineer "attempting to be ethical" should be protected by the State;
- The inclusion of a code of ethics in the registration act;
- The question of whether the Board of Registration should even make an attempt to enforce a code of ethics; and
- The question of whether the prospective benefits of the proposed changes would outweigh the potential detriments.

1. Forum Planning

During the initial forum planning period, the following representative groups, concerned with engineering education and registration, were invited to share their thoughts on these issues:

- Engineering technical societies
- National Council of Engineering Examiners
- American Society for Engineering Education
- Industry
- Engineers' Council for Professional Development
- Board of Registration for Professional Engineers
- California Department of Consumer Affairs
- Conservation groups
- Futurists
- Recent engineering graduates, and
- Legislative staff

To promote extensive, candid discussion and to facilitate and stimulate a high quality of exchange of ideas among representatives of these groups, an informal legislative hearing, or forum, was held. Its purpose was to promote basic position presentations rather than philosophical hypotheses.

To further stimulate interest, two rather extreme approaches to engineering registration were reviewed. One was to eliminate State registration of engineers altogether; the other was to require that all engineers in responsible charge be registered. Since most engineers are already exempt from the registration act, and since the only justification for State registration of engineers is the protection of the general public, it was decided that the second approach would be more effective. Consequently, preprint Senate Bill No. 17, dated July 14, 1976, was drafted. The preprint was a culmination of some of the most current thinking on State registration of engineers, including proposals by the National Council of Engineering Examiners, the National Society for Professional Engineers and the Board of Registration for Professional Engineers. It addressed engineering education, licensing requirements, examination processes, ethics and many other matters, all of which are examined in this study. (See Appendix I.)

A preprint bill is a technique used in the California Legislature to obtain reactions from the public and special-interest groups on legislative proposals, without the introduction of a formal piece of legislation. The preparation of a preprint follows the same process as formal legislation. The draft is then approved by the Legislative Counsel's office and is printed in standard legislation form. However, a preprint is not entered into the system nor scheduled for formal committee hearings.

2. Modification of the California Engineering Registration Act

Preprint Senate Bill 17 was drafted to amend Chapter 7 of the Business and Professions Code, concerning "professional engineers." The preprint completely reorganized the chapter; deleted technical disciplinary titles and references; required the registration of all practicing engineers "in responsible charge"; reorganized the standing committees of the Board of Registration; added an advisory committee to the Board; added a code of ethics to the chapter; and defined the technical and nontechnical considerations of engineering practice.

a. Purpose of the Act

The only justification for registration of engineers is to provide protection for the public. While it is intended that the Registration Act provide for the safeguarding of life, health, property, and public welfare, the preprint would also safeguard the "public good."

Historically, the intention of the Act was to protect the public from bodily harm or from harm to public or private property. The addition of "public good" extended the purpose and function of the Registration Act to cover the protection of public resources and encourage the proper fiscal management of engineering projects (especially those involving public funds).

b. Definitions

The preprint definition of "engineering practice" was developed by the National Council of Engineering Examiners in the document, "Model Law." This definition expanded the range of engineering work covered by the Act, and eliminated all references to the various technical disciplines of engineering.

The current California Registration Act requires licensure by technical discipline. At this time, there are nineteen different licensed technical disciplines. This has caused extensive public confusion, and has created difficulties in determining where the separation between some disciplines exists. Many disciplines have overlapping duties, and many newly recognized disciplines, such as nuclear engineering, embody several of the other technical disciplines. California, as one of the few states in the nation that licenses by technical discipline, would be brought closer to the national norm by the elimination of licensure by discipline as proposed in the preprint.

The Rodda preprint also redefined "responsible charge." This term is one of the most important elements in engineering licensure. It establishes that portion of engineering practice directly regulated by the Act. The remaining engineering activities are considered subprofessional and are not included in the licensed practice of engineering. The incorporated definition of "responsible charge" in preprint SB 17 states: "An engineer is in responsible charge of work when he determines technical questions of design, development, application, certification, and construction, or when he personally supervises engineering work." This definition is consistent with those supported by NCEE and the National Society of Professional Engineers.

Preprint SB 17 possesses a section which enumerates the technical and nontechnical parameters that are generally involved in the practice of engineering. The section states that life, health, property, public welfare, and public good are dependent upon the engineer's knowledge of these parameters. The inclusion of these parameters in the Act would provide the Board with guidelines for the formulation and evaluation of exams and curricula in relation to equivalency of experience. In contrast, the present California Act is primarily concerned with the technical aspects of practice, even though engineering practice has both technical and nontechnical elements.

c. Administration of the Act

Board work, under the current Act, is divided among numerous standing committees, each representing a recognized engineering technical discipline. The elimination of disciplinary licensing and the addition of new Board responsibilities under the preprint would require the reorganization of the Board. The reorganized Board would include four standing committees: the engineer-in-training committee, the registration exam committee, the education qualifications committee, and the ethics committee.

d. Education

Under the existing Act, the Board must approve curriculum qualifying the applicant for experience credit towards the six-year experience requirement. As stated in its Rules and Regulations contained in the California Administrative Code, the Board approves all four-year ECPD-accredited engineering education programs as qualifying curriculum and grants four years' experience credit to an applicant with a Bachelor of Science degree from such a program. Currently, the Board does not review the ECPD requirements in light of engineering practice requirements in California. The preprint would require the Board, as a minimum, to review ECPD accreditation requirements. As previously stated, the practice of professional engineering has become extremely complex--a combination of technical and nontechnical parameters. A review of engineering curricula approved by ECPD indicated that Bachelor of Science degree programs are heavily oriented toward basic and applied sciences, with little or no attention given to some of the principal "parameters" present in professional engineering practice. However, the practicing engineer who becomes licensed must have some level of understanding of these parameters in order to properly protect the public health, welfare, safety, and good. If engineering educational programs include these parameters, then the understanding derived should satisfy the experience requirement year for year. If the educational program does not do so, then partial or no experience equivalency would be granted. The Board would be required to make this determination under the revised Act. In addition, graduation from a Board-approved curriculum would satisfy the first exam, EIT, requirement.

e. Rules of Conduct

Rules of ethical conduct were included in the preprint. This inclusion was in accord with the recommendation by Ad Hoc Committee on Professional Development of the Board of Registration. The rules incorporated into the revised Act included provisions from codes of ethics adopted by major engineering societies.

A nondiscrimination clause, developed by Congressman John E. Moss, California, was included within the Rules of Conduct to protect engineering employees from discriminatory action or reprisals from their employers as a result of exercising their professional responsibilities under state law. Since over 85 percent of all practicing engineers are employees of others, and since the preprint would include all engineers in "responsible charge" regardless of their place of employment and technical discipline, the exercising of responsibilities by an engineer in light of the Rules of Conduct could create conflicts between an engineer-employee and the employer, which could result in termination or other reprisals. If the Act required an engineer to exercise his professional responsibility under state law, then the law would need to provide protection for the employee from reprisals. Without this protection, the enforcement of the Code would be completely ineffective.

Rules of conduct have been incorporated into registration acts in some other states. Because they have dual purposes, i.e., protection of the profession and protection of the public, the need for such rules of conduct in any practicing profession has been acknowledged both by the professions and by the public.

The incorporation of Rules of Conduct (code of ethics) into the proposed Act would standardize a code for all engineering practice and create a basis for enforced compliance. Under current engineering practice, there is no mechanism to stimulate compliance other than threat of expulsion from a technical or professional engineering society requiring compliance with its code of ethics as a condition of membership. An alternative to incorporating rules of conduct into the Act would be for the Act to specify that the Board will establish and enforce rules of professional conduct under Board rule.

f. Registration

Preprint SB 17 would eliminate "grandfathering" and "eminence" as methods of obtaining registration. In addition, the EIT exam would be waived for applicants with a bachelor of science degree from a Board-approved curriculum.

Currently, the Board may establish a grandfathering period for every new technical discipline approved by it. This eliminates examination requirements and bases registration strictly on at least nine years of acquired experience. With the elimination of technical disciplinary licensing, the need for grandfathering would also be eliminated. The same philosophy would apply to registration by eminence. Provisions may have to be made for a transition period, since as previously stated, the revised Act would require all engineers "in responsible charge" to be registered, and under California common law, a person cannot be legislated out of his job--a job that he has been satisfactorily accomplishing for a specified period of time prior to the passage of the law.

g. Examination Content

As proposed in the NCEE's Model Law (see Appendix F), the registration exam outlined in the preprint would consist of two eight-hour sections. Section I would test for proficiency in areas of engineering science and design. Section II would test, in an essay form, the ability to apply both technical and nontechnical knowledge as they would relate to characteristic engineering projects. Thus, the examination requirements in the revised Act would be more specific than those which exist under the current Act. The applicant would be permitted to demonstrate his ability to apply knowledge and experience and assume "responsible charge."

h. Exemptions

The revised Act would eliminate nearly all exemptions and specify that all engineers in "responsible charge" be registered. Under the current Act, industry, utilities, and the federal government are exempt. Consequently, the majority of engineering practice is exempted. The NCEE and NSPE have recommended that to protect the public there should be no exemptions in State licensing of engineers.

The general philosophy for licensure has been for a state to provide some minimum standards of competence that a practitioner must pass in order to offer services to the public. In the case of engineering practice, who is the public? What part of the public deals directly with an engineer? What part of the public lacks the ability to determine competence without state intervention and protection?

Only a very small percentage of engineering (some experts say as little as five percent in terms of dollar value) is offered to that segment of the public who lacks the ability to determine competence. However, the protection of the public is required regardless of the ability of the procurer to determine competence. Thus, engineers working for government agencies in certain areas of public works are required to be licensed, even though the governmental agency may have the ability and resources to determine competence.

Others believe that the legal liability of the person, agency, firm, company, etc., should determine the need for licensure to protect the public. If an engineer offered professional services directly to a consumer, then he should be licensed and also carry the liability for the professional practice. If the engineering service were offered through another legal entity, such as a partnership, corporation, governmental agency, etc., then the engineer, as an employee, would be protected by the liability of the other entity.

However, there are numerous anomalies in the application of the Act. One corporation offering mechanical engineering services for the air conditioning of an office building must use registered mechanical engineers. However, the same corporation offering the same services to a public utility for an office building is not required to use registered engineers.

Since the application of the current Act affects only a very small segment of engineering practice, and since the application is confused by other considerations, it is very difficult to enforce. The principal type of violations of the Act which are brought before the Board involve licensed engineers with a complaint against a nonlicensed engineer who is providing services. It is extremely rare for the Board to consider cases of incompetence.

The elimination of exemptions under the preprint would create major considerations for those entities currently exempt. The question to be answered is can the public health, welfare, safety, and good be protected through liability and retribution (restitution) through court action, or should the process of engineering be the responsibility of individuals who have demonstrated minimum competence and are "exposed" to the loss of their ability to practice if incompetence is demonstrated? Which method best serves the public need? The preprint bill would provide for both methods by requiring that all engineers in "responsible charge" be registered. This would establish minimum standards of competence and still permit an injured party to litigate cases of injury.

i. Advisory Committee

The preprint would establish an advisory committee, consisting of numerous members of the engineering community, to serve as a mechanism for continual evaluation of profesional education in those areas where practicing engineers are licensed by the State. Basically, the advisory committee would have four functions: (1) to provide for the exchange of views among those concerned with the practice and education of the engineering profession; (2) to identify the major needs and concerns of the people of California as they relate to the engineering profession; (3) to examine education programs and licensing requirements in light of such concerns; and (4) to make recommendations to the Board based upon the advisory committee's examination of educational programs and licensing requirements.

3. Summary of Written Reviews of SB 17 Preprint

The revised Act, Preprint Senate Bill No. 17 (see Appendix I), was a compilation of the current thinking of individuals and groups on various aspects of engineering registration. It was not a formal piece of legislation, but it received the same research, analysis, and legal drafting as a formal piece of legislation would receive. Reactions to this draft bill are reported in the remaining sections of this chapter.

a. Engineering Education

In an initial review of the preprint draft, responses to the following questions were solicited from members and representatives of the previously identified groups:

- Do you agree that engineers in "responsible charge" (see Section 6706 of the preprint draft) should have knowledge of the "parameters" listed in Section 6709 of the draft?

- Do California engineering education programs adequately prepare persons to develop and utilize technology needed by society?

- Should the State Board of Registration for Professional Engineers become more actively involved in engineering education accreditation?

Responses to these questions are summarized in the following section. (All but representatives of conservation groups participated.)

b. Breadth of Engineering Education

What should be the content of a Bachelor of Science in Engineering program? Members of the engineering profession have provided many different answers to this question and will continue to do so in the future. Although the details of the answers vary, the engineering profession generally agreed with the philosophy that engineering students need a strong foundation in basic physical and engineering science fundamentals, with some exposure to design, and social and behavioral sciences. However, how the tradeoffs are resolved in a four-year Bachelor of Science in Engineering program is subject to much debate.

Most of those responding to the questions on the preprint draft believed that, in theory, it was desirable for an engineer to be well-rounded, having at least some exposure to each "field of understanding." Concern was expressed, though, that the inclusion of the "fields of understanding" in the registration law might be interpreted to mean that all engineers in "responsible charge" would have to be experts in each field of understanding. Others were concerned that a requirement that all engineers in "responsible charge" be knowledgeable in each "field of understanding" might substantially reduce the number of engineers eligible for positions in "responsible charge." Most persons agreed, however, that an engineer should have enough exposure to the fields to be aware of the need to ask for the help of a specialist.

The following excerpts, typical of the many received, reflect a general agreement that engineers should have a knowledge of, or at least an awareness of, the "parameters" listed in Section 6709 of the draft legislation. For brevity, only a few are presented here:

> Yes. (Clorox Corporation, ASME, Dean of Engineering, California, etc.)
>
> "Engineers in 'responsible charge' should have knowledge of those 'parameters,' and more." (ASME)
>
> "Engineers in 'responsible charge' should have a knowledge of the 'parameters' listed in Section 6709. While engineers' technical skills are integral to safeguarding life, health, property, public welfare, and public good, good engineering design must accommodate the total environment described by social, biological, economic, and political systems." (Dean of Engineering, the University of Santa Clara)

Several respondents noted that an engineer should not be expected to have a detailed knowledge of each of the "parameters" listed in Section 6709. It was also feared that the addition of more "nonengineering" course requirements would substantially reduce "essential technical training," or unreasonably lengthen the time required to obtain an engineering degree.

> Typically, responses indicated ". . . that, in general, engineers in 'responsible charge' should have knowledge of the parameters listed. This does not necessarily mean detailed knowledge of each nor that all of them should be required courses in engineering curriculum. To require additional nonengineering academic courses would either dilute essential technical training or materially extend the time required in school. The former would be inadvisable and the latter would discourage many

from pursuing engineering careers in a society that is already short of technical skills. Most of the non-engineering parameters listed are those of which a competent engineer develops knowledge during on-the-job training and experience after graduation, which in our opinion, is the best way to acquire working knowledge." (Pacific Gas and Electric Company.)

Other responses pointed out the difficulty of defining the group of engineers that should have some knowledge of each of the "parameters." One question that can be raised along this line of thought is--Does an engineering student know what type of practice he is destined for or should the educational process provide potential for the broadest opportunities for the engineering graduate?

Standard Oil Company was especially concerned that the "parameters" written into law today may not meet the needs of tomorrow:

"We concur that it is desirable for engineers in 'responsible charge' to be well-rounded persons, skilled in a specific engineering discipline, with a perspective gained by training or experience that embraces a broad spectrum of political, social, educational, economic, and other considerations. There is substantial doubt as to whether it would be possible to quantify these parameters and decide with assurance that one could measure or somehow discern absolutely that a candidate is so equipped. We are concerned that a list of 'parameters' written into law today will not, per se, include the most critical needs of tomorrow. The 'parameters' with which this legislation deals are dynamic, not static, and will vary as the times and needs vary." (Standard Oil Company of California.)

About one-third of the respondents did not believe that engineers should have a knowledge of all the "parameters" listed in Section 6709. Left unanswered, however, was whether or not engineers should have at least some degree of exposure to each of these "parameters."

"I do not concur that an engineer in 'responsible charge' should have knowledge of all the 'parameters' listed in Section 6709 of the draft in order to safeguard the public welfare. A knowledge of the nontechnical parameters (Communication Arts, Political Science, Social, and Behavioral Science, and Humanities/History) is not necessary to the performance of an engineer. A knowledge of the parameters--Physical Science, Engineering Science, Systems

Management, and Biological Systems--are only necessary to engineers whose areas of expertise are allied with these fields. An engineer should have expertise in these parameters: design/application, engineering technology, and multidisciplinary engineering as they apply to his/her area of competence. Professional ethics and a knowledge of economics and law as they apply to engineering are also necessary." (Golden Gate Section, Society of Women Engineers.)

Other firms, including Hewlett-Packard Company, emphasized that engineers are usually only part of a team of specialists and that the individual project manager (who may or may not be an engineer) relies upon "accumulated experience" and several specialists "to ensure that the team effort is successful." Consequently, most engineers need to know only the "parameters essential to the engineering design itself." Additionally, concern was expressed that if engineers in "responsible charge" were required by law to be knowledgeable of each "parameter," the number of engineers eligible for positions in "responsible charge" would be substantially reduced. Then, by definition, most engineers would be reduced to technicians with only limited advancement opportunities.

The California State Personnel Board was concerned that only "bona fide" occupational qualifications would be required, and was doubtful that engineers would need knowledge of each "parameter" to perform effectively in all engineering positions. Thus, the Board wrote:

"A general statement cannot be made that all engineers in 'responsible charge' should have a knowledge of all of the parameters being proposed. We are concerned that in engineering, as well as all job areas, only bona fide occupational qualifications are required. It is doubtful that it could be shown that all engineering disciplines require knowledge of each parameter you have listed in the draft legislation. The basic curricula now required allows little opportunity for electives. If all parameters were required, such a curricula would probably take more than four years to complete.

"In State service, our engineers in 'responsible charge' are required to have preparation that is considered appropriate for the special engineering discipline and job level. Depending on the particular engineering disciplines, this preparation would probably include knowledge of some of the parameters you have listed." (California State Personnel Board.)

In effect, the only substantial disagreement among the respondents over the "parameters" concerned the degree of understanding an engineer should have of each "parameter" as a function of the engineer's role in the corporate or agency environment. Those who interpreted Section 6709 as requiring that each engineer in "responsible charge" possess expert knowledge of each "parameter" usually did not believe that engineers, or for that matter anyone, could reasonably be expected to possess such a high degree of understanding of each "parameter." However, those respondents who interpreted Section 6709 as requiring engineers in "responsible charge" to have merely an "awareness" (see V.A.2., Comprehensive Summary, and VI.A.2., Degrees of Understanding, for discussion of the term "awareness" and the learning scale used in this study) or better, depending upon the "parameter" in question and the engineer's job, usually answered that such engineers should, to some extent, be knowledgeable of each "parameter."

c. Adequacy of Engineering Education

For many years, the relevancy of engineering education to the practice of engineering has been questioned by educators and practicing engineers alike. This debate has resulted in numerous studies, eight of which are reviewed in the second part of the detailed discussion. Consequently, engineering education and the adjustments and controls proposed by preprint Senate Bill 17 (see Appendix I) were major issues for inquiry during forum planning and participation.

Respondents were asked to present their impressions of engineering education as it related to the proposals in the preprint. Responses were varied, as some felt that they were confronting legislation which would allow the State to "dictate" curricula. Educators participating in the initial review, and others, generally believed that ECPD-accredited California engineering education programs were adequately preparing students to utilize technology and to meet societal needs and wants. The responses from representatives of industry, technical societies and other groups were mixed. The following pages present the different viewpoints with excerpts from the written responses.

Much of the praise expressed by educators and technical societies for California engineering education programs applied to ECPD programs only.

> "In my opinion, those California engineering education programs which are ECPD-accredited are adequately preparing persons to develop and utilize technology as needed by our society. The accrediting process for engineering programs throughout the years has been very

effective in assuring that engineering programs continually meet the needs of the engineering profession. The maximum period for which any engineering program is accredited is six years, and accreditation is far from 'pro forma.' The accreditation requirements are reviewed annually, and changes continually occur. All of the major professional engineering societies, as well as the National Council of Engineering Examiners, participate in establishing the criteria. These criteria will continue to change as society's needs change. I know of only two California public universities or colleges which do not have accredited programs. One of these is too new to be accredited, and the other is a unique program. I am certain that both of these will be accredited in the near future." (Dean of Engineering, CSU, Northridge.)

"It is the position of the IEEE that those schools whose programs have been accredited by the ECPD adequately prepare persons to develop and utilize technology needed by society. ECPD has as its constituent members most of the technical professional societies, the American Society for Engineering Education, the National Society of Professional Engineers and the National Council of Engineering Examiners. The main purpose of ECPD is to accredit programs in engineering education. As can be seen from the constituent societies listed above, the cross section of technical professionals, educators, and engineering examiners are all involved so that the proper criteria for the accreditation process can be established." (The Institute of Electrical and Electronic Engineers, Inc.)

In contrast, industry generally expressed unrestricted approval of California engineering education programs, whether accredited or not:

"We believe that the California engineering educational programs are providing us with graduates who have a good understanding of the 'parameters,' even though it is not reasonable to expect that they could be fully informed on all of the nonengineering parameters listed, upon graduation. We find that most of our engineers have strong intellectual drive and absorb knowledge, not only in engineering, but nonengineering fields, quite rapidly in the balanced atmosphere of work experience and in their personal intellectual pursuits." (Pacific Gas and Electric Company.)

"We have found that the education our engineers receive from California schools is generally of a high quality and compares well with the education received by engineers we hire from universities in other states. Overall, the California-educated (engineers) have a good grasp of the technical skills necessary to perform well in the corporation and are sensitive to the nontechnical aspects of the engineering profession . . .." (Union Oil Company of California.)

The Dean of Engineering, California Polytechnic, who felt that engineering education programs were adequately preparing persons to develop and utilize technology needed by society, suggested that the question should be reworded to apply to policymakers: "In today's world of technological advance, do those persons responsible for decision making on technological applications have the educational background to help them make wise decisions? The answer would have to be, 'no.'"

While of the opinion that California engineering education programs were adequately preparing students, the executive director of ASEE pointed out that there was "still room for experiment."

"California education programs (and those of other states) certainly are adequately preparing persons. Churchill has written, 'It is already demonstrated that a nation's power to prosper in peace and survive in war depends very largely on its degree of technological advance. Americans have realized this, and it is for this reason that their output per capita and consequent standard of life are so high.' In the late 19th century, American engineers studied in England, France, and Germany. In the late 20th century, students from every country in the world aspire to study in American schools. The American system of engineering education is the result of 100 years of careful development. Full scale studies have been conducted about one each decade in this century.

"There is, of course, still room for experiment and progress. Currently, a fraction of American schools are experimenting with Experiential Education in Engineering, as a mode of preparation. The practice of engineering, however, cannot be entirely taught in the schools. The requirement of a period of practice before final registration is the recognition of the need for an 'apprentice' component of the engineer's career. The extensive and rapidly growing 'continuing education' component of the engineering education system is concrete evidence of the engineer's recognition that formal schooling is only a part of an engineer's education. For the part that they do cover, the formal education programs in California and elsewhere do a superb job." (Donald F. Marlowe, Executive Director, ASEE; Past President, NCEE.)

A member of IEEE, who believed that present programs were adequate, strongly questioned the need for further governmental intervention in the evaluation of engineering education programs:

"I believe that engineering education programs are adequately preparing persons to develop and utilize technology needed by society. The largest educational segments are State University/College and University of California systems. All of these are State entities. Do we need 'government on government?' I believe the Professional Societies (such as IEEE, ASCE, ASME, etc.) along with ECPD and in cooperation with industry are adequate to do the job." (Region VI Director, IEEE.)

The "parameters" of engineering practice, as listed in Section 6709 of the preprint, and as proper guidelines for determining the adequacy of engineering education, came under a great deal of discussion. Many believed that it was not necessary for an engineer to have a knowledge of each parameter. The president of Hewlett-Packard Company emphasized that an engineer was only part of a team and that few engineers ever "reach top level responsibility." Consequently, although California engineering education programs do not provide his company with engineers that have an understanding of each "parameter," Mr. Hewlett does not believe that the engineer should be required by the State to possess that knowledge.

Similarly, C. F. Braun and Company responded that if California programs were required to provide engineers with an adequate understanding of each parameter, an "inappropriate demand would be placed upon California educational facilities."

Standard Oil Company of California questioned whether any educational program "can assure that industry will get well-rounded, creative, highly motivated, farsighted, socially conscious engineers. Standard Oil's chief engineer added:

> "The qualities that motivate graduate engineers to keep up technically and also to be concerned with the change in political, social, ethical, and economic conditions cannot be imbued or guaranteed by any given educational system or curriculum." (Standard Oil Company of California.)

Although great concern was expressed for the newly graduated engineers' lack of exposure to nontechnical aspects of engineering projects, concern was also expressed for the limited technical training an engineer received during his educational process. A representative of Litton Data Systems replied that the California programs were, with some reservations, supplying their company with "minimally trained" engineers. However, "We would recommend the expansion of the curricula to ensure an adequate foundation covering both technical and nontechnical parameters," he stated, rather than ". . . diluting the technical in favor of the nontechnical parameters."

One engineering technical society, representing a specialty area of engineering recently established for "title" registration, expressed a belief in the possible need for new engineering programs, particularly in view of the recently established disciplines.

In relation to the above statement, the Board of Registration has established eleven new categories of "title" registration, only four of which have parallel accredited degrees. A review of California Engineering Education programs, as suggested by ASSE, would undoubtedly suggest the establishment of new curricula. However, the effort and budgetary requirements necessary to establish new curricula to meet the educational needs of the newly licensed disciplines would be considerable and would result in a substantial increase in workload, and budgetary demands for the University of California, the State University and Colleges system, private institutions, and the California Postsecondary Education Commission.

In summary, the written responses to preprint Senate Bill 17 concerning the adequacy of engineering education programs in California, contradicted much of the research on engineering education and the opinions expressed in surveys and interviews conducted as part of this study. These responses probably resulted from the "adversary environment" of the legislative forum, for which they were prepared. Presently, California's registration act requires the State Board of Registration for Professional Engineers to approve curricula that qualifies for experience equivalency. To do this, the Board automatically accepts ECPD accreditation without review. At best, the Board can influence curricula accreditation on ECPD's Board of Directors. Preprint Senate Bill 17, if enacted, would require the Board to directly examine engineering curricula in light of engineering practice.

In addition, the responses to preprint SB 17 were substantially influenced by the respondent's interpretation of the "parameters" listed in Section 6709. Those who interpreted the provision as a requirement that engineers possess expert knowledge of the "parameters" usually responded that California engineering education programs do not and should not be expected to educate engineers to meet this requirement. Those who interpreted the provision as merely establishing that engineers should have at least an awareness of each "parameter" (depending upon the "parameter") usually replied that the California programs were adequately preparing engineering students to meet the requirement of Section 6709 and the needs of society as well. Many of these responses were with reservation; however, industry representatives often agreed with engineering educators in that engineering education programs were adequately meeting the needs of engineering practice. Many industry representatives added that if an employee moved into a position where there was a need for greater understanding of the nontechnical "parameters" of engineering practice, then on-the-job training or continued education would usually fill the need. In a team project, these employers viewed the engineer's role as one of providing technical expertise with other team members providing the nontechnical expertise.

d. Accreditation

California's current registration act provides that a graduate from a Board-approved four-year bachelor of science degree curriculum may receive four years of experience credit toward the six years of experience required for professional registration, or four of the nine years' experience required for grandfathering. As mentioned in the preceding pages, the Board automatically approves curricula accredited by ECPD without review. Preprint Senate Bill 17 would require the Board to become directly involved in the review of curricula, an extreme change from the current practice of the Board. Responding to whether or not the Board should become more actively involved in the evaluation of engineering education programs, the greatest percentage of respondents were firmly against Board involvement.

Many reservations were expressed with respect to the proposed measure. Aerospace Corporation and Pacific Gas and Electric Company did not believe that the State Board of Registration would have adequate expertise to evaluate all the disciplinary engineering programs.

C. F. Braun and Company viewed the proposed Board involvement in the evaluation of engineering curriculum as "unwarranted interference in the private affairs of industry and individuals."

Much of the opposition to this proposal was based on a belief in the adequacy of the present system, on a belief that there was no justification for a change from current evaluation procedures. It should be noted that most of the respondents represented entities currently exempt from the Act.

> ". . . I would certainly not favor the State Board of Registration for Professional Engineers becoming directly involved in the evaluation of engineering education programs. My stance on this question is based on my judgment that the accreditation process through the Engineers' Council for Professional Development is more than adequate in seeing that the engineering education programs meet the needs of the engineering profession. I do not think that the State Board should become involved in a separate approval process beyond ECPD accreditation." (Dean of Engineering, CSUC, Northridge.)

Many respondents, recognizing some justification for increased Board involvement in the current process, suggested compromise measures. For instance, the Assistant Director of Education and Training Programs for ERDA noted that communication between the licensing board and educators was "absolutely necessary."

> "A healthy intercourse between the licensing board and the educators is absolutely essential. Each is in a position to advise the other; the educators to advise the board on what fields of study are germane to the objectives of licensure and the board to advise the educators on the skills required to meet licensing requirements. It is important, I think, to recognize that the educators represent a constituency of engineers and the education establishment, while the licensing board represents a constituency of the public. It is, therefore, inappropriate for the board to dictate educational programs, just as it is presumptive for the educators to certify the impact of their graduates, in perpetuity, on the public welfare. A rule of reason must

apply in the interaction of the two groups so that a check-and-balance situation ensues. (J. C. Kellet, Jr., Assistant Director for Education and Training Programs, Energy Research and Development Administration.)

In relation to the above statement, a CSPE chapter member suggested that the Board work through NCEE to improve ECPD policies and operations. For more direct involvement with ECPD accreditation teams, the Vice President for Institute Relations at Caltech suggested that perhaps a Board member should serve on each accreditation team as an active member, rather than as just an observer.

Other respondents approved of increased, but limited, Board involvement in the evaluation of engineering education programs. Standard Oil Company favored the Board providing guidance to engineering education programs. Along this same line of thought, one technical society expressed the belief that the Board should be active in evaluating engineering education, but should not have a dominant role in the evaluation process.

The Executive Director of ASEE supported the present system, but expressed concern about the possibility that California may be considering developing its own independent accreditation process.

> "In most states (and I believe in California) there is some cross-fertilization between the engineering education programs and the engineering registration programs through the use of common volunteer personnel. Many engineering deans and professors have served on registration boards, and many board members have attended accreditation inspections. Many engineers feel that greater participation of active, practicing engineers in accreditation visits would be helpful.
>
> "One might read into this question an inference that California might consider establishing its own accreditation system, responsive to the demands of the registration process. For some years, New York had its separate system of accrediting curricula, but ultimately abandoned it. I would suggest that the requirements of reciprocity (or comity) among states should receive high priority in any such consideration. The existing national registration examinations and national accreditation programs were developed to ease problems created by the great mobility of engineers--in both their personal and professional lives.

"The matter of the Clare Committee proposals regarding admission to Federal District Courts in the Second Circuit, in which five subject areas of study were specified for admission, and the consequent problems of the Law Schools, is a current example of the dangers of regulating curriculum decisions by means of rigid registration requirements. The registration process itself is still an imperfect instrument, probably no better than the curriculum development process. While both are still in a state of development, too rigid ties between them would damage both." (Donald E. Marlow, Executive Director, ASEE, and Past President, NCEE.)

Latent in most of the responses was a very real dread of direct government intervention in the educational process. As one technical society member pointed out, the difference was between "direct" and "indirect" interaction.

Those respondents who approved of the concept of increased active Board involvement in the evaluation of engineering education programs qualified their statements with warnings of the difficulties such a proposal might encounter.

"There is an immediate need to broaden the outlook of engineering technologists. The State Board of Registration for Professional Engineers can facilitate this process. However, you must consider too that without proper controls built into the system, the appointees with some allegiance to the Department of Consumer Affairs can ride roughshod over the feelings of the professional engineers. Engineering is not really a branch of consumerism and younger folks who grew up in the 1960s and who are now involved in consumer protection often have definite antitechnology biases. If these persons are not educated to the past and to future possibilities of the engineering profession, they could introduce dangerous polarities into the evaluation of engineering education programs." (David A. Goodman, Futurist, Newport Neuroscience Center.)

The range of replies presented in the previous pages indicated that few persons favored the proposed changes. In fact, most respondents expressed a strong objection to direct governmental intervention in engineering education. While many suggested increased Board involvement within the existing system, each suggestion was carefully designed to prevent the Board from assuming a dominant role in the accreditation process. Those who felt that active involvement by the Board in program evaluation could be a positive factor in the improvement of engineering education were quick to point out the difficulties that such a proposal would face.

In essence, participants felt that the most acceptable approach to increased Board involvement in program evaluation was through the existing process, first, by strengthening its involvement in NCEE, and second, by having a Board member act as an observer with accrediting teams visiting California campuses. The latter might also be enlarged to a role of active participation.

The summary opinion on the proposal was heavily negative. In general, engineering employers and educators claimed that they were satisfied with the present system of accreditation. Furthermore, as one respondent observed, the profession has long worked to nationalize registration exams and accreditation programs to ease problems created by the great mobility of engineers. A proposal that the California Board of Registration become involved in engineering program evaluation could threaten this national structure. This position is enhanced by the fact that the majority of Board members are "lay" persons with no background in engineering. The dichotomy between opinions expressed in the surveys and interviews, and the responses to the preprint legislation may have resulted from the fact that a majority of the participants in the initial review represented entities currently exempt from the Act. Provisions of the preprint would eliminate all exemptions. The idea of State intervention into an area currently not influenced by State mandate may have had an overriding effect on the positions presented in conjunction with the forum.

e. <u>Engineering Registration</u>

While no specific question regarding registration was asked of participants in the initial distribution and review of the preprint draft, many respondents commented on the proposed changes in the nature of registration in California. Most comments addressed specific concerns with portions of the preprint, and a number of participants, mainly those representing areas of engineering practice currently exempt from the Act, questioned the purpose of the preprint and the necessity for registration in general.

f. <u>Necessity for Change</u>

Industry representatives were particularly surprised by the appearance of a piece of draft legislation proposing to drastically revise the present engineering registration act, and questioned the need for change in the present law.

"It is not altogether clear to us exactly what problem is being solved by the proposed legislation. If, as stated in your letter, it is an attempt to generally improve the quality of life associated with technological activities, it is in our judgment, counterproductive, overreactive and not appropriate in view of the traditional role of engineering in our society." (Vice President, Rockwell International.)

"I encourage you to fully investigate the need for the suggested legislation before introducing changes that might inhibit the existing successful system. Your idea of a forum sounds like a good vehicle to initiate such an investigation. Before proposing legislation to the Senate that would expand engineering registration requirements far beyond the engineering discipline, problems with the present system (if they exist) should be identified and carefully examined. I am sure you agree it would be imprudent to impose new controls and examination requirements if none are needed, as such bureaucracy and constraints would likely discourage a number of individuals from entering the engineering profession." (Senior Vice President, Union Oil Company of California.)

g. Registration

The question of the need for change has its foundation in the conflicting opinions expressed by participants on the need for universal registration, especially given the corporate structure. While the purpose of registration to safeguard life, health, property, public welfare, and public good was not in question, respondents did debate the necessity of registration to attain this goal. One argument was that registration of all engineers in responsible charge was essential to promote the public health, welfare and good; the other was that registration was only necessary when the engineer dealt directly with a public who had no means of determining competency. The basic concerns were expressed by an official for the federal Energy Research and Development Administration:

"Licensing is a process responsive to the public, not the licensed professional. Success derives from the degree to which licensing improves the public welfare; does it protect the citizen from fraud? Does it promote economic and safe products and procedures?" (Assistant Director for Education and Training Programs, Office of University Programs, Energy Research and Development Administration.)

Those respondents who supported mandatory registration firmly believed that promoting professionalism in engineering would strengthen the engineer's dedication to the public. In contrast, many respondents seriously questioned the need for mandatory registration of engineers in responsible charge:

"One must question the basic proposition that engineering activities . . . must be regulated by the State to adequately assure the safety of the products purchased by its citizens. The proposed legislation does not govern the safety of products. It regulates engineering performed by manufacturers and others within the State. It is not clear how regulating engineering activities within the State will be linked to the safety of products purchased by the State's citizens. In contrast, the existing safeguards of product safety regulation and standards, or the legal precedents of the manufacturer's responsibility for his products has a clear one-to-one relationship with citizen protection." (Vice President, Engineering, Litton Data Systems.)

"To require registration of all practicing engineers who are in responsible charge might go beyond what you would like in dealing with the quality of professional engineering. Many engineers report within corporations and do not interface with the public. Certainly they must never forget their responsibilities to the public, but those responsibilities are ordinarily handled by the corporate interface . . . ." (Professor, Chemical Engineering, Vice President for Institute Relations, California Institute of Technology.)

h. <u>Exemptions</u>

As expected, the issue of exemption from registration elicited the same opposing viewpoints as did the need for registration. Engineers employed in industry, public utilities, and the federal government are currently exempt from registration. Preprint Senate Bill 17, on the other hand, would eliminate all exemptions. This change attracted a great deal of attention from the respondents.

There was some strong support for the elimination of industrial and public utilities exemptions:

"Deletion of the industrial exemption is . . . controversial and traumatic . . . . I believe in it inherently, for the uplift of the engineering profession in its ability to serve the public. In other words, I believe legislation prohibiting the widespread industrial exemption will lead to stronger young men and women entering the engineering fields. They will see a much clearer horizon for their own goals achievement than they do now with industrial exemption in most California industry." (Associate Dean for Engineering Continuing Education, University of California, Los Angeles.)

"I think it is most unfortunate that registration or licensing is not essential to engineering practice by the overwhelming majority of practicing engineers. I personally would very much favor a change to hold a license, without exception . . .. Furthermore, I think that deans of engineering schools and engineering faculty who teach advanced subjects should be considered as holding positions of responsible charge. I realize that there may be considerable resistance to such a change among the engineering profession, and I would favor a grandfathering approach for those engineers now exempted from registration in order to achieve a more inclusive group of registered engineers. I see no justification for any exemptions. There are arguments offered that removing the industry exemptions would require large numbers of engineers to spend inordinate amounts of time toward achieving registered status, sometimes at significant costs to their employers. If that statement were true (doubtful!), it would stand as an admission that large numbers of unqualified persons are practicing engineering under the industry exemption. Requiring registration of those persons would be in the best interest of society, as well as the profession." (Dean of Engineering, California State University, Northridge.)

Most of the respondents, however, objected to the elimination of the exemptions. Industry representatives argued that the engineering work performed within their companies was sufficiently covered by corporate controls, and that both industry and public utilities were already subject to sufficient legal liability and government regulation to assure the competence of their engineers.

An argument was also presented in support of the exemption of engineering educators from mandatory registration under any act:

"I believe that college and university professors should be either specifically exempted or included under a special provision in the registration process. As a group, these professionals have attained the highest levels of academic achievement having once undergone more stringent examination and qualifying procedures than those presented by the P.E. examination. However, these individuals are expected to have a high degree of specialization both in training and in practice, and I don't believe that they can be expected to display the broad and more general attributes sought in practicing P.E.'s being examined under the current method of registration." (Assistant Professor, Engineering and Applied Science, University of California, Los Angeles.)

The preprint also eliminated the exemption for federal employees. However, the General Counsel for the National Society of Professional Engineers questioned the constitutionality of this change:

"This is only a technicality, but Section 6748 should be eliminated inasmuch as State licensing laws do not apply to federal employees while in the performance of their duties as such employees. The proviso, therefore, would be ineffective as a matter of constitutional law."

i. Registration by Technical Discipline

The present California engineering registration law licenses engineers by technical discipline. There are 19 disciplines currently recognized by the Board; however, only three of them limit practice to licensed engineers; the remaining ones limit the use of the title. The preprint would eliminate licensing by technical discipline. Additional information on licensing by technical discipline can be found under the summary of forum proceedings, Section 4, following.

Respondents presented conflicting views on this subject:

"We have tried to 'come on strong' for the advantages of a single nonspecialized registration for the last few years, with limited success to date. Now it is definitely included in the thrust of the new proposal." (Associate Dean for Engineering Continuing Education, University of California, Los Angeles.)

"The elimination of engineering specialties and disciplines from licensing provisions could decrease the technical skills required to engineer safe, reliable products--thus being counterproductive." (Vice President, Rockwell International.)

j. EIT Examination

A number of respondents agreed with the proposal to eliminate the EIT exam requirement for graduates of ECPD-accredited engineering programs. Most, however, added an internship subsequent to graduation as a qualification, and felt that the experience gained therein should be subject to Board approval.

"I have long regretted that the engineering profession is the only one, to my knowledge, that does not give the registration examination to the immediate university graduate. If an experience component subsequent to graduation is required for registration, I would suggest a period of internship subsequent to graduation from an accredited program, but not necessarily prior to taking the registration exam. The Board would pass on the appropriateness of the internship prior to granting registration to the individual." (Dean, School of Engineering and Computer Science, CSU, Northridge.)

"Inasmuch as it is proposed to break some significant new ground in this bill, would it not be advisable to take a major step to eliminate the engineer-in-training concept altogether? In its place, I would propose consideration of the approach indicated in the enclosed NSPE publication, "A New Concept for Engineering Registration." Under this concept in place of an EIT status, all qualified registrants would be licensed as professional engineers with the proviso that those entering the profession would not be authorized to offer services to the public or to certify engineering documents until they met the experience requirements as determined by the Board." (General Counsel, National Society of Professional Engineers.)

k. Rules of Conduct

Rules of conduct for professional engineers were included as part of the draft legislation. Respondents had two primary concerns about the rules: First, most felt that the rules did not belong in the body of the act. They felt that the Board should be mandated to establish such a code under the Rules and Regulations of the Board of Registration for Professional Engineers.

Second, they were concerned about the inclusion in the rules of conduct of a section protecting the engineer from discharge or discrimination by his employer in the event it became necessary for the engineer to report violations of the chapter occurring at his place of employment to the Board.

"It would be preferable, I suggest, to not include the specific Rules of Conduct in the law itself, but rather to authorize the Board to adopt rules of professional conduct . . .. The rules should be subject to revisions from time to time as new insight is gained and conditions may change. If the rules are in the law itself, it will be necessary to seek amendment of the law . . . if the authority is given to the Board to adopt the rules and amend them as needed, the legal aspect can be better treated by administrative action of the Board rather than through amendment of the law by the Legislature." (General Counsel, National Society of Professional Engineers.)

". . . the remainder of these sections leave an invitation for an immature or disgruntled employee to unjustifiably wreak havoc with a project by creating disturbance and delays, and thereby add seriously to the project cost. His reasons might be real, but far more likely would stem from inexperience or inability to understand, or would arise from purely philosophical views motivating a wish to harass or stop the project." (Senior Vice President, Pacific Gas and Electric Company.)

"It could create serious personnel conflicts within a company as the engineer seems to be separately responsible to the State for the public-good aspects, although he is still paid by the employer. Such problems must move to Sacramento and possibly the courts for resolution. Administration and adjudication of this system could be a nightmare." (Vice President, Research and Engineering, Rockwell International.)

1. Effect of Proposed Changes

While some participants agreed with the executive director of the National Council of Engineering Examiners that " . . . the tentative draft is a well-prepared document (see Appendix I) and should strengthen the laws pertaining to engineering registration . . .," most individuals, particularly those from industry, expressed doubts about the future of engineering in California should the proposed changes be enacted:

"One must also question what the potential economic impact will be to the state passing such regulatory legislation of engineering activities. Most products having substantial engineering content that are manufactured in one state are sold in other states or countries. Some products are not sold at all within the state where they are manufactured. Almost all products purchased by citizens of one state are manufactured in other states or imported.. Consumers will tend to buy the cheapest suitable products regardless of where they are manufactured. There is little question that engineering costs, hence product costs, will be increased due to the limited supply of suitable registered engineers. Manufacturers located in states having such legislation will be noncompetitive and will suffer reduced business volume or will consider relocation to other states. States having such legislation probably will tend also to discourage new manufacturers from locating in that state due to increased cost of engineering services and the relative difficulty in filling engineering job openings in case of needed rapid expansion. The state will lose work force and revenue dollars from pursuing such a course of action. The state cannot remedy this situation by imposing a requirement that all goods imported into the state also be manufactured under similar conditions as this would be an unreasonable restraint of trade under the Interstate Commerce Clause of the Federal Constitution." (Vice President, Litton Data Systems.)

m. Summary

Central to each issue on which comments were offered was the primary conflict of opinion over the need for registration. Some educators, and few individuals from technical societies, supported mandatory registration and the balance of proposed changes. Industrial representatives and the remaining individuals opposed mandatory registration and the corresponding proposals.

Judging from the initial responses to the subject of registration and administration of the act as presented in the preprint, the draft was neither accepted nor rejected. The issues raised by the proposal have existed for many years and remain unresolved.. As one respondent pointed out, " . . . the assessment of value of licensing must be accomplished by a broader based group than representatives of only the educational community and the practitioners themselves." This was attempted, but the nonengineering groups felt incompetent to contribute.

4. Summary of Forum Proceedings

The public forum on Preprint Senate Bill No. 17 was held on July 26, 1976, in a Senate hearing room in the State Capitol. Five panels were assembled, each dealing with a major aspect of the preprint legislation: (1) justification for registration of engineers; (2) education requirements for registration; (3) qualifications for registration; (4) miscellaneous requirements and provisions; and (5) industry and public utilities exemptions. The panelists represented engineering societies, industrial management, educational administrators, educators, practicing engineers, and engineering unions. Senator Rodda was assisted in conducting the forum by staff consultants to the key legislative committees and a past member of the Board of Registration for Professional Engineers. Senator Rodda's opening statements made it clear that the forum was to be held in an informal manner to stimulate frankness and candor in presentations. Nevertheless, most of the presentations were quite formal, and represented stronger positions than those presented and noted during the forum review.

A complete transcript of the forum was made and has been retained as part of the file on this project. The following sections present a brief discussion of the principal issues.

a. Purpose of Engineering Registration

Forum participants generally agreed that the purpose of engineering registration should be to safeguard public health, welfare and safety. They also agreed that the existing registration law should continue to serve as the foundation for engineering registration and should be changed only when a need for change was demonstrated.

b. The Need for Change/Justification

Participants in the forum disagreed among themselves on the need for change. Three major schools of thought were identified:

(1) There is no need for change. Existing institutions are serving "us" well.

(2) There is a need for change. Improvement in the existing institutions is possible. However, this improvement should be "evolutionary" instead of "revolutionary."

(3) There is a need for drastic change.

> "The many exemptions in the present law permit intense economic pressures for competitive businesses to prevail over sound engineering judgment. The registration of engineers in separate specialties has created an explosion of new registration disciplines under pressure from specialized engineering groups attempting to register their members by "grandfathering" rather than by examination."

Forum participants gave the most support to the first two schools of thought. It must be noted, however, that most of the testimony probably represented management level positions in large corporations and policy level positions in major universities.

Those who supported the first school of thought did not believe in a need for change. In effect, it was said that "Engineering enterprise has brought enormous success to California under existing institutions." Numerous examples of these successes were cited, including California's leading position in agriculture, aerospace, electronic- and computer-based industry, and environmental quality management. One individual added, "Engineers with vision, creativity, industry, and education at advanced levels have been vital to all of these and to the living we now enjoy."

Those who supported the second school of thought recognized that the complexity of engineering practice required "evolutionary" change rather than "revolutionary." Those who viewed gradual change as more effective and beneficial than rapid change were self-employed engineers of small consulting firms and employees of large companies whose professional responsibilities were "diluted."

Those who supported the third school of thought stated that "The Registration Board was unsuccessful in eliminating many flagrant abuses of the Professional Engineers' Act." They pointed out that the new specialty categories substantially increased the Board's commitments to processing applications and made it nearly impossible to enforce an already unenforceable law. These individuals supported mandatory registration of engineers in "responsible charge," arguing that the large number of unregistered engineers in industry could continue to practice under the responsible charge of a registered professional engineer. They concluded that, "The proposed legislation would provide the public with protection from technological injury at virtually no increase in cost occasioned by administration of the Act or by displacements in private industry."

c. Definitions

For many years there has been considerable debate concerning the definition of terms commonly included in engineering registration laws. Preprint Senate Bill 17 was drafted to stimulate discussion and clarification of these definitions 15/, 16/, 17/, 18/, which were extensively criticized during the forum. Although some participants believed these definitions to be an improvement over some of the existing ones, there was a consensus that clearer definitions should be formulated before changing the existing definitions.

d. Education

Forum participants generally agreed that California engineering education programs were doing a good job. They believed that the needs of a diverse job market were being met by the wide variety of engineering education programs in California.

The participants did not agree on whether or not engineering students should be exposed to all the "fields of understanding," and on what the extent of exposure should be. It was pointed out that only a limited amount of course material could be "squeezed" into a four-year program.

The question of teaching technology to engineering students was also discussed. Participants generally agreed that it was impossible and impractical for universities and colleges to teach students technology, because it changed too quickly. Most agreed that the current emphasis on fundamentals should be continued. (This position taken in the forum contrasted obliquely with feelings expressed by individuals determined in other parts of this study.)

Only one major criticism of engineering education was expressed in the discussion. The president of an engineering society representing 7,000 engineers stated that engineering students were not properly prepared for employment in large industry:

". . . They don't hear anything about the loss of identity, the profit-motivated policies carried out mainly by personnel and other labor relations people . . .. We find, particularly in the aerospace industry, quite a few leaving after the first year because they are becoming a number and they are marching to a different drummer, so to speak . . .."

e. Rules of Conduct

Most participants were extremely critical of the rules of conduct and did not believe that such rules should be included in the Engineering Registration Act, particularly since numerous engineering societies, such as NSPE and NCEE, already have a Code of Ethics. Generally, it was felt that the engineering profession was doing an "excellent job of establishing and maintaining exemplary standards of conduct in engineering matters and that the proposed legislation would, without enhancing these standards in any way, create turmoil within the profession by injecting new responsibilities of an ill-defined nature into the professional relationship." This position was not unanimous, however.

The principal of a large civil engineering firm noted, however, that individual society codes of ethics actually had "no effect and force" on practicing engineers. If an engineer failed to adhere to the prescribed code of ethics of the engineering society of which he was a member, the society could terminate his membership; but it couldn't prevent him from practicing.

The rules of conduct included in the Act were comprised of provisions from the code of ethics of NSPE, NCEE and ECPD. Interestingly enough, many of these provisions received substantial criticism by participants. A nondiscrimination provision, similar to the one included in HR 14068 (94th Congress), was extensively criticized by engineering management. The provision reads:

"No employer shall discharge or in any manner discriminate against any employee because such employee has filed any complaint or instituted or caused to be instituted any proceeding under or related to this chapter or has testified or is about to testify in any such proceeding or because of the exercise by such employee on behalf of himself or others of any right afforded by this chapter." (Section 6710.3(a)).

Under the provisions of the bill, the Board of Registration would be given the power to investigate such discrimination complaints and bring appropriate court actions. Engineering management believed the provision would introduce the government as a third party in employee-employer disputes and subvert responsible management practices of large companies.

In summary, there was some agreement among participants that rules of conduct might be more appropriately placed in the rules and regulations of the Board of Registration for Professional Engineers rather than having them specified in the Act.

f. Registration

Several major aspects of the registration process were discussed, including the elimination of "grandfathering," disciplinary licensing, waiver of the EIT exam for graduates of ECPD-accredited engineering education programs, and the content of the professional engineers' registration exam.

The majority of the forum participants were opposed to the elimination of "grandfathering" and disciplinary licensing. Currently, when a new discipline becomes licensed there is a "grandfathering" period during which persons practicing in the discipline may obtain registration based upon their references and work experience. Few take the exam once the "grandfathering" period has ended, unless registration is required by that discipline of engineering practice. Those who opposed Preprint Senate Bill 17 provisions to end these practices argued that specialization in engineering necessitated disciplinary licensing and that the "grandfathering" process was at least as effective as the examination process in determining whether an applicant was qualified to practice in a particular field of engineering. Those favoring the elimination of "grandfathering" and disciplinary licensing argued that these practices had recently brought the existing registration law to a state of crisis. One engineer noted:

"Within the last year alone, more new registration titles have been added than were established in this state in all previous time. The initial applicants in the new disciplines will not be required to pass the usual qualifying examination; therefore, the public will not be assured of their competence. This avenue cannot now be closed under the existing law since there are presently recognized over 100 specialties in the field of engineering and more can be defined virtually at will.

"But the problem does not end there. Even before these latest additions, the Registration Board was unsuccessful in eliminating many flagrant abuses of the Professional Engineers Act. With these latest additions, and the others sure to follow, the enforcement problems are greatly intensified at the same time that increased staff commitments to processing applications will be required. Thus, the present law which is already ineffective will become even more unenforceable.

"The legislation proposed in your Preprint Senate Bill No. 17 is a magnificent solution of the type long proposed by professional engineers. The simplicity of administration of the single registration will assure the public of a minimum level of competence with all registered engineers while freeing the registration board staff for enforcement duties or investigation of malpractice. The problem of establishing when specialized services must be obtained to provide the "area of competence" rests clearly with the professional engineer who is also in the best position to determine where such services are required in any given work.

"The offending industry exemptions are eliminated while still permitting the large number of unregistered engineers in industry to continue to practice under responsible charge of a registered professional engineer. The legislation proposed would, therefore, provide much greater protection for the public from technological injury at virtually no increase in cost occasioned by administration of the act or by displacements in private industry." (Statement prepared by Robert J. Bentson, member and director of the Structural Engineers' Association of Northern California and delegate and president of the California Legislative Council of Professional Engineers.)

Several persons disagreed that "grandfathering" was an effective method of determining competence. They held that " . . . testing was more effective and equitable than 'grandfathering,' and ensured equal treatment of applicants; and that the elimination of 'grandfathering' and 'disciplinary licensing' would simplify the registration law, making it possible to more effectively enforce it." Both engineering management and educators who opposed these provisions of Preprint Senate Bill 17 argued that they would serve only the licensed practitioner at the expense of the public.

Unlike the issue of "grandfathering" and disciplinary licensing, panelists generally agreed that the EIT exam should be waived for graduates of ECPD-accredited engineering education programs.

The content of past professional engineering exams was questioned by a substantial number of forum participants. Several viewed the questions as "academic," and suggested that the examination be lengthened and several essay questions be added concerning general aspects of engineering practice within a social context. Others did not believe it was possible to measure an individual's competence through testing, and suggested that more weight should be given a person's credentials. Some believed that it was not possible to measure competence until something negative happened. They felt that it was impossible to take effective preventative action and suggested that the only method of protecting the public was through court action. This threat of liability, they reasoned, would deter people from knowingly doing something harmful to the public health, welfare and safety.

g. <u>Exemptions</u>

Most of the forum participants opposed mandatory registration for engineers in "responsible charge" for a variety of reasons:

(1) It is too difficult to define the lines of responsibility for extremely complex products.

(2) The differentiation of responsibility among various engineering disciplines, and differences in State registration would result in "fierce" record-keeping problems.

(3) There is "no evidence connecting the PE examination with the sophisticated and involved analyses and decisions required in real life situations, and safeguarding the public." (Statement prepared by General Manager of G.E., in San Jose.)

(4) Mandatory nonspecialized registration laws would create extensive problems for interstate commerce.

(5) The only justification for registration is to protect the unsophisticated consumer. Engineers usually do not, however, interact with the public. This interaction is the responsibility of corporate management. Consequently, there is no justification for eliminating current exemptions.

(6) Mandatory registration laws would increase the production costs of many goods.

h. Summary

Preprint SB 17 incorporated most of the elements that have been of concern to the profession in engineering education, societal needs, and the licensing of engineers in the State of California. Numerous articles have been written, studies have been conducted, and speeches have been made on these subjects. However, the threat of State intervention into areas that have been controlled by entities other than State government caused public expressions of concern for every aspect of the draft legislation. There was little support for the proposal from any one group since concern felt by each for a particular element of the bill was so great that the entire draft was challenged. Those concerned with engineering educational programs feared the loss of volunteer control of accreditation and State-established standards of curricular acceptability. Those representing manufacturing companies were concerned over the proposed loss of exemption and the attendant requirements imposed upon companies for use of engineering talent. Those groups representing disciplinary segments in the engineering profession were concerned over the potential loss of the use of a title that had been established after much effort with the

Board of Registration. They saw no need for single registration and opposed the elimination of grandfathering provisions. Representatives of groups currently covered by the practice provisions of present law displayed concern for the inclusion of all engineering practice under the proposed legislation, and opposed the draft for this reason. The same groups also found the incorporation of rules of conduct into the proposed act quite distasteful. Groups that had proposed specific changes in the Act in the past even criticized those same changes in the draft legislation.

In general, there was an attempt made to limit the application of the Act to a small number of cases in which a property owner employed a land surveyor to resolve a boundary-line dispute with his neighbor. It was felt that the only justification for State intervention into the free marketplace was for the protection of the uninformed citizen from damage caused by an incompetent practitioner offering services directly to citizens. It would be difficult to justify engineering licensing in California based upon such a narrow application of the Act.

i. Conclusions from the Forum Proceedings

The following conclusions could be drawn from the presentations given at the forum. These should be compared with other data gathered during the study.

(1) Engineering educational programs in California are providing all of the necessary requirements for industry and are sufficiently diversified to satisfy the breadth of marketplace needs;

(2) The current examination requirements, including grandfathering, are adequately ensuring competent engineering practice;

(3) There is no need for mandatory licensure of engineers, since industry is liable for any injury that may occur from incompetency;

(4) Disciplinary licensing is better than nonspecialized or single professional registration;

(5) There is no need for the incorporation of a code of ethical practice as part of the Registration Act;

(6) The only type of engineering practice that should be licensed in California is a small segment of land surveying that is offered directly to a citizen, not a public agency or private industry that has at its own disposal the ability to determine competency without State intervention; and

(7) The general public in the State of California is well served by the current educational system and registration practices, and where problems exist, they should be resolved through court action to determine liability.

It is apparent from these observations that, under the threat of state-mandated efforts, the positions taken by nearly all participants were quite different from those positions taken previously by others when there was no threat of government mandate.

5. General Observations

The objectives of the forum were effectively fulfilled, and the major issues affecting the complex profession of engineering were illuminated. California representatives of the engineering community were able to present their respective positions on the coordination between engineering education and registration and on the effectiveness of registration in providing protection of the public.

The forum was structured to effectively stimulate discussion of proposals in the draft legislation which addressed engineering education and registration. These proposals elicited the presentation of policy positions on the basic issues.

Forum participants generally agreed that current California engineering education programs provide a variety of engineers with the knowledge and skills necessary for the needs of the diverse job market. This position contrasted with the recommendations of many prior studies and with the results of interviews conducted in this study. This dichotomy may be attributed to the fact that the preprint carried the threat of government intervention, while the prior studies and interviews were only the expression of opinion subject to debate.

Participants also generally believed that the current Registration Act was satisfactory and that there was no justification for any change in the law. They supported disciplinary title registration and the proliferation of new engineering registration categories with attendant grandfathering. They also strongly supported industrial and public utility exemptions.

The popular opinion of the representatives was that only that portion of engineering practice offered directly to the "uninformed" public should be subject to registration under the Act. Members of Senator Rodda's hearing panel explored this position with the participants. As an example, it was explained that a surveyor could be contacted through a telephone listing by a property owner attempting to resolve a boundary dispute with his neighbor. Because of this direct contact with the uninformed public, the surveyor should be licensed.

All other engineering is offered to, or conducted by, public or private entities that have the ability to determine competence. The public is protected, according to forum representatives, by the sophistication of engineering employers. Statistically, under this concept there is no justification for the registration of a major number of the approximately 52,000 engineers presently registered in this state.

Forum participants also firmly believed that legal liability was the prime motivator for the protection of the health, welfare and safety of the public. The threat of litigation encourages engineering competency. Critics of this approach maintain that while litigation against the incompetent engineer or company is one method of protecting the public, a much better approach would be to prevent injury through registration which would eliminate the incompetent, rather than depend upon a system of retribution and restitution.

The positions presented at the forum indicated that the education of engineers will continue to be heavily influenced by those concerned with the process, educational institutions, and educators, and that any attempt by the State to establish general standards for engineering education programs will be actively opposed. Also, the positions indicated that the various disciplinary segments in the engineering community did not see any justification for a broadening of the coverage of the Registration Act and would not support any effort to do so.

This study addressed the role played by the State in the protection of the public. It was recognized that the major portion of all engineering is conducted through a legal entity other than an individual practitioner. It also appeared that there was no interest in having the State establish minimum standards of competency and administer a registration system affecting all engineers in all modes of practice. The preference, by the profession and engineering employers, was to keep the State out of the process through exemptions for industry, utilities, and federal practice. However, some of the major problems in engineering projects which resulted in loss of life, were experienced in areas exempt from registration laws, despite the fact that many of these projects were subject to established State and federal regulations. It appears that the current trend in society will continue, that the threat of liability and damages awarded by the courts will ensure the competency of the practitioner.

VII. ENGINEERING ADVISORY COMMITTEE

A. General Background

The principal objective of this project was to identify a system for the periodic evaluation of engineering education and licensing programs to ensure that the needs of society are met by the practicing professional. It was reported that major differences existed between these elements and that there was very little evidence of any coordination among them. Although it is recognized that, in a free society, the independence of the postsecondary education system must be insulated from adverse, near-term policy influence, it has also been recognized by the California State Legislature that "coordination and planning are vital elements in providing postsecondary education" with the capability to meet the needs of the people. (California Education Code, Section 22710, Ch. 5.5)

Concerted efforts have been made to bring representatives of the practicing profession into the review and accrediting process, but the educational system has remained relatively independent from outside evaluation. The Engineering Council for Professional Development has a national charter for the periodic review of the four-year undergraduate program in engineering, but the organization's efforts to involve representatives from industry and the practicing community have not been totally successful. Consequently, the accrediting committee is composed of a majority of engineering educators. Also, the accrediting process is somewhat limited to the curriculum offered in the first two years of a four-year program.

The Board of Registration for Professional Engineers has standing committees on educational and disciplinary requirements, but it, too, has historically and automatically accepted the accreditation requirements established by the Engineering Council for Professional Development, and has given little attention to the relationship of the licensing process to the practice of engineering in society.

The California Postsecondary Education Commission's charter has been limited to general evaluations of the need for engineering programs in light of prevailing demands for specialized engineering manpower. The Commission, with its responsibility for program and budget review, has been careful not to include curriculum evaluation.

As the practice of engineering becomes more subject to public policy established by the State and federal governments, and as technical options are increasingly more influenced by social, economic, political, environmental, aesthetical, and legal constraints, there is an increasing necessity to develop some method of continual evaluation and coordination that will correspond to the shifting problems and needs of society. The Commission is a possible vehicle for accomplishing this through the formation of an Engineering Advisory Committee under its existing mandate. (See Appendix J.) This advisory concept is also applicable to other professions, such as medicine and law, where there are formal degree programs in the postsecondary institution and State licensing requirements for the practitioners.

B. Establishment and Goals of the Advisory Committee

The Commission on Postsecondary Education, under existing mandate and within established goals and objectives (see Appendix J), should establish the Engineering Advisory Committee. The proposed Committee, within the structure of the Commission, would facilitate the accomplishment of the following general goals:

1. To delineate the "fields of understanding" that characterize the practice of engineering as it relates to evolving societal needs.

2. To evaluate and make recommendations concerning engineering curricula in light of the "fields of understanding" and encourage its adaptability to the broad demands of engineering practice and its correlation with societal needs.

3. To evaluate and make recommendations concerning the engineering registration process as it relates to and reflects engineering practice, education and societal needs.

4. To issue reports of findings and recommendations to increase public awareness and understanding of the interaction of engineering education, licensing and registration.

C. Composition of the Engineering Advisory Committee

The membership of the Engineering Advisory Committee would serve at the pleasure of the Commission, and would be composed of, but not necessarily limited to, representatives from various segments in the profession and society:

a. Postsecondary education institutions

b. The practicing engineering profession

c. Engineering employers

d. Public policymakers

e. Consumer groups

f. The Board of Registration for Professional Engineers

g. Department of Consumer Affairs

h. Engineering students

i. Science education in secondary schools

Recognized representative organizations should be solicited for nominees for appointment to the Advisory Committee and appointments should be made so that no single group would constitute a majority on the Committee. One staff person should be appointed to serve the Committee's administrative needs. Additional staff should be provided based upon the Committee's approved plan for program review and evaluation. The staff would assist the Advisory Committee in formulating recommendations, preparing them for presentation to the Commission and the Board of Registration for Professional Engineers, and represent the Commission to the Board, as required.

D. <u>Duties of the Advisory Committee</u>

The Engineering Advisory Committee would have the following duties:

a. Identify major needs and concerns of the people of California as they relate to the practice of engineering;

b. Examine existing and proposed professional engineering education programs in light of public concerns;

c. Develop recommendations for program modification or special projects to make engineering education programs relevant to engineering practice and submit these recommendations to the Commission;

d. Define the job market parameters which affect future engineering manpower requirements;

e. Develop criteria for budget analysis of engineering education programs to be used in program analysis and in the review of new programs;

f. Formulate counseling criteria for the four segments of postsecondary education and secondary education to increase student awareness of the education and practice requirements of a career in engineering, and submit the criteria to the Commission for appropriate action;

g. Evaluate programs, methods of funding, service delivery systems and techniques for continued education for the engineering profession;

h. Determine basic minimum requirements for practice of the engineering profession and present these recommendations to the Board of Registration for Professional Engineers;

i. Assist the Board of Registration in the formulation of examination criteria;

j. Assist the Board of Registration in the development of qualifying criteria for engineering education curricula to be used as equivalency toward the experience requirements of registration; and

k. Evaluate the level of understanding that should be obtained in the four-year education programs in each of the "fields of understanding" which represent engineering practice.

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FOOTNOTES

1/ Appendix II, "Background of National Priorities for Use of Engineering and Scientific Talent," Energy and Engineering Education - Project E-E, Assembly Education Committee, California Legislature, May 1975.

2/ NCSBEE later became the National Council of Engineering Examiners.

3/ Proceedings of the National Council of State Boards of Engineering Examiners, 13th Annual Convention, New York City, September 29-30; October 1, 1932, p. 12.

4/ SPEE later became the American Society for Engineering Education.

5/ Proceedings of the National Council of State Boards of Engineering Examiners, 1932.

6/ Letter to Senator Albert S. Rodda, July 21, 1976.

7/ ECPD 43rd Annual Report, September 30, 1975, p. 89.

8/ All schools, except West Coast University, have ECPD-accredited engineering education programs.

9/ Some campuses have historically been known for having basic research-oriented engineering education programs that assume the student will continue for a master's and a doctorate at the institution, then conduct research. Other campuses are known for their practical practice-orientation.

10/ "Specific course requirements" in this analysis are defined as required courses within a particular "field of understanding." For example, if "Engineering 100, Heat Transfer" was required for a bachelor of science degree in engineering, it would be considered a specific course requirement. Also, if a student was offered a choice between two or more four-unit classes, i.e., "Physics 100, Principles of Motion" and "Chemistry 102, Principals of Chemical Reactions," the choice would still be considered as four units of specific requirements within the physical science "field of understanding."

11/ To facilitate the development of an elective classification scheme, the "fields of understanding" were divided into technical and nontechnical fields. The technical fields of understanding encompass physical science, life sciences, engineering sciences, design/application, engineering technology, whereas the nontechnical fields include ethics, communication arts, management, economics, law, political science, behavioral science, humanities, and history. Electives were classifed as: "Technical," where a class from two or more technical fields of understanding could be selected; "nontechnical," where a class from two or more nontechnical fields could be selected; and "restricted," where a class from a "technical" or "nontechnical" field could be selected.

12/ Depersonalized transcripts are transcripts with no identifying information. The person whose transcript is being examined remains anonymous.

13/ Articulation agreements between the four segments of higher education permit the transfer of credits toward the baccalaureate degree. There is a need for more comprehensive counseling of students to ensure that particular courses are within the articulation agreements and will result in transferable credit from one segment or campus to another. Time and financial restraints did not permit the investigation of this need in this project; however, this difficulty was of some concern to the faculty interviewed as part of this project.

14/ A structural engineer must first be a registered civil engineer.

15/ 6704. "Engineering practice" and "engineering work," within the intent of this chapter, shall mean any service or creative work, the adequate performance of which requires engineering education, training and experience in the application of special knowledge of the mathematical, physical and engineering sciences to such services or creative work as consultation, investigation, evaluation, planning and design of engineering works and systems, planning the use of land and water, and the inspection of construction for the purpose of assuring compliance with drawings and specifications; any of which embraces such services or work, either public or private, in connection with any utilities, structures, buildings, machines, circuits, equipment, processes, work systems, projects, and industrial or consumer products or equipment of a mechanical, electrical, hydraulic, pneumatic, nuclear, aero-dynamic, or thermal nature, insofar as they involve safeguarding life, health, property, public welfare or public good and including such other professional services as may be necessary to the planning, progress and completion of any engineering services.

A person shall be construed to practice or offer to practice engineering within the meaning and intent of this chapter who practices any branch of the profession of engineering; or who, by verbal claim, sign advertisement, letterhead, card, or in any other way represents himself to be a professional engineer, or through the use of some other title implies that he is a professional engineer or that he is registered under this chapter; or who holds himself out as able to perform, or who does perform any engineering service or work or any other service designated by the practitioner which is recognized as engineering.

16/ 6706. "Engineer in responsible charge," within the intent of this chapter, means the individual who determines technical questions of design, development application, certification or construction, or personally supervises engineering work.

17/ 6708.1. "Public welfare" involves the general well-being of the public.

18/ 6708.2. "Public good" involves the utilization of public resources.

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APPENDIX A

ENGINEERING PROJECT ANALYSIS

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ENGINEERING PROJECT ANALYSIS

It is axiomatic that engineering, science, and technology touch nearly every aspect of daily living. The needs and wants of society have cumulatively comprised the standard of living that is the hallmark of American life. The demands of society and the emphasis placed upon the priority of those demands has shifted according to the times over the past one hundred years. Needs have become wants, and wants have become needs depending upon the social and political implications.

The principal issue raised by this study was the relationship between the education of those who have the responsibility for transferring science and technology to the processes, products, materials, and developments that society both needs and wants, and the methodology in which the transfer process actually takes place. Of further concern was the protection of the public health, welfare, safety, and good in the technological fields and the State's responsibility for this protection. In the latter case, the whole subject of engineering licensing was addressed.

The parameters of engineering practice vary according to the conditions existing at any particular time. In times of crisis and national security, society waives many concerns to expedite the transfer of technology to societal needs. In most cases, technical decisions are heavily biased by nontechnical considerations. Correspondingly, the demands upon engineers who implement technology change. Hence, the types of knowledge involved in engineering projects and the level of awareness needed in order for engineers to function in a professional and ethical manner in the technological transfer process become key issues.

Three major, publically recognized engineering projects in recent California history were analyzed to identify the integrated types of knowledge involved in them: (1) the Santa Barbara Channel oil development and disastrous oil spill, (2) the Bay Area Rapid Transit system, and the (3) Diablo Canyon Nuclear Power plant design and development. The Santa Barbara Channel oil project was used to examine the public's interest in the area of environmental quality control. The Bay Area Rapid Transit system was presented as a public transportation need. And finally, the Diablo Canyon Nuclear power development exemplified one of the energy options available to the public for satisfying the increasing demand for energy resources.

Because the Bay Area Rapid Transit system and the Santa Barbara Channel oil incident have been the subjects of many reports and investigations, the types of knowledge involved in each was readily reduced and analyzed. In contrast, the design and development of a nuclear power plant was relatively new and involved both subjective and objective analysis.

The parameters, or specifications, developed from the analysis of these projects led to the development of the "Fields of Understanding" which were subsequently used for a comparative analysis of engineering educational programs and licensing of engineers in California.

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1. SANTA BARBARA CHANNEL OIL PROJECT - ENVIRONMENTAL QUALITY

The tragic Santa Barbara Channel oil spill of January 1969, heightened public awareness and concern for pollution. State and national attention were focused on the polluting effects of the spill. Governor Reagan in his "Spirit of the 70s" State message pointed out the importance of the environment to the quality of life. "There is no subject more on our minds than the preservation of our environment, and the absolute necessity of waging an all-out war against the debauching of that environment . . . . Along the Santa Barbara coast, seeping oil continues to ruin the beauty and endanger wildlife . . . ."

a. Background

Many of the major events preceding the spill have been summarized by Charles E. Mc Carty in his study entitled, The Santa Barbara Channel Oil Disaster: A Case History of Environmental Exploitation With Recommendations For Reform. A portion of this summary is quoted below:

"As early as 1955, the State of California recognized the need to preserve the aesthetic qualities of the Santa Barbara area, and thus enacted the Shell-Cunningham Act, which created a sanctuary some sixteen miles long in the State waters off Santa Barbara. According to the provisions of this Act, no drilling platforms could be erected within the sanctuary unless it could be shown that oil production in areas beyond the State's three mile limit was draining the pools within the State waters of the sanctuary.

"In 1958, the first offshore platform was established in State waters off Summerland by Standard Oil of California. In all, eight offshore platforms have been erected in the State waters of the Santa Barbara Channel, four to the east and four to the west of the City of Santa Barbara. In addition, there are four underwater completions.

"In December of 1966, the Department of the Interior announced that it was calling for bids on a lease block in federal waters adjacent to the Standard lease. The federal government contended that the Standard operations were draining oil from pools in federal territory. The County of Santa Barbara was apparently not consulted on this matter prior to the bid call, despite assurances from the Interior Department in February of 1966 that consultations would be undertaken. The lease was granted to a combine of Continental Oil Corporation, Phillips Petroleum, and Cities Service Oil Co. on December 15, 1966, for $21,289,000.

"On December 19, 1966, the Santa Barbara County Board of Supervisors requested that the Interior Department refrain from granting any further leases until local consultations had been undertaken with county officials. In January of 1967, the federal government agreed to the county's request, although it had already requested the oil companies on December 29, 1966, to inform the Interior Department of the areas in the Santa Barbara Channel in which the companies would be interested in exploring and drilling.'

"Late in January, 1967, the Department of the Interior informed the county that the locations of proposed federal lease sites would not be made available to the county until the bids were actually called for. The county had requested the information because it was feared that a proliferation of federal leases offshore of the sanctuary would endanger the existence of that sanctuary.

"The County Board of Supervisors subsequently requested the Interior Department to extend the sanctuary seaward to Santa Cruz Island, and asked for a one-year moratorium on the granting of leases. J. Cordell Moore, Assistant Secretary of the Interior for Mineral Resources, stated, with respect to the county's requests, that oil companies had spent several hundred million dollars exploring for oil potentialities in the channel and they would 'probably raise a lot of flack' if the county requests for a delay were granted. He reminded the county officials that the oil companies 'can bring a lot of pressure to bear on Congress.'

"In September of 1967, the Interior Department proposed the establishment of a two-mile wide buffer zone seaward of the State sanctuary within which no leases would be granted by the federal government. The county requested a delay in the granting of the leases in 1967, and a decision was to be made by October 15. Any comments from the county would have to be made before that date. On the 28th of September, however, Secretary of the Interior Udall agreed to the county's request for a delay to study the proposed leases, and granted a 60-day moratorium on the bid call, although the county had requested a six-month delay in which to prepare its report.

"The county report was completed on November 20 by County Oil Well Inspector David K. Bickmore, and it was decided to send a delegation from the county to Washington, to present the report to the Interior Department.

"Also on the 20th, the U.S. Army Corps of Engineers held a hearing in Santa Barbara on the request of Phillips Petroleum Company, the operator for the three-company combine which had leased the tract adjacent to the Standard platform off Summerland, for a permit to erect a permanent platform (Platform Hogan) on its lease. Although this was the first formal hearing on any facet of oil operations in the federal waters off Santa Barbara, it was a relatively perfunctory one. Colonel Norman Pherson, District Engineer for the Corps of Engineers, placed a limitation on the scope of the hearing, stating that the only concern of the Corps of Engineers, and thus the only concern of the hearing, was the navigational hazard posed by the erection of the platform. He stated, 'The lease itself is not the subject of this hearing, and we are not here to discuss long-range developments.'

"Donald W. Solanas, Western Regional Oil and Gas Supervisor of the U.S. Geological Survey, stated at the hearing that 'it is of critical importance that there be no delay in the installation of this platform.' He stated that some 10,000 barrels (420,000 gal.) of crude oil per day was being withdrawn by the Standard operation on the State lease, and that <u>some</u> of this oil <u>could</u> be coming from federal pools. Thus, the platform should be erected to prevent a possible drainage from the federal lease. The permit was granted on January 10. It is interesting to note that, even as the hearing was in progress, some 50 days before the permit was even granted Phillips was towing the platform into position, apparently sure in the knowledge that the permit would in fact be granted.

"On February 6, 1968, the Interior Department opened the Santa Barbara channel to bids from the oil companies. By the end of the bidding period, bids totaling $603,204,284 had been offered and accepted. The two-mile wide buffer zone had been withheld from the leased area. In addition, three bids offered for blocks adjacent to the buffer zone were rejected, and these blocks were added to the zone.

"On May 23, 1968, Union Oil Company, operator of a lease for a combine of Gulf, Texaco, Union and Mobil, requested a permit to erect a permanent platform on Lease 402, just off the buffer zone. The Corps of Engineers refused a request to hold public hearings on Union's application to erect Platform 'A' on the grounds that the Corps could not concern itself with matters pertaining to conservation and aesthetics. The Corps held its jurisdiction to be limited only to the determination of navigational hazards, and the proposed platform did not, in the Corps' opinion, present such a hazard.

"On September 15, 1968, Platform 'A' was installed on the Union lease. A second platform, Platform 'B', was installed shortly afterward, and also in September, Union sought a permit to erect a third platform, 'C', on Parcel 402.

"Agreements had been reached between the county and the Interior Department pertaining to the aesthetics of the channel, which included camouflage of offshore platforms by paint and 'Fail-Safe devices' on the platforms to prevent spillage, etc.'"

Despite the spillage safeguards, oil began to spill into the channel January 28, 1969. Shortly before noon that day, drillers on Union Oil Company's Platform "A," located six miles off the coast of Santa Barbara, were withdrawing the drilling bit from Well A-21 when drilling mud began flowing from the top of the drill pipe. After the mud stopped flowing, a noxious hydrocarbon mist poured from the open pipe and engulfed the drilling rig. Efforts to connect blowout preventers to the top of the pipe were unsuccessful because of the difficult working conditions.

After twelve to thirteen minutes of unsuccessful efforts to control the flow of mud, gas, and hydrocarbon mist from the pipe, the order was given to drop the drillpipe into the bottom of the well and to close the blind rams at the top of the well. This maneuver halted the flow of material from the top of the drillpipe. However, gas and oil were seen rising to the surface of the sea at this time about 800 feet from the platform.

The well was not controlled until February 8, 1969, after a minimum of 200,000 gallons of heavy crude oil had spilled into the Santa Barbara Channel covering an estimated area of 600 to 800 square miles. Even after the well was controlled, oil continued to seep from the ocean floor at an unofficial rate of 1,000 gallons per day. General Research Corporation of Santa Barbara, using mathematical formulas based on the thickness of oil on seawater, estimated that the flow of oil was as heavy as 210,000 gallons per day the first twelve days after the spill, and 8,000 gallons per day after the well was controlled.

Despite the risk involved, the U.S. Department of the Interior, relying upon information gathered by the oil companies and the U.S. Geological Survey, leased the federal territory for the purpose of oil drilling. According to Dr. Barrow, President of Humble Oil Company, the decision to drill for oil in the Channel was largely based on economic factors. Total energy demand was considered as the sum of three major sectors -- transportation, residential-commercial and industrial. Despite conservation measures, the growth in demand for energy was forecasted to be 4.2 percent per year during the foreseeable future. He noted that nuclear power, hydro power, coal, gas and oil would be used to meet this demand. Dr. Barrow reasoned that petroleum must account for most of the increased supply to meet the demand because of the nuclear delays, clean air problems with coal, and shortage of natural gas. Moreover, to minimize the U.S.

dependence on foreign oil sources, Dr. Barrow concluded that offshore oil sources should be developed. Thus, he viewed the benefits as outweighing the costs of such production.

In addition to the economic argument for developing the oil reserves in the Santa Barbara Channel, numerous historical arguments to justify and to oppose drilling in the Channel had been made. In Oil Pollution and the Public Interest: A Study of the Santa Barbara Oil Spill, A.E. Keir Nash, Dean E. Mann, and Phil G. Olsen explained the historical arguments summarized below, made by proponents and opponents of offshore oil drilling:

> The proponents of Channel oil drilling argued that Santa Barbarans had historically benefited from Channel oil. In 1776, a Spanish missionary noted that tar was washed up onto the shore and used by Indians to bind their woven baskets. Later, Spanish explorers used it to caulk leaky ships. During the latter half of the nineteenth century, a few Santa Barbara citizens sold the natural asphalt to make sidewalks and streets. By 1901, 350 small wells had been drilled. No one objected to the drilling or to the fact that the wells were not capped when abandoned in the 1920s. Thus, proponents argued that Santa Barbarans had historically benefited from the oil, and that arguments for "vested aesthetic rights" had little foundation.
>
> Opponents of Channel oil drilling argued that during the middle third of the twentieth century the socioeconomic structure of Santa Barbara changed from a predominantly agricultural economy to an amenity-oriented economy in which aesthetic conditions became vital. As evidence of this change, opponents cited numerous historical events: the earthquake of 1925, which resulted in concern for environmental quality, (the Community Arts Association was established then to provide free architectural advice to owners of demolished businesses who agreed to rebuild in graceful Spanish style); the enactment of city ordinances restricting advertising signs and controlling development; development of light industry which did not threaten established retirement and resort sectors; and the division of economic interests between the coastal region south of the California Coastal Range and the northern or inland county which became committed to growth in agriculture, mining, manufacturing and missile bases. Thus, critics argued

- that the decision to drill for oil in the Channel did not adequately take into account the interests of Santa Barbarans living and owning businesses near the coast.

b. Project Analysis

Numerous challenges with offshore oil drilling in the Santa Barbara Channel have been identified, and are summarized and categorized below according to the "fields of understanding."

(1) Physical Science

The severity of the spill was largely a result of the local geology of the ocean floor. After the blowout-preventers were activated, oil and gas from lower-level high-pressure petroleum-bearing strata was unable to find relief at the closed-off well head. Oil and gas thus escaped from the uncased hole part-way down, and flowed upward through highly porous sand and fractured rock lying just below the ocean bottom. From there, it bubbled to the surface of the Channel waters. (See Figure I.)

(2) Engineering Science

At the time of the oil spill, 3-3/8-inch conductor casing extended from the drilling platform to a point 238 feet below the ocean floor. No other casing was set. Outer Continental Shelf Orders, issued by the Department of the Interior, required a minimum of 300 feet of conductor casing which totaled 25 percent of well depths to 7,000 feet. Both of these requirements had been waived by the USGS Regional Supervisor. USGS spokesmen have argued that sound engineering practice dictated the casing variance on Union's well. However, Union subsequently stated that the spill could have been prevented if sufficient casing had been used.

(3) Design

Clean-up measures had not been adequately tested prior to the spill. Additionally, the adequacy of design of equipment and ocean floor drilling techniques had been questioned, particularly the design of equipment to seal a blowout or capture an oil spill.

(4) Ethics

According to Nash, Mann and Olsen, a former member of the Platform "A" drilling crew charged Union's drilling contractor with ignoring safe drilling and extraction practices. The charges have not been proven or successfully refuted in court.

The casing variance granted Union Oil by the Federal Government also raises ethical questions.

(5) Management

As a result of regulatory jurisdictional conflict among government agencies, no systematic approach was developed to protect the ecology of the Santa Barbara Channel.

(6) Economics

The oil spill resulted in numerous costs resulting from damage to the fishing industry; damage to boats and the boating business; a decline in restaurant patronage; decline in volume of sales and values of beach-front property; damage to seawalls, fences, gardens, and residences.

Channel drilling was viewed by many federal officials as a desirable alternative to greater reliance on foreign imports. However, many critics argued that only the oil depletion allowance, import taxes and quota systems made a high-risk area like Santa Barbara an attractive alternative, given existing technology.

(7) Law

Numerous civil and criminal law suits were filed in conjunction with the spill. The civil suits involved liability questions and the criminal suits sought the abatement of a public nuisance. According to the study conducted by Nash, Mann, and Olsen, the California courts were more likely than the federal courts to rule in favor of the Santa Barbara residents. Questions of jurisdiction were raised, including original jurisdiction and/or exclusive jurisdiction of the Federal District Court in suits arising out of offshore leasing, and whether this barred all concurrent exercise of jurisdiction by the State courts even after the damage has reached property on California shores.

The applicability of liability doctrines was also confusing. According to one doctrine, injuries exist for which there are no legal remedies. A second doctrine states that when engaged in "ultrahazardous" activity, one must use his property in a manner not hazardous to others so that even in the absence of negligence, a defendant could have to pay for damages suffered by a plaintiff. And a third doctrine refers to a balancing of the interests at stake. For example, if the plaintiff's grievance concerned mere personal convenience and the defendant's activity was necessary for the public welfare, the defendant would not be liable for damages suffered by the plaintiff.

(8) Political Science

Numerous political developments affected the offshore oil drilling project at Santa Barbara. Some of the more important developments are summarized below.

In September of 1967, the Santa Barbara County Board of Supervisors obtained a sixty-day drilling moratorium; a federal "no drilling" buffer zone extending two miles out from the California three-mile limit; and assurances that the platforms would be camouflaged by paint and made as pleasing to the eye as possible. Within a month after the spill, an estimated 70% of the adult southcoast population had signed the "GOO" petitions to "Get Oil Out" and demanded a complete cessation of channel oil development. This show of support for elimination of channel oil drilling encouraged Senator Alan Cranston and Congressman Olin Teague to introduce numerous congressional bills to regulate and even eliminate drilling in the channel. Stringent federal regulations were enacted after the spill. However, they did not address the "aesthetic affront" to Santa Barbara's scenery and the detriment to its capacity to attract tourists and retired persons.

A November 1968, referendum on a proposal to permit Humble Oil Company to construct an onshore oil processing plant overturned the Board of Supervisors' decision to permit such a facility by a vote of 44,290 to 41,404.

In June of 1969, a high level commission appointed by President Nixon's scientific advisor, Dr. Lee Du Bridge, recommended an accelerated program of well

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drilling to reduce the underground pressure that was forcing oil to the surface of the ocean floor.

(9) Life Sciences

The spill damaged the channel's ecological system. Birds, sea lions, and even whales were killed. Tidal pools and beaches were covered with oil. The barnacle population and surf grass were destroyed.

Union Oil's use of a water-and-sand mixture, pumped under high pressure to clean oil covered rocks, eliminated a large number of crabs, algae, limpets, and snails. The oil dispersants used by Union Oil were highly toxic.

Some scientists were distressed by the possible effects which a very thin, micromillimeter film of oil spread across the oceans of the world might have upon the earth's refraction index. Others were concerned about the affect of such a film on the water cycle: Such a film, they said, could decrease the evaporation of water, hence rainfall.

(10) Humanities

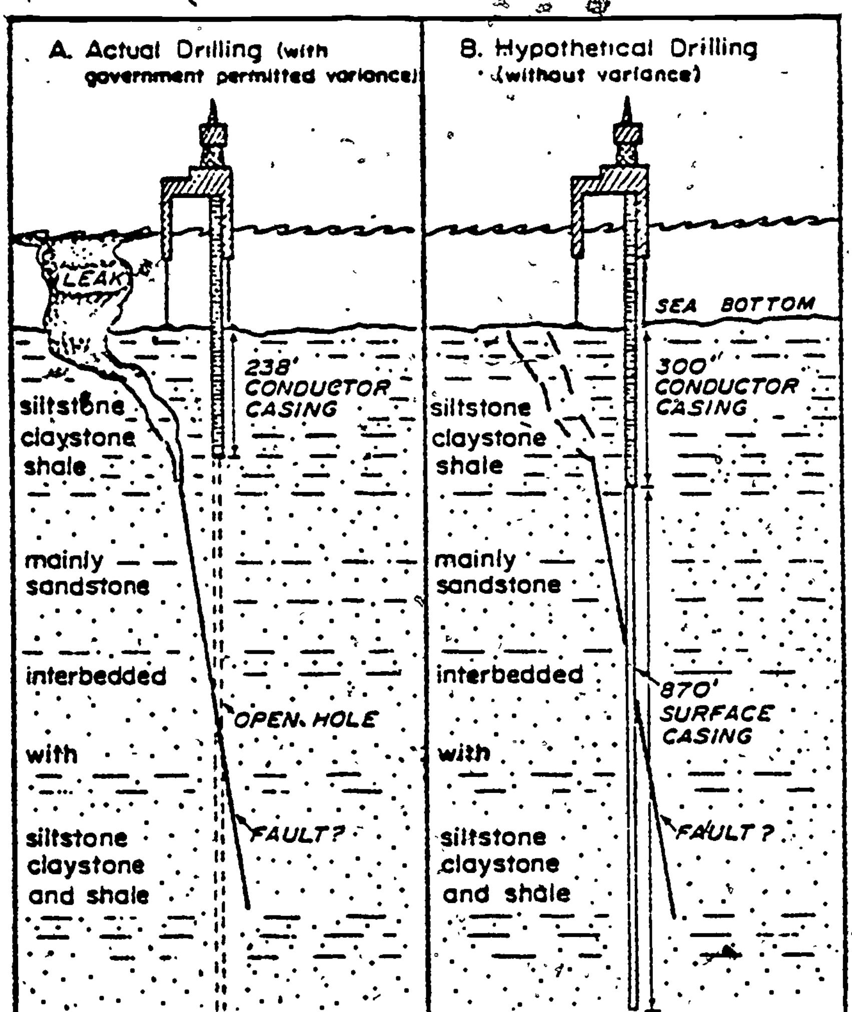
The residents of Santa Barbara viewed the oil rigs as an aesthetic affront, and the spill as a further assault on the scenery of the channel.

c. Summary

Since engineers are usually in control, and make some of the major decisions in engineering projects, should they at least have an awareness of all of the parameters of concern in such projects? What level of understanding is necessary for the safe conduct of major engineering projects such as oil exploration in a critical ecosystem?

A much greater indepth analysis is required to determine cause and effect relationships between actions taken or omissions which resulted in the Santa Barbara disaster. The analysis presented here is similar to "Monday morning quarterbacking," i.e., looking at an event after the fact and trying to extrapolate in a reward direction.

FIGURE



NOTE: Figure A shows the casing program in Union's Well A-21 as approved by the federal government. The federal requirements for a full 300' of conductor casing and approximately 870' of surface casing, as shown in Figure B, were waived. Note that oil might have been prevented from escaping to the surface if a second string of surface casing had been installed in A-21. The sketches are diagrammatic. Actual geology and fault-fracture patterns are much more complex than shown.

<u>Oil Pollution and the Public Interest: A Study of the Santa Barbara Oil Spill</u>, A. E. Keir Nash, Dean E. Mann, Phil G. Olsen.

2. THE BAY AREA RAPID TRANSIT SYSTEM - TRANSPORTATION

For many years, rapid mass transit has been portrayed as that ideal of the future where technology will effortlessly cater to mankind's every need. Just how successfully technology will fulfill the dictates of the future was tested by the massive engineering project which created the Bay Area Rapid Transit (BART) system, a system developed in response to a demand to provide San Francisco, Oakland, and the surrounding urban areas in the San Francisco Bay Area of California with a safe, reliable, inexpensive means of commuter conveyance.

The breadth of this engineering project was so great that it dealt with all aspects of the transportation subject. Feasibility studies, dating back to 1951, were examined to determine the underlying nontechnical aspects of the project and to analyze their effect on the technical aspects. The actual construction of the system was also reviewed, with emphasis on the deficiencies found within the project and their relationship to the "fields of understanding."

a. Background

Most of the following historical material was taken from a paper prepared by Norman Kennedy, Associate Director of the Institute of Transportation and Traffic Engineering. In "San Francisco Bay Area Rapid Transit: Promises, Problems, Prospects," Mr. Kennedy traced the history of BART from its creation in 1949, presenting the arguments for and against the system; describing some of the major problems confronted and solved by BART during the construction period; and appraising its role in the total transportation system of the Bay Area. Other sources of information are included in the bibliography found in Section VIII.

In 1949, the California State Legislature established the Bay Area Rapid Transit District, but no action was taken in the following two years to establish the district as an active agency. However, newspapers carried articles throughout 1950 concerning the need for an educational campaign in behalf of a rapid transit system.

During the 1951 legislative session, the 1949 Act was amended to create a BART Commission to study and investigate the rapid transit problems of the San Francisco Bay Area. In July 1952, the Commission engaged consulting engineers to assist in its study. The consulting firm submitted its report in December, concluding that, "a unified rapid transit system. . .is necessary if the ultimate potential of the region is to be realized." (Kennedy, p. 2) The firm recommended that the Commission prepare a long-range regional development plan, undertake origin and destination studies of interurban passengers, study the general economic and physical functions of private and mass transportation, prepare an overall regional transit plan, prepare preliminary plans, and make a financial analysis of the first stage of construction.

Relying on the report, the Commission asked for an appropriation of $400,000 from the State Legislature and an additional $350,000 from the nine Bay Area counties. The Commission stated, "The increasing seriousness of the traffic congestion and the increasing heavy toll that is being taken in lives, property damage, and in adverse effect on the economy of the area demand that prompt action be taken now to arrive at a definite solution to the problem of moving people safely and conveniently through adequate transportation facilities." (Kennedy, p. 2)

Although consulting engineers and the Commission did not specifically state that a rail system was required, a writer for the San Francisco Chronicle concluded that, "Steel rails and rubber tires, coordinated to form a regional rapid transit system, are the key to orderly, prosperous growth of the nine-county San Francisco Bay Area." (Kennedy, p. 2)

In response to the funding request, the Legislature granted to the Commission $400,000 in 1953 to match the $350,000 expected from the nine counties. In August of 1953, the Commission announced its selection of the New York engineering firm, Parsons, Brinckerhoff, Hall, and MacDonald (PBHM) to conduct a study of rapid transit possibilities for the Bay Area.

The PBHM report was officially submitted to the Commission and was released to the public on January 5, 1956. The report's summary of major findings, conclusions and recommendations began with:

"'The San Francisco Bay Area Rapid Transit Commission in initiating this survey set forth for investigation these basic questions:

1. Is an interurban rapid transit system needed for the Bay Area?

2. If so, what areas should rapid transit serve and along what routes should it be constructed?

3. What type of rapid transit facility would best meet the Bay Area's needs?

4. Is the cost justified?'" (Kennedy, p. 4)

In response to the first question, PBHM wrote, "We, on our part, are convinced that the prosperity of the entire Bay Area will depend upon the preservation and enhancement of its urban centers and subcenters. Sustaining these as concentrations of employment, commerce, and culture will depend on the reinvigoration of interurban transit." (Kennedy, P. 4) A "main line" system comprising 123 miles was recommended in answer to the second question. The firm concluded that a "supported train" system, including the application of rubber tires, was the most desirable alternative for the Bay Area. According to Kennedy, the advantages of such a system were never discussed in detail. They were referred to only in general terms as possible time savings to travelers, safety and the effect on business and commerce. In describing the report's justification for the proposed system, Kennedy quoted the following statement found in the report: "We do not doubt that the Bay Area citizens can afford rapid transit; we question seriously whether they can afford not to have it." (Kennedy, p. 4)

The PBHM report was accepted favorably by everyone according to newspaper accounts at the time. Kennedy summarized the public's reaction to the proposed system by quoting an editorial found in the San Francisco Chronicle of April 15, 1956:

> "A panel of selected speakers, engineers, planners, redevelopment consultants, economists, legislators--talked to a daylong conference of some 200 civic leaders one day last week about rapid transit.
>
> "They agreed that rapid transit is, beyond dispute, the most important single problem facing the Bay Area--that the future well-being of this nine-county metropolitan area, an economic as well as a geographic unit, is bound up in the free and easy movement of people and goods.
>
> "Despite the importance and urgency of the problem, despite that its engineering and financial aspects have been expertly engineered and researched and reported upon and widely publicized, the conference indicated that there is

profound and general public ignorance about rapid transit--what it is, what it will accomplish, who will pay for it, and how, why its cost is so richly justified. It appears, said one speaker, that we have been talking to ourselves.

"Whereupon other speakers prophesied with considerable head-shaking that unless the public is educated, unless it is made aware of the findings of engineers and economists, unless it is made to want rapid transit badly and want it now, the exhaustive reports on which the State and the nine counties have just spent $750,000 will collect dust and accomplish nothing more." (Kennedy, pp. 6, 7)

According to Kennedy, the Chronicle declared its intention to do its part to educate the public to the need for rapid transit. Kennedy adds, "The other major newspapers joined in the 'educational campaign' as civic and political leaders carried the matter to the State Legislature for appropriate legislative action to create a public agency and provide it with a supply of money." (Kennedy, p. 7)

This concerted marketing effort was successful. The Bay Area Rapid Transit was granted the powers considered necessary to enable it to finance, construct, and operate a modern rapid transit system within its boundaries by the State Legislature in 1957. After much political maneuvering (see Kennedy for detailed information), the number of counties included in the BART district was reduced to three and BART's major capital financing plan was approved by the district voters. The bond issue included a $792 million general obligation issue for construction of the basic system exclusive of the trans-bay tube and its approaches, and the required rolling stock.

One week after the successful bond election, the BART Board announced its intention to continue employing the joint venture of Parsons, Brinckerhoff, Quade, and Douglas; Tudor Engineering; and Bechtel Corporation to design and supervise construction of the 75-mile system.

After the dismissal of allegations made in an injunction suit brought by a number of engineers charging that the engineering contract was a "give away program," and further political maneuvering and planning, eventually construction of the BART system began. The trans-bay tube and related approaches were to be constructed through revenues provided by the State of California which derived these revenues from tolls associated with the operation of several Bay bridges. In addition, the district was authorized to impose a one-half cent sales tax in the three BART counties in order to support a $150 million bond issue which was found to be required to complete the 75-mile system. Also, the federal government under grant contracts to the district provided financial assistance for research, beautification, certain construction projects and transit vehicle procurement. The rolling stock was acquired as the result of another allocation by the Legislature. The nonconstruction portion of the district's program has to be paid for by property tax assessment in the three county district funds made available by gasoline sales tax and operating revenues.

During the construction phase, much attention was given to other nontechnical aspects of the BART system. Numerous painters and even a mosaicist were hired to make the BART system look attractive. Two different kinds of transit cars were designed, substantially increasing production and operation costs, to give the trains a modern streamlined appearance. In addition, numerous studies were conducted to determine rapid transit's impact on social mobility and the corresponding consequences. For example, many urban affairs experts concluded that transit systems such as BART could be used to overcome the physical and social immobility often found in ghettos.

Mr. Kennedy's research and numerous other articles and studies indicate that the justification for BART was primarily based on economics and nontangible cultural considerations. The news media, employing communication arts, played an important role in selling the project to the public. The scope of the project was eventually determined by political and economic considerations. Consequently, many of the technical decisions were largely determined by nontechnical considerations.

b. Project Analysis

Many technical and nontechnical considerations were involved in the design, development, construction, maintenance, and operation of a rapid transit system such as BART. Many decisions made in response to nontechnical demands resulted in significant developmental, constructional and operational costs and system deficiencies. These increased costs and system deficiencies were identified in a report prepared by the Legislative Analyst of the California State Legislature. The following section discusses these deficiencies which were categorized and analyzed according to the "fields of understanding:"

(1) Design

The BART system was designed to use an automatic train control system (ATC) for speed, braking, acceleration, and train spacing. Some of the design deficiencies in this system, identified by the California State Legislature, are summarized below:

To minimize the problems of signal cross talk from adjacent track sections, Westinghouse selected a power level that was considerably below that utilized in conventional track circuits for train detection purposes. The voltage and current was not sufficient to break through the thin layer of rust and dirt film existing between the train wheels and the track to provide for reliable protection of a train that was stopped on the track or in some sections of the track crossovers. Under these conditions, the train protection circuits in the local station ATC equipment did not take required corrective action to slow other trains on the track in order to avoid a potential collision.

It was reported during the legislative investigation that the BART ATC system was designed for dry rail conditions and that no detectors had been installed to automatically reduce train speed under adverse rail conditions. It was noted that BART could encounter wet rail conditions at grade level and elevated track sections and could possibly encounter ice conditions on the Orinda grade.

Within the car-borne ATC equipment, speed control and program braking circuits incorporated speed control crystal oscillators which could generate erroneous speed commands to the car traction motors. In the event that an erroneous speed command called for increased speed above that designated for a particular speed zone, a fail-safe stop would not occur. According to a written modes-of-failure analysis prepared by the Battelle Memorial Institute in September 1971, the speed control circuits as designed by Westinghouse made no provision for fail-safe braking in the event that one of the crystal oscillators generated a speed command other than required. Battelle inferred in its report that crystal oscillators could operate at a frequency mode other than that intended without having a manufacturing defect present. The report stated that high quality quartz crystals have more than one possible mode of vibration in signal output, based upon physical dimensions, thermal effects, aging, and crystalographic orientation of the crystal.

Several problems with the transit cars were identified by the legislative investigation. There were inadequate hand holds in areas six to eight feet on either side of the entrance doors and at the front and rear of the transit cars. Gaps between the station platforms and trains were observed. This problem presented a very serious hazard to boarding passengers because the doors are open for only 20 seconds under normal schedule operations and are closed automatically by the train control system. There were several incidents of children catching their feet sideways in this gap during pre-revenue tours and revenue service. In addition, unexpected large volumes of passengers resulted in broken air springs beneath the cars and even wider platform gaps. Also, the adequacy of ~~the~~ structural safety of the lightweight BART transit were questioned after a Chicago accident where new lightweight transit cars incurred unexpected structural damage at a reported impact speed of 30 miles per hour.

Examination of the Fremont track extension during the legislative investigation revealed that the track run-out area extended only forty feet beyond the station platform before the start of the sand barrier. This terminal track extension represented only one-half of a car length which was inadequate to complete the emergency braking of trains to be scheduled through the Fremont station. BART was unable to present any evidence to the State Legislature of having engineered the sand pile barrier with adequate safety factors which should have been included within shock absorbing and restraining structures at all track terminal points.

(2) Communication Arts

During the investigation, BART was in the process of preparing a manual of operating procedures. The procedures were being presented in narrative form rather than in a form allowing for quick reference. The manual also contained procedures for train operators, yard personnel, shop personnel, and maintenance personnel. The Legislature recommended that the procedures for each job category be split into individual manuals and would be most effective written in brief, easy-to-refer-to check list formats. It was further recommended that the manual be reduced to pocket size and be designed to permit quick revision with insert pages.

Technical problems within the automatic train control system, which were critically related to train protection and passenger safety, were communicated to the safety engineers in general terms, if at all.

(3) Ethics

Numerous ethical questions involving conflicting considerations and value judgments were raised in the discussion of BART. According to the California Society for Professional Engineers (CSPE), three engineers working for the BART ATC section identified design deficiencies in the ATC system. They notified the BART management of the problems and asked that action be taken to correct them. When the BART management did not take corrective action, the engineers went to the BART Board of Directors. They were subsequently dismissed from their jobs by the BART management.

One of the engineers was a member of CSPE and contacted the society for assistance. The society was unsuccessful in its attempt to determine the cause for dismissal, but conducted interviews to determine the merits of the engineers' claims. As a result of these interviews, the society circulated a public petition calling for a legislative investigation of the BART system with emphasis on the safety and cost aspects. The petition was successful.

The three dismissed engineers suffered financial and personal hardship and subsequently filed suit against BART. The CSPE and the IEEE prepared briefs concerning the ethical questions involved. A formal amicus curiae was filed in behalf of the three engineers by the IEEE. The amicus curiae focused upon the engineers' responsibility to protect public safety above all other considerations. The case was settled out of court. Thus, the legal/ethical issues involved did not, according to CSPE, become a matter of public record.

The primary issue was the adequacy of the automatic train control system. BART and PBTB took a public position that all cars in revenue service had been subjected to formal qualification and acceptance testing of the speed control circuits. All evidence available to the Legislature indicated that the speed control circuits on all transit cars that were currently in revenue service did not possess required fail-safe features and had not been adequately qualified for reasonable assurance of passenger safety.

PBTB indicated that operational testing of the speed control and breaking circuits had been completed for all local station ATC equipment on the Fremont line prior to the starting of revenue service. A review of the testing documentation by the Legislative Analyst Office revealed extensive deficiencies in the test data sheets. In addition, documentation evidencing completion of safety tests which were essential to pre-revenue qualification of the local station ATC equipment had not been completed, reviewed and approved by responsible officials of PBTB, BART or PUC in order to establish the required certification of these critical circuits. According to the state legislative report, pre-revenue qualification and acceptance testing of the ATC system placed in revenue service on the Oakland to Fremont line was not completed and adequately documented for car-borne, local station and central control center ATC equipment. Many compromises were made to place transit cars in revenue service on September 11, 1972. The legislative investigation found that the PUC created a false sense of security by issuing an order it could not implement. General Order 127, stated that all plans and specifications for the BART ATC system had to be reviewed and approved by PUC prior to construction and installation. Following completion of construction, inspection of this system by a representative of PUC was required prior to receiving written approval for operation of the completed systems. The General Order also required that all features of the ATC system possess fail safety and that all trains should be detected continuously with separation between trains not less than the maximum stopping distance of the following train. In addition, route selection was to be provided for the alignment and locking of the protected routes wherever trains may diverge, converge, cross or conflict in any way. Also, the train protection was supposed to insure that speeds of trains never exceeded a safe distance profile over the entire system. The State Legislature concluded that PUC did not have the technically qualified personnel necessary to carry out the provisions of this order.

On October 2, 1972, a BART train traveling southbound from the Union City station ran past the Fremont station platform into the sand barrier at the end of the track, injuring four passengers and the operator, and damaging several transit cars. BART's contention that in the Fremont accident the emergency braking system was operative and had slowed the train down to approximately 26 miles per hour before the train impacted the sand barrier, contradicted the testimony of the train operator and other accident witnesses who offered sworn testimony to the BART and PUC inquiry boards that the train was traveling 40 to 50 miles per hour. According to the legislative investigation, the approximation of 26 miles per hour was based upon an erroneous resistance factor and a resultant erroneous determination of kinetic energy for the Fremont accident. In addition, BART calculations made no allowance for a considerable amount of energy absorbed by a wood retainer wall and pilings which were sheared off by the train, several large equipment boxes wrenched from under one of the cars, and distortions of the underbody frame members. These factors combined to indicate that the train may have been traveling at a rate of speed at impact which was closer to the speed reported in sworn testimony.

(4) Management

In the Legislative Analyst's report, numerous management deficiencies were discussed. In summation, BART management circumvented the mandatory requirement of Section 28990 of the Public Utilities Code requiring competitive bidding for all procurement contracts in excess of $3,000.

In awarding the contract, BART accepted the proposal of the lowest bidder without requiring prior demonstration of the proposed system before giving the go-ahead for final design and installation. The competitive bid, with which Westinghouse won the ATC contract, was based upon a system design which was totally different from the design which it subjected to test at the Diablo Test Track. The Westinghouse design deviated significantly from the proven designs of General Railway Signal Company and Westinghouse Air Brake Company. Prior to the award of the contract to Westinghouse, representatives of the Public Utilities Commission stated orally and in written communications to BART management that the past experience of the potential bidders in building automatic train protection, track circuits, and signaling equipment should be given priority consideration in conjunction with evaluation of quoted bid prices.

In the opinion of the State Legislature, the cost-plus retainer agreement between BART and PBTB was disadvantageous to BART because it established inadequate controls over charges for reimbursable costs, overhead costs and profit. Although agreed upon budget controls may have served to provide some restraint over expenditures, the basic agreement offered no incentives to control excessive costs. A cost-plus fixed fee agreement with possible increases for enlarged scope, negotiated on an annual basis, would have been more advantageous.

The same unit in the organization had the responsibility for both purchasing and receiving. The Legislature concluded that, "This practice is not consistent with maintaining sound internal controls which should provide for the separation of purchase order placement and receiving functions."

In awarding the contract for transit vehicles, BART based its decision on the low bid Rohr Corporation submitted for the basic order of the first 250 cars. The propriety of this decision was questioned by the Legislature because BART needed more than 250 cars to operate the 75 mile system. The bid submitted by Pullman was actually the lowest total bid for 350 cars.

In evaluating the bids for the basic 250 cars, BART applied a calculated efficiency adjustment to each bid to allow for an estimate of car weight and electric power consumption made by the bidding company. If the bidder's estimates of weights and/or power consumption were below a standard value, his bid was reduced prior to evaluation. If his estimates were above the standard value, his bid was increased. The validity of this correction to actual power consumption was questioned by the Legislature because of doubt on the part of engineers that this energy could be fully utilized by other trains to produce a power savings for BART. The Legislature concluded that, "This procedure for adjustment provided an opportunity for the bidders to make arbitrary weight and power consumption estimates to produce a low bid and then delay any offsetting penalty until the completion of the contract."

The legislative review of accident, incident, and discrepancy reports related to failures in the ATC equipment revealed a lack of consistency in information presented and a variation in report forms used. Organizational policies establishing reporting responsibilities, reporting distribution, and follow-up corrective action responsibilities were not visible. Distribution of these reports varied making analysis of the problems and systematic corrective action very difficult.

"The field notes of PUC engineers monitoring revenue service also contained indications of occurrences where the operator initiated emergency braking because of possible malfunctions in the ATC equipment. This would indicate that the BART reporting system was failing to report and document all incidents and discrepancies that occur in the ATC system."*

The Legislature concluded that a condition of fragmented responsibility and authority in matters involving safety existed between the Operations Department and the safety engineering group of the Insurance Department. Effective working lines of communication and follow-up had not been established between the Operations Department and the Insurance Department. A review of the then current activities of the BART safety engineering organization revealed that the safety engineers were primarily involved in housekeeping and safety problems within the station and shop facilities, parking lots, train ways, and the rear areas. Attention to these safety matters was viewed as important; however, there was minimal involvement of safety engineers with the critical safety aspects of train operations.

BART had not established capability in its organization to trouble shoot, or maintain and operate the complex ATC equipment. In order to provide the necessary technical support in the operational phrase, BART was forced to enter into a professional services contract with Westinghouse. The cost of this contract was forecast to be $400,000 for the first contract year. The Legislature concluded that, "Since Westinghouse was demonstrating a lack of ability to bring the system into operation, it appeared that BART was taking an unwise risk depending upon Westinghouse to maintain the system."

In developing the San Francisco Bay tube design, BART apparently did not document a comparative analysis of the original joint design, the proposed mechanical sliding joint design, and other available alternatives.

PBTB and BART committed themselves to extensive rework of trans-bay tube sections and fabrication of the new sliding joint sections (to replace the rubber gasket design included in the original plans) without making prior estimates of the costs of this work and without obtaining contractor bids or estimates. The work was started without approved change orders, and continued for several months before the BART Board of Directors was notified of the work and informed of expected costs.

PBTB developed the concept of the fare collection system and subsequently issued specifications and drawings which indicated the configuration of the machines and how they were to be interfaced within the individual BART stations. In keeping with the performance contract, IBM provided PBTB with design information to adjust contracts for the construction of BART stations such that the fare collection equipment could be accommodated by the structures in the station. According to the Legislature's findings, PBTB failed to notify the individual contractors building the stations of these design changes. Consequently, significant alteration of station interiors was required. BART had to pay the cost of this remedial work, estimated at $183,500, because both IBM and the individual contractors performed according to the terms of their individual contracts.

(5) Law

The Legislature concluded that, "The retainer agreement (between BART and PBTB) was vague in establishing compensation standards and required definitive interpretations."

c. Summary

The BART system is currently operational. The cost of operating the system and amortizing the capital investment has been determined to be such that the system will always require heavy financial subsidy. The system is probably one of the most modern in the country, but the deficiencies have definitely reduced its attractiveness to the taxpayers. Additionally, the company that produced the rolling stock is no longer in that business, and the availability of equipment for the future is subject to question.

3. DIABLO CANYON NUCLEAR POWER PLANT - ENERGY

The design, development and construction of a nuclear power plant involves a multiplicity of complex, interrelated issues. For example, the least expensive design may not be in accordance with government regulations and public sentiment. In effect, many engineers are in "responsible charge" of various aspects of such a complex engineering project, and are required to make decisions often involving trade-offs that accommodate the conflicting demands of interest groups, public sentiment, and government regulations. These demands involve numerous "fields of understanding."

In the following sections, many of the issues confronting engineers are discussed as they relate to the "fields of understanding." Considerations involved in the design and development of a specific power plant (the Diablo Canyon site) are discussed, followed by a more general discussion of those issues involved in the design, development and construction of nuclear power plants.

The Diablo Canyon Power Plant, developed by Pacific Gas and Electric, typifies a major engineering endeavor, i.e., a coast sited power plant development. The project has been the subject of controversy because of its location near earthquake faults, and because of potential environmental interaction with coastal ecological systems.

a. Alternative Generation

The most widely publicized considerations leading to the selection of nuclear-fueled power generation over other alternatives were economic. In 1970, hydroelectric generation constituted half of the power resources available to meet PG&E area systems needs. However, much of this hydroelectric capacity is low capacity factor power which is generally used during peak load periods. Requirements for the seventies are primarily for base-load generation for which a nuclear plant is well suited. This choice also conserves fossil fuel resources, and avoids air pollution problems associated with fossil fuel plants.

Site Selection

Political, economic, regulatory, safety and ecological consideration helped determine the selection of the Diablo Canyon site. After extensive study, the site was found to best meet the needs of PG&E's electric customers on the one hand, and the various public and private interests in land use, ecological values, natural resources and recreation on the other. The search for a suitable site began in 1960, and by 1962, attention centered on a site in the coastal dunes near Nipomo, 18 miles southeast of the Diablo Canyon site. Although the site had been zoned for heavy industry, groups interested in preserving the Nipomo Dunes area for its ecological and recreational values urged PG&E to seek another site. With the cooperation of the State Resources Agency and the Sierra Club, the Diablo Canyon site was finally selected.

b. Alternative Cooling Systems

The shoreline discharge system, part of the Diablo Plant's ocean water cooling system, was selected because of competing ecological and construction considerations. Several alternative systems were examined, including cooling towers and evaporative cooling ponds.

Nuclear plants, such as Diablo Canyon, operate with a thermal efficiency of about 32 percent. About a third of the energy released by the fission process is converted to electricity, the rest must be dissipated as waste heat. At Diablo Canyon a "once-through" cooling system using ocean water was selected. Water pumped from Diablo Cove is circulated through the plant's condensers and back down to the shoreline discharge structure. In the process, the water temperature is raised about 18° F.

Because of high additional costs and lack of environmental advantages, alternative discharge and cooling systems were not justified. In cooling towers, evaporation of large quantities of fresh water produces the cooling effect. This was seen, however, as a poor use of a scarce resource. Salt water was considered for use in the towers also, but environmental pollution from salt emissions into the atmosphere was deemed too serious. Another alternative, cooling ponds, would also avoid raising the temperature in Diablo Cove, but would require substantial land area and a water supply to compensate for large evaporation losses. It was PG&E's belief that once-through cooling, using ocean water, was the least expensive alternative and would result in the highest power plant efficiency with minimal land use.

c. Biological Impact

Biological effects were considered and evaluated by a series of studies in Diablo Cove and surrounding waters. The primary objective was to establish background conditions and the impact of the thermal discharge on marine life. Due to its commercial importance in the area, the abalone industry there was given considerable attention. Although the cooling water discharge could create unfavorable thermal conditions in the Cove for some species, other species less sensitive to the warmer water would eventually replace them, resulting in a change in species composition in the Cove, but a denser and richer association of organisms.

d. Radioactive Discharges

Design, cost, legal and ecological considerations are primarily involved in the control of radioactive discharge. In the operation of a nuclear power reactor, most of the radioactive materials produced are contained within the fuel elements of the reactor vessel. Small quantities of liquid and gaseous material are released from the plant by a strictly controlled process. The design of the plant keeps these releases as low as practical and also within AEC limits. Because not all of the radioactivity generated is retained in the fuel rods, the power plant is equipped with an extensive waste handling system. Radiation monitors and radiochemical analysis maintain surveillance over releases from the waste disposal system.

Man can be exposed to radiation in two primary ways, externally, from gaseous wastes, and internally, from ingestion of seafood containing concentrated radioactive wastes. It was estimated that radiation exposure to persons in the vicinity of the plant would be 0.6 millirem per year. Tests also determined that in no case would "body burden" of any species group in Diablo Cove exceed the permissible "body burden" for man. Because lower forms of life are less sensitive than man to radiation, it was concluded that no hazard to marine ecology existed due to plant operation. To verify these conclusions, an extensive environmental monitoring program was designed to aid in confirming the effectiveness of waste disposal systems and to develop procedures for increased protection of the public from the radioactive effluents of plant operation.

e. Construction Effects

In building the units at Diablo Canyon, contractors focused their efforts toward preservation of the area's ecological and aesthetic qualities. During construction, efforts were made to minimize adverse environmental effects associated with large scale construction activity. Overall topographic, vegetative and wildlife characteristics of the site were disturbed as little as possible.

Road, warehouses, laydown areas and the construction camp were planned to be as unobtrusive as possible. The access road from the town of Avila Beach to the plant site was carefully routed to accommodate any future potential land use and to consider the natural and scenic features. Cuts were kept to a minimum, and grading was matched to natural contours. Landscaping with native plant materials minimized ecological impact on local flora and lessened erosion problems.

PG&E cooperated with environmental preservation groups to minimize disturbance of the large coastal oaks in Diablo Canyon. Although the oaks were not unique or rare, the switchyards were arranged at different levels to fit the topography and avoid large oak stands. Where necessary, natural appearance and forage were restored by a long-term landscaping program.

Special criteria were used for breakwater construction to prevent adverse environmental effects. Dirt and debris discharges were controlled to prevent objectionable foaming. Beaches impaired during construction were restored to their original condition and protected against heavy ocean surf by precast concrete tribars.

To help restore the site after construction, persons knowledgeable in restoration methods and familiar with native flora tested soil stabilization methods developed a comprehensive program for vegetation supply and natural landscaping used on the site.

f. Aesthetics

Aesthetic considerations greatly influenced the design of the Diablo facility. PG&E's philosophy was to have the architecture of the plant make a bold statement that would compliment the natural coastal setting. The plant was treated as an integral part of its surrounding and care was taken to unify and contain the various plant functions within as limited an area as possible. Earth colors were used on the structures to harmonize with natural surroundings, while natural concrete finish was matched to the texture of the sea cliffs. Power plant outbuildings were arranged to give proportion and balance to the setting. For instance, the horizontal turbine - generator building, with narrow windows and rounded roof structure, reflects the sloping hills nearby; the reactor containment building contrasts with a rounded vertical element.

g. Waste Disposal

Complex and controversial issues in the area of design, political science, physical science, systems management and biological systems are involved in the management of nuclear waste. During reactor operation, most of the radioactive wastes are contained in the fuel rods. As the fuel rods expend their energy, they are periodically removed from the reactor and stored until such time as they can be shipped to a reprocessing plant to have the residual fuel separated from the waste materials. Since the wastes consist of a multiplicity of "created" elements which have their own radioactive characteristics, management of them becomes a major design consideration. Some of these wastes have a very short half-life, however, some have a half-life of thousands of years (Plutonium 239). At present, wastes are stored in cooling ponds at the individual power plants for eventual shipment to a federal depository. The ERDA plans to solidify these wastes and bury them in stable geological formations such as salt mines. However, it is a widespread opinion among scientists that waste disposal will require a high degree of perfection, and social and geologic stability to avoid endangering subsequent generations. The chance of premature waste release could pose a threat for hundreds and even thousands of years. Engineers will be challenged by the complexities of the disposal issue as methods are brought into full use in 25-30 years.

h. Safety of Operation

In an engineering project the magnitude of a nuclear plant, there are many areas of concern in regard to safety of operation. Consideration of biological systems, design, life sciences and law are a few of the fields involved. Because the hazards of nuclear plants are potentially large, all parts of the nuclear fuels cycle must be examined for public risk.

Although the largest fraction of the radioactivity in the reactor is due to the isotopes and transuranic elements produced in the fissioning of uranium, the remainder is the result of the capture of neutrons by the reactor structure material. Once the reactor shuts down, there is a rapid decay in radioactivity which produces heat. It is the need to remove this residual heat after shutdown which has led to the concern over the many safety features of the reactors. The Nuclear Regulatory Commission was created to ensure adequate protection in reactors by specifying multiple barriers to contain radioactive material and emergency systems to maintain the effectiveness of the barriers.

Competition from other power sources is another aspect of power plant economics. Reliability is also an important issue in the economy of plant operation. If nuclear plants break down more frequently than coal or oil-fired plants, then some of their economic advantage is lost. Because nuclear plants involve higher initial capital costs than conventional plants, they are particularly sensitive cost wise to changes in "capacity factor." This is because a conventional plant is able to cut back full deliveries in the event of a plant breakdown, but this is not easily done in a nuclear plant (it's fueled only once a year). So, fine tuning is much more important to the engineer concerned with nuclear power generation than with the less complex oil or coal technology.

j. Public Policy

Nuclear power has become a topical issue in recent years. In California, the voters considered a change in the Constitution to severely curtail the development of new power plants and reduce the operation level of existing ones. Proposition 15 (Constitutional Amendment) was one of the hotly contested ballot issues in the June 1976 election in California. In conjunction with the issue before the voters, the Legislature considered three other pieces of legislation that in essence addressed many of the same issues contained in the proposition. In particular, the issue of nuclear power development brought into focus the interaction between engineering and the public need. Many engineering companies, utilities and manufacturers became involved in this issue, and there was greater interaction between the technical community and the general public than had ever before occurred.

The importance of the development of public policy in a technical area was a traumatic lesson to the engineering community that had little previous understanding of the political and governmental process. Many engineers were called upon to sit on a panel to discuss the issues. Television appearances and other media contacts were frequent. Other engineers were asked to testify in the hearings conducted by the California Legislature in conjunction with the Proposition and the three legislative bills.

What should be the extent of the engineer's understanding of the political and governmental process in light of the significant relationship between the development of public policy and the application of science and technology to social needs? Should engineers be communicating directly with the uninformed public and provide input into the legislative process in areas concerning technology? Should engineers restrict their involvement to technical matters and rely on nontechnically trained individuals to develop the public policy that determines the course of the engineering projects?

The voters turned down Proposition 15, but the Legislature passed the three bills that accomplished many of the goals of the Proposition. Engineers and engineering societies were heavily involved in providing the public with information on the nuclear power issue. Because a clear majority of engineering projects are the subject of public policy, is greater interaction between engineers and the public needed to ensure that technology is applied to the best long range interest of society? How much attention should be given to the political and government process in the engineer's educational experience?

k. Summary

The development of a nuclear power plant was selected because it best exemplified the breadth of parameters involved in a single engineering project and the effect of public awareness of the issues on the engineer who must make continuous tradeoffs in the design and development of such systems. The least expensive approach may not meet the need for environmental and safety considerations. The design that minimizes costs may not be satisfactory in light of government regulations or public feelings. The most convenient site location may be very disruptive to the ecological system or may require further knowledge of the seismic characteristics of the chosen area.

What should be the extent of the engineer's technical and nontechnical knowledge of the factors involved and what should comprise the technical delivery system? What is the engineer's ethical responsibility in the design and development of systems of keen value to society on the one hand, but with major social considerations on the other? These questions must be raised in the education of engineers and in the evaluation of their minimum capability for State licensing purposes. Currently, there are no State licensing requirements for engineers who design and develop nuclear power plants. Their design is closely controlled by the federal government.

4. FIELDS OF UNDERSTANDING

The analysis of engineering projects provided a great deal of information on types of knowledge involved in engineering practice. From this information, a listing of the technical and nontechnical parameters of engineering practice was developed. Fourteen separate parameters were identified and defined:

Physical Science: The precise description of existing phenomena, often using mathematical models.

Engineering Science: The application of a knowledge of mathematical and natural sciences gained by study, experience, and practice to develop ways of utilizing materials and forces.

Design/Application: The process of applying various techniques and scientific principles for the purpose of defining a device, a process, or a system in sufficient detail to permit its physical realization.

Engineering Technology: The use of products, systems, processes, devices, mechanisms, and technical know-how associated with the practice of engineering.

Ethics: Standards of conduct.

Communication Arts: The study of effective language use.

Management Science: The study of methods of applying manpower, material and other resources to produce goods and services.

Economics: The development and study of theories of production, distribution and consumption of goods and services.

Law: Any established practice which is potentially enforceable by judicial action.

Political Science: The study of the interaction of individuals and/or structured groups with other structured groups.

Behavioral Science: The study of the individual and social behavior of people.

Life Science: The sciences of living organisms.

Humanities: Sensitivity for and appreciation of aesthetics and art.

History: The study of man's heritage.

These types of knowledge were called the "fields of understanding," encompassed in all types of engineering practice. It was clearly recognized that it would be impossible for an engineer to be an expert in each of these fields. Consequently, the degree of understanding of the "fields" an engineer should possess is relative to his function in an engineering project. Understanding must increase proportionately as the individual's scope of responsibility increases. However, it was also recognized that every engineer should have some exposure to all of these fields if the practice of engineering is to be responsibly conducted.

In order to account for the varying "degrees of understanding" an engineer may be required to possess at any time in his career, a "learning scale" was developed:

0 -- None: Having little or no knowledge of a subject area.

1 -- Awareness: Having sufficient knowledge of a subject area to recognize problems in that area and the type of talent needed to solve them.

2 -- Sensitivity: Having sufficient knowledge of a subject area to recognize problems in that area and the type of talent needed to solve them and having the ability to make some preliminary judgments concerning problems in that area.

3 -- Proficiency: Having sufficient knowledge of a subject area to recognize problems in that area and develop solutions to them.

4 -- Expertise: Having sufficient knowledge of a subject area to develop new approaches to solving difficult problems in that area.

The "fields of understanding" and "degrees of understanding" are employed throughout the study as guidelines in the analysis of engineering education and registration in their application to solving societal needs/wants.

APPENDIX B

HIRING, PROMOTION, AND TENURE ATTITUDINAL SURVEY

APPENDIX B

HIRING, PROMOTION, AND TENURE ATTITUDINAL SURVEY

I. Introduction

The effect of faculty profile in the development and maintenance of high quality engineering educational programs has been alluded to in prior studies. To further evaluate this effect on the hiring, promotion, and tenure practices of some of the major engineering educational institutions in California, a survey was conducted. The questionnaire covered specific topics and included an open attitudinal question.

Faculty from the University of California, California State University and Colleges, and the independent colleges and universities were surveyed. The methodology, analysis of responses, findings, and conclusions are presented in this appendix.

II. Distribution of Survey Questionnaire

Faculty were contacted through their institutions which were identified through the ECPD annual report. It was requested that all engineering institutions with accredited engineering programs provide copies of the questionnaire to their faculty members. The questionnaires, when completed, were to be returned by each faculty member directly to the California Commission on Postsecondary Education.

III. Survey and Response Rate

Of 1,648 questionnaires sent to institutions, 29 percent were returned. The following analysis was supported:

The mean response rate from all campuses of the University of California was 46 percent; for the California State University and Colleges system, 40 percent; and from the independent colleges and universities, 24 percent. Table I summarizes these findings.

The number of questionnaires sent to each school was based upon an estimate of the number of engineering faculty as indicated in the most current school catalog. In May of 1976, the questionnaires were sent to each dean of an accredited engineering program with a letter of instruction to distribute the questionnaires to each faculty member, and if necessary, to duplicate additional copies as required.

TABLE I

Questionnaire Response

Institutions	No. of copies sent & estimated no. of faculty	No. of responses	% response on copies sent	Mean % response per school $\bar{X}$
California State Universities	375	128	34%	40%
University of California	615	304	49%	46%
Independent Universities and Colleges	658	41	6%	24%
ALL SCHOOLS	1,648	473	29%	35%

It appeared as though most responses had been completed by the end of June 1976. However, in August 1976, a package of completed questionnaires, representing more than two-thirds of the total UC responses, was received. These had apparently been accumulated by the University's central office in "University Hall" (Berkeley) before transmittal to the Commission on Postsecondary Education. As a result of the staggered receipt of the responses, a comparative analysis was made to ascertain variations, if any, in the data received from the faculty members directly, and that which was received from the University.

IV. Findings

A. Faculty Background

The survey examined three major aspects of faculty background: (1) How many faculty members were tenured; (2) the type and origin of the degrees received by faculty members; and (3) the percentage of the faculty with experience in engineering practice.

The survey results indicated that a high percentage of the engineering faculty received their education from relatively few, institutions, and that ninety-seven percent had doctorate degrees. Of a total of 64 schools identified, Stanford, UC Berkeley, UCLA, Cal Tech, and the M.I.T. awarded 46 percent of the doctorate degrees. Sixteen percent of the respondents received their advanced degrees from Stanford University. Further analysis indicated that 75 percent of the doctorates had been awarded by 20 schools in the United States.

B. Engineering Practice

Ninety-eight percent of the responding faculty indicated that they had some experience in engineering practice. The cumulative experience profile of all responding faculty was 13.2 years. The University of California faculty indicated an average experience of 14.3 years; California State University and Colleges and independent colleges and universities indicated an average of 13.1 and 12.2 years, respectively.

These data did not distinguish between part-time consulting and full-time activities, although some faculty respondents equated a year of part-time consulting activity with a full year of engineering experience. This was one area of disappointment in the formulation of the questionnaire, since the actual nature of experience affects the understanding of engineering practice.

C. Hiring Practices

Faculty are hired through a review process involving tenured faculty and school administration. Faculty committees make recommendations; administrators implement them. An institution's policies form the basis for screening eligible applicants and consequently are important in determining who is hired as a faculty member.

Since engineering faculty participate in the hiring process, a survey question was designed to determine how faculty members ranked nine possible hiring criteria used in their institutional setting. A majority of the faculty members from the University of California and the independent colleges and universities ranked the doctorate degree as the most important hiring criteria (65 percent from UC; 60 percent from independent schools). Significant variation was noted from school to school. Table II presents the reduced data from this inquiry. The hiring criteria were ranked on a scale from 1 (most important) to 9 (least important). A more refined presentation showing the priority ranking of hiring criteria appears in Table III.

TABLE II

Ranking of Hiring Criteria

	Industry Experience	Ph.D.	Teaching Experience	Publications	Research	Masters Degree	Public Service	Prestige of Institution Previously Employed	Prestige of Institution Degree Received
Private	4.9	2.7	4.3	3.8	2.8	7.0	7.4	5.4	4.7
UC	5.5	1.9	3.9	3.4	2.1	7.7	7.4	6.2	4.8
State	2.1	2.2	2.5	5.0	5.2	7.1	6.8	7.0	6.7
All	4.1	2.3	3.6	4.0	3.0	7.2	7.2	6.2	5.4

It should be noted that the data are cumulative and that variation existed among faculty members in each of the three segments of higher education. Respondents from the California State University and Colleges segment ranked industrial experience as most important, and the doctorate degree second in importance.

TABLE III

Priority Ranking of Hiring Criteria

	ALL	PRIVATE	UC	STATE
1	Ph.D.	Ph.D.	Ph.D.	Industry exp.
2	Research	Research	Research	Ph.D.
3	Teaching exp.	Teaching exp.	Teaching exp.	Teaching exp.
4	Publications	Publications	Publications	Publications
5	Industry exp.	Prest./degree	Prest./degree	Research
6	Prest./degree	Prest./prev. em.	Industry exp.	Public service
7	Prest./prev. em.	Industry exp.	Prest./prev. em.	Prest./degree
8	Masters	Masters	Masters	Prest./prev. em.
9	Public service	Public service	Public service	Masters

D. Promotional Criteria

Engineering professors were asked to rank research, teaching and public service by the degree of emphasis each was given in promotional practices within their departments. Table IV shows the results of this inquiry according to the school systems of origin.

One-hundred percent of the respondents from the University of California indicated that research ranked number one in priority in their departments. Eighty-six percent ranked teaching and public service second and third in importance.

TABLE IV

Ranking of Research, Teaching and Public Service
by Institution

Insti.	1. Research 2. Teaching 3. Public Service	1. Teaching 2. Research 3. Public Service	1. Public Service 2. Research 3. Teaching	1. Research 2. Public Service 3. Teaching
UC	86%			14%
STATE	11%	30%	59%	
PRIVATE	15%	68%	17%	
ALL	38%	32%	25%	5%

Fifty-nine percent of the respondents from the California State University and Colleges felt that their department priorities were oriented toward public service, research, and teaching, in that order. Thirty percent felt that the proper ranking order placed teaching first, with research and public service following. Only eleven percent of this group agreed with the University of California in ranking research as number one in priority. Sixty-eight percent of the faculty from the private schools showed a belief that their departments were primarily interested in teaching, research, and public service ranked in that order. Possibly, the faculty from the California State University and Colleges were responding in light of the State mandate in the "Master Plan for Higher Education" in which the University of California was identified as the research facility for the State of California in higher education matters.

It is difficult to draw precise conclusions from any survey, but the data from this inquiry seem to fit a pattern of past recognition. The engineering education programs in the University of California tend to be biased toward basic science, math, and research. The engineering programs in the State University System seem to be sensitive to practicality and public reaction. The private institutions seem to emphasize teaching ability.

E. Attitude Toward Tenure

The respondent's feelings on the general subject of tenure varied widely. Some felt that tenure was essential to achieve academic freedom, since the system permits a tenured faculty member to express his/her feelings without threat of retaliation from the University administration. Without this protection, the faculty turnover would be high, security low, and much time would be spent on resolving faculty/administration problems. One respondent stated that it was a choice between tenure and formal collective bargaining, though the latter issue is now well-established on some university campuses.

Some respondents felt that the tenure system was self-defeating in that it locked some faculty members into positions that might otherwise be available to more creative and innovative individuals. "The system promotes stagnation at the top," according to several of the responding faculty members. One respondent succinctly presented the general opposing view when he stated, "As I see it, the meaning of tenure is no longer 'protection of academic freedom, and from summary dismissal,' but rather a license to stagnate. I believe the tenure system in its present context costs many engineering students the quality education they deserve. Half of the faculty of the School of Engineering at (name omitted to protect confidentiality) spend less than 20 hours a week doing what they are paid for. Five- and ten-year-old class notes that have never been revised are commonplace, and one professor doesn't even bother with notes, he reads the book to the students."

There were many and varied responses to the open question, but only the major issues have been presented herein.

In summary, the tenure system and its effect upon the attitude and behavior of the professional staff involved in engineering education has been a subject of debate for many years. In engineering, the institutions' policies and practices that establish the profile of the faculty have a direct effect on the type and quality of education the student receives. Education is not the only institution influenced by systems such as tenure. Conflicts have existed in public employment and private industry for many years that have led to the development of systems to provide security to workers. Though these systems have been used primarily by non-professional workers, there is increasing interest being shown by professional workers for more formal methods of resolving disputes between workers and management. The Civil Service system, collective bargaining under the National Labor Relations Act or corresponding public policy for state, local, and federal workers, are all attempts to provide some stability to the work place and to reduce the impact of human frailties in managing the activities of workers. However, the basic question is still paramount. How do these systems provide incentives through promotional policies that encourage innovativeness and creativity? Ideally, university policies should produce a dynamic faculty with insight not only into effective teaching techniques, but also into the actual practice of engineering with a clear understanding of the basic scientific principles upon which the technical aspects of engineering are based. A faculty of this nature is imperative in order to best serve the needs of students, the practicing profession and the public.

APPENDIX C

A REVIEW OF TENURE STUDIES

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A REVIEW OF TENURE STUDIES

Prior studies of engineering education have emphasized the importance of faculty in providing consistently top quality engineering education programs; however, many critics charge that the existing tenure system hampers their effectiveness to prepare the engineer for practice in "real life" situations.

In reviewing general tenure studies, it was observed that their approach was negatively critical, rather than objectively analytical. This tone was prompted by increased politicization of elements within academic institutions; diminished public confidence in the performance of colleges and universities, especially the quality of teaching within them; a nationwide debate on the purposes and direction of higher education; and severe financial constraints. The Special Committee on Campus Tensions and the President's Commission of Campus Unrest identified the operation of tenure as a possible cause of the widespread campus unrest of the 1960s. The following studies, briefly summarized, are some of the principal examinations of tenure.

1. The Rights of Nontenured Faculty: The New Constitutional Doctrine of Perry v. Sindermann and Board of Regents v. Roth, by Dr. P. Allan Dionisopoulos, states that academicians are not likely to accept the contention of present tenure system critics that the protection of academic freedom requires that there be no distinctions between teachers. He cites Perry v. Sindermann and Board of Regents v. Roth as evidence of an urgent need to pursue the question of the due process to which nontenured faculty members are entitled.

2. Steady-State Staffing in Tenure-Granting Institutions, and Related Papers, by W. Todd Furniss, was stimulated by questions of the viability of conventional tenure systems in a steady-state situation. The paper deals with the development of a college or university personnel policy "suitable for a time of little or no expansion in student or faculty numbers and also a time when stability follows a period of rapid growth coupled with considerable change in faculty expectations and in the governance patterns of our institutions."

3. The Faculty Promotion Process: An Empirical Analysis of the Administration of Large State Universities, by Fred Luthans, looks at the university as a functioning organization, and attempts to justify the use of management concepts in the analysis of academic administration. It provides a descriptive

presentation of promotion policies and practices in 46 large state universities and utilizes empirical data to analyze central control of decentralized business faculty promotions.

After summarizing the central and decentral promotion policies and practices found, Luthans concluded that (1) only 8 percent of the faculty sample felt their promotion process was well accepted and contributed to high morale; that (2) there was no evidence of well-formulated, understood and accepted promotion policies in most universities; and that (3) most policies were neither fully communicated nor their results fed back. He advocated central control of the promotion process to maintain standards and assure maximum faculty contributions to the goals of the university.

The Carnegie Commission's policy report on tenure, Governance of Higher Education, made three recommendations dealing with the decision making process in American colleges and universities:

1. That the principle of tenure should be retained and extended to campuses where it does not now apply;

2. That tenure systems should be so administered in practice (1) that advancements to tenure and after tenure are based on merit, (2) that the criteria to be used in tenure decisions are made clear at the time of employment, (3) that codes of conduct specify the obligations of tenured faculty members, (4) that adjustments in the size and in the assignments of staff in accord with institutional welfare be possible when there was a fully justifiable case for them, (5) that fair internal procedures be available to hear any cases that may arise, and (6) that the percentage of faculty members with tenure not become excessive; and

3. That persons on a 50 percent or more time basis should be eligible for tenure, but the time elapsed prior to making a decision on tenure should be counted on a full-time-equivalent basis.

Academic Tenure in American Higher Education, by B.N. Shaw, reporting on the tenure policies and procedures of the participating state universities and land-grant colleges in effect during 1968-1969, provided data for the review and/or comparative analysis of tenure.

Two of the nine conclusions drawn by Shaw in his study were that:

1. Thirty percent of the participants answered "data not available" on tenure termination proceedings and faculty dismissals, highlighting a serious deficiency in proper record keeping in these areas; and

2. That tenure termination cases were not frequent in the state universities and land-grant colleges. (14 of 80 institutions reported only 27 faculty dismissals in a 10-year period.)

Shaw made four recommendations for further examination of tenure, and suggested a format for a statement on academic tenure policies and procedures.

In a collection of essays, The Tenure Debate, by Bardwell L. Smith and Associates, important issues facing higher education were ". . . the evaluation and improvement of teaching; the balance between teaching and research, and which kinds of research are appropriate to a university; the ingredients and process of shared governance; the complex relationship between the academy and society; and the dimensions and vehicles of learning available."

Faculty Tenure: A Report and Recommendations by the Commission on Academic Tenure is perhaps the most extensive study of tenure done thus far. The report (1) examines the operations of the tenure system, (2) evaluates criticism of tenure, (3) considers alternatives to tenure, and (4) makes detailed recommendations for improvement and modification.

The major recommendation of the report was that faculty tenure should be retained ". . . because it is still the only reliable guardian of academic freedom." It is the Commission's belief that the many deficiencies of tenure were in its application and administration. These deficiencies, it was felt, were remediable by reform efforts in institutional policy, practice and professional standards, and priorities on the part of individual institutions and by faculties themselves.

The Commission's view was that the problems facing higher education were due to educational changes and could not be resolved by any simple change in academic personnel practice, such as in the modification or abolition of tenure. The Commission did not find the alternatives to tenure as workable or effective as a strengthened and renewed system of tenure.

The Commission's 47 proposals advocated (a) new emphasis on institutional responsibility, (b) attention to some neglected elements of an effective tenure system, (c) recognition of tenure problems as related to the professional development of the faculty, (d) specific means of strengthening institutional tenure plans in normal operations, (e) consideration of a number of special problems of current concern, and (f) measures for needed information and research to assist colleges and universities in improving and maintaining effective faculty personnel programs.

Conclusion

The tenure process is a matter of great concern to the academic world. How this concern is reflected in the quality or direction of instruction provided in California engineering education programs is presented in the survey results on hiring, promotion, and tenure selection criteria in the main body of the report.

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APPENDIX D

PROFESSIONAL AND TECHNICAL SOCIETY SURVEY

APPENDIX D

PROFESSIONAL AND TECHNICAL SOCIETY SURVEY

1. Background:

Numerous technical organizations, representing the technical disciplinary lines of the engineering profession, have developed in the last 100 years and for many of these disciplines, parallel accredited degree programs are offered in California educational institutions. These technical societies have a significant input into the structuring of engineering education in their respective disciplines because of their representation on the Board of the Engineering Council for Professional Development, and the participation of their membership on accrediting teams. Additionally, in California, registration of professional engineers is by technical discipline, and the technical societies have played a role in lobbying actions resulting in the establishment of new licensed technical disciplines. Once the new disciplines are established, the licensing requirements are developed by the Board of Registration with the assistance of the technical society.

All of the societies, with the exception of the California Society of Professional Engineers, are divided into local sections of national organizations. The CSPE is a statewide organization composed of chapters. The state societies such as the CSPE, comprise the controlling Board of the National Society of Professional Engineers with representation based upon state society membership. Thus, this single organization represents the interests of registered and nonregistered engineers of all disciplines. In contrast, there are several autonomous sections of the American Society of Civil Engineers in California, but each is a member of the ASCE national organization. The same is true for the societies for mechanical and electrical engineers, etc.

2. Objectives

A survey questionnaire was prepared and sent to 42 individuals in 15 major technical and professional engineering societies representing a broad spectrum of engineering disciplines.

Among the objectives of the survey were:

- To determine the relationship of the professional and technical organizations with the Board of Registration;

- To ascertain the specific interest of each society in the Act; and

- To determine whether engineering societies support the concept of mandatory registration for engineering practice.

The survey also covered: engineering examinations; alternatives to registration; licensing through the "grandfathering" method; work experience applied toward registration; "fields of understanding" in the registration procedure; and codes of ethics for engineering practice.

Each individual surveyed received an overview of the engineering registration act in California, a listing of the "fields of understanding" together with definitions, and a copy of the questionnaire.

3. Survey Groups

The following technical societies were contacted:

*American Institute of Aeronautics and Astronautics
American Institute of Chemical Engineers
*American Institute of Industrial Engineers, Inc.
American Institute of Petroleum Engineers
*American Society of Agricultural Engineers
American Society of Civil Engineers
American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.
*American Society of Mechanical Engineers
*American Society for Metals
*American Society for Quality Control
*Institute of Electrical and Electronics Engineers, Inc.
*Institute of Traffic Engineers
*Society of Fire Protection Engineers
Society of Manufacturing Engineers
*Structural Engineers Association of California

Responses were received from 13 individuals representing 10 of the 15 societies; a 67 percent return. The asterisks on the above list indicate those societies which responded.

With the exception of the American Society of Heating, Refrigerating, and Air-conditioning Engineers, the disciplines represented by the survey group are licensed under the California registration laws. Three disciplines, mechanical, electrical and civil engineering, are covered under mandatory practice provisions (with the exception of the exempt areas of practice).

4. Survey Findings

a. Liaison With Board of Registration

Eighty percent of the responding societies reported that they maintain some contact with the Board of Registration for Professional Engineers. The type of liaison varied from volunteers to ad hoc committees, and the frequency of contact ranged from weekly to two times per year. In two cases, the engineering groups claimed they had no contact with the Board. Most respondents indicated that their societies primarily communicated with Board staff members on matters before the Board, but a few also had some direct contact with Board members.

b. Primary Concerns With Engineering Act

In general, the special interests of each responding society were reflected in the following concerns expressed about the administration of the Professional Engineers Act:

1. Mandatory registration for all engineers with no exemptions;
2. Minimization of proliferation of narrowly defined engineering specialties;
3. Maintenance of high standards of engineering practice;
4. Enforcement of the Professional Engineers Act;
5. Registration of qualified engineers in the discipline of a particular branch;
6. Development of satisfactory registration examination;
7. Maintenance of the status quo;

8. Preparation of test questions;

9. Use of "professional engineer" as a meaningful and respected title by peers and the public;

10. Being informed about changes in the Act;

11. Changes causing hardships with existing practicing engineers;

12. Fair treatment of particular engineering disciplines by the Board; and

13. Safeguarding the "title" concept of the Act as presently written.

c. Monitoring Legislation and Legislative Advocates

Eighty percent of the responding engineering organizations indicated that they monitored legislation pending before the California Legislature pertaining to amendments to the Professional Engineers Act. However, eighty percent of the organizations have no paid legislative advocates/lobbyists. Over half use volunteers to follow legislation, and some rely on legislative information and research disseminated by the staff of the California Society of Professional Engineers. CSPE is not a lobbying body in the true sense, but the organization does monitor legislation and makes its findings available to members and to other interested organizations.

d. Mandatory Registration

Fifty percent of the societies favored the concept of mandatory registration for all engineering practice; twenty percent opposed it, and thirty percent did not express a viewpoint.

e. Automatic Registration for Graduates

Seventy percent of the societies did not favor automatic registration of graduates of the Engineers' Council for Professional Development accredited engineering curricula; twenty percent favored it. The same seventy percent who did not approve favored two state examinations at the termination of the Bachelor of Science program, one on principles and the other on engineering practice, separated by a specific period of time, such as two years. This is the current practice in California for established engineering specialty disciplines.

f. Registration Alternatives

Seventy percent of the societies felt that there were no alternatives to registration to provide minimum standards of competence for the protection of public health, welfare, safety and good. Thirty percent favored alternatives such as a degree from an accredited curricula, certification by the related engineering technical society, or in one instance, certification by the employer's backing and reputation.

g. Grandfathering

Ninety percent of the engineering groups favored grandfathering of currently practicing engineers in California; only the Structural Engineers Association of California opposed it. (Grandfathering is the current practice for licensing engineers into newly established specialty disciplines. Qualified applicants do not have to take written examinations.)

h. Experience Credit

The engineering societies unanimously felt that experience credit toward registration should be granted for formal engineering education. Eighty percent said they would grant a straight equivalency, year-for-year credit; ten percent favored half equivalency credit; and ten percent favored 25 percent equivalency credit. Current practice is straight equivalency for accredited degrees; half equivalency for partial or nonaccredited degrees.

i. Fields of Understanding

In the registration-examination procedure, the organizations were asked to assign a weight factor to the various "fields of understanding." Subjects receiving major emphasis were given a rating of four; moderate emphasis, a rating of three; light emphasis, a rating of two; and non emphasis, a rating of one. Since ten organizations responded, the highest possible score for each subject was 40. The following is a listing of the "fields of understanding" with the cumulative rating given by the engineering societies:

Engineering Science	36
Physical Science	36
Design/Application	32

Ethics	28
Communication Arts	24
Economics	22
Management	21
Law	20
Life Sciences	15
Behavioral Science	12
Humanities	10
History	10
Political Science	10

j. Code of Ethics

Sixty percent of the societies indicated that their organizations had a code of ethics for engineering practice, thirty percent said their groups had no code, and one society gave no response.

5. Survey Conclusions

a. Most engineering societies were cognizant of the operations of the Board of Registration for Professional Engineers, and maintained some form of contact with the Board on a regular basis. The answers to the survey questions reflected each organization's desire to protect its own special interest.

b. The engineering societies were generally satisfied with current practices and procedures, and generally favored, maintaining the status quo.

c. Fifty percent of the respondents favored changes in the area of mandatory registration. Ninety percent said that currently practicing engineers should be grandfathered into licensed engineers.

d. Most of the surveyed organizations saw no educational need to broaden the social, economic, business, legal or political environment of the engineering students. The majority of the survey group emphasized engineering and physical sciences rather than total problem orientation.

APPENDIX E

CONTINUED PROFESSIONAL DEVELOPMENT REQUIREMENTS FOR RE-LICENSURE

APPENDIX E

CONTINUED PROFESSIONAL DEVELOPMENT REQUIREMENTS FOR RE-LICENSURE

In October 1971, the California Senate adopted a resolution (SR 218) by George Deukmejian relative to continuing education as a means of encouraging registered professionals (not limited to engineers) to keep abreast of new professional developments in the fields for which they were licensed. The resolution stated that continuing education was necessary in order to safeguard the health and safety of the public. The legislation required each licensing agency in the state to file a preliminary report on continuing education and describe the approach or plan it would be prepared to adopt for its licensees.

The Board of Registration for Professional Engineers appointed the Ad Hoc Committee on Professional Development to respond to the Senate resolution. The final report of the Committee was submitted to the Board on September 30, 1975. This project examined the report and reviewed its recommendations to determine the Board's position on continued professional development.

At the time, the Committee recommended that the Board not mandate professional development as a requirement for registration renewal. Rather, it urged the Board to publish a periodic summary of significant Board actions, departmental legal opinions, Attorney General opinions, new rules, newly adopted Board policies, and disciplinary actions for use by all registered engineers.

The Committee pointed out that a large percentage of all engineering work performed in this state was not performed by registered engineers because of the exemptions allowed by Sections 6746 and 6747 of the Act, and because the Act controls only the practice of engineering in the civil, electrical, and mechanical disciplines. The Committee recommended the elimination of these exemptions so that regulations, meaningful to the public interest would be required of all individuals practicing engineering.

In addition, the Committee recommended that the Board:

- Encourage registration, particularly by universities, for all engineering students as soon as possible after graduation;

- Increase enforcement efforts, including better coordination with code enforcement officials to assure compliance with Board disciplinary actions and provide for more effective disciplinary actions for violations; and

- Establish a permanent professional development committee which would, among other things, establish a code of ethics and/or rules of conduct as part of the Professional Engineers Act. The Committee supported each engineer's obligation to maintain professional development on an ethical as well as technical level.

The Ad Hoc Committee observed that a mandated program of professional development, applicable to those engineers presently registered, would provide little or no improvement in the welfare of the public because only a minority of those registered offer their services directly to the public. Therefore, the Committee concluded that mandated professional development of registered engineers was not necessary in order to assure the public health, safety, and welfare and would not necessarily improve services to the public.

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APPENDIX F

NCEE "MODEL LAW" - ENGINEERING REGISTRATION

APPENDIX F

NCEE "MODEL LAW" - ENGINEERING REGISTRATION

The National Council of Engineering Examiners (NCEE), composed of representatives from state and jurisdictional registration boards, is a strong advocate of registration for practicing engineers, and is highly respected for its many years of experience and research. A document entitled "Model Law" was prepared by NCEE and is a reference work and guide to provide "greater uniformity of qualifications for registration, to raise these qualifications to a higher level of accomplishment and to simplify the interstate registration of engineers . . . ." This document indirectly presents the views of the member boards on the relationship between engineering education and registration, and societal needs/wants. The major provisions of the "Model Law" are presented below.

1. Purpose and Definitions

According to the "Model Law," regulation of the practice of engineering is required "to safeguard life, health and property, and to promote the public welfare . . .", and is a requirement for anyone practicing engineering. The term "practice of engineering" is the key to the scope of the Act and its purpose. The practice of engineering is given a comprehensive definition of this term: "any service or creative work, the adequate performance of which requires engineering education, training and experience in the application of special knowledge of the mathematical, physical and engineering sciences . . . ." Numerous examples of engineering practice are provided, including "such services or work, either public or private, in connection with any utilities, structures, buildings, machines, equipment, processes, work systems, projects, and industrial or consumer products . . . ." Thus, under the "Model Law," there are many areas of engineering practice included for registration which are historically exempt under the California Act.

2. Board Composition and Powers

The composition of the Registration Board and its source of appointees would also differ from the process under the California Act. Under the "Model Law," the Board would consist entirely of professional engineers, appointed by the Governor from a list provided by the State's representative engineering societies. In California, as a result of legislation passed in 1976, a majority of the Board members are nonengineers.

The "Model Law" would provide the Board with the power to:

a. Adopt and amend all bylaws and rules of procedure not inconsistent with the constitution and bylaws of the state. Adoption of Rules of Professional Conduct would be a primary duty.

b. Subpoena witnesses, compel their attendance, and require the submission of books, papers, documents, or other pertinent data in any disciplinary matter or in any case where a violation of the Act is alleged.

c. Apply for injunctive relief in cases of civil procedure to enforce the provisions of the Act.

d. Subject an applicant for registration to such examination as deemed necessary to determine his qualifications.

3. Registration Process

The "Model Law" would provide four different approaches for registration as a professional engineer:

a. Under registration by endorsement, a person holding a certificate of registration from another state with qualifications comparable to or more strict than the state in which application is made, may be registered without further examination.

b. In the second registration method, a graduate of an engineering curriculum "approved by the board," with four years or more of progressive experience on engineering projects (California requires two years of experience) may take two eight-hour examinations, the first dealing with fundamentals of engineering, and the second with the principles and practice of engineering. To qualify for state registration, the applicant must pass both examinations.

c. A third registration method is similar to the above except that it applies to graduates of an engineering or related science curriculum which has "not been approved by the board." In this case, the applicant must have eight or more years of acceptable experience (current California law requires four years of experience), and must also pass two examinations in order to become registered.

d. Under the fourth method, a graduate of an engineering or related science curriculum with 20 years or more of progressive experience becomes registered by passing the examination on the principles and practice of engineering.

The midpoint in the registration process, the engineer-in-training certificate, is incorporated into the "Model Law," but the requirements for it differ from the current California Act. Qualification is allowed through two alternate procedures. A graduate of an engineering curriculum approved by the Board may take the fundamentals of engineering examination upon graduation. A graduate of an engineering or related science curriculum not approved by the Board must have four years of progressive experience on engineering projects before he/she may take the exam. Upon passing the examination, the applicant is granted the certificate as an engineer-in-training.

4. Practice Provisions

The "Model Law" further regulates the practice of engineering in regard to public works. "The state and its political subdivisions . . . shall not engage in the practice of engineering involving either public or private property without the project being under the direct charge and supervision of a professional engineer . . . ."

Under a section entitled "Right to Practice," the "Model Law" states that in corporate practice one or more of the corporate officers designated as being responsible for the engineering activities and decisions must be a registered engineer. Furthermore, all final drawings, specifications, plans, reports or other engineering papers or documents involving the practice of engineering must be signed off by a qualified professional engineer. However, "No such corporation shall be relieved of responsibility for the conduct or acts of its agents, employees or officers by reason of its compliance with the provisions . . ." of the Act.

5. Other Provisions

The administrative procedures of the "Model Law" are not substantially different from those found in the California Act. However, the proposed Act retains exclusive control over the use of the words "engineer" and "engineering."

6. Summary

There are a number of controversial proposals in the "Model Law": mandatory registration, no industry or utility exemptions, a board composed entirely of professional engineers nominated by professional engineers, education requirements for all methods of registration, exclusive possession of the words "engineer" and "engineering," and conditional responsibility for all engineering activities reposing with the professional engineer, backed by corporate responsibility.

State registration boards endorse the "Model Law" as an "ideal" state registration act. By requiring a four-year degree for all methods of registration, and requiring registration in order to practice, the "Model Law" firmly establishes the relationship between engineering education and registration. However, the "Model Law" does not address societal needs/wants or the content of engineering education beyond the stated purpose of the Act.

APPENDIX G

INDUSTRY SURVEY ON ENGINEERING EDUCATION AND LICENSING

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INDUSTRY SURVEY ON ENGINEERING EDUCATION AND LICENSING

Since the majority of all engineers are employed by industry, a questionnaire was designed to determine how companies that employ engineers view the breadth of engineering education, the need for continued education, hiring preferences of industry, and engineering registration.

1. The College Placement Annual, 1975; the California Manufacturer's Register; and the Mirror Times One-Hundred Listing were used to obtain a cross section of California companies employing engineers.

   The first publication, the official directory of the regional placement associations, provides information concerning the positions customarily offered to college graduates by principal employers. Questionnaires were sent to 44 companies listed in the Annual; eight were returned.

   The second publication, the California Manufacturer's Register, is a listing of the manufacturing firms in California. Of the 145 questionnaires mailed to companies identified from this publication, nine were returned.

   The last publication, the Mirror Times One-Hundred Listing listed the 100 companies in California with the greatest gross sales in the 1975 fiscal year. Questionnaires were sent to all of these companies; ten were returned.

   The twenty-seven returned questionnaires (10.9%) were from companies producing high technology products (33%) and consumer products (16%), companies engaged in research and development (24%), construction (14%), and consulting firms (5%). The remaining four-percent response was from companies producing products and services that required some engineering input. There was a wide variation in the number of employees and engineers employed by these companies representing a desirable cross section of California companies.

2. Findings

   The responses of the companies identified from all these publications did not vary substantially from each other, and were therefore grouped for the discussion following.

a. Breadth of Engineering Education

In the National Science Board's report of 1972, The Role of Engineers and Scientists in a National Policy for Technology, it was established that a transition "toward a concern for a heightened and broadened use of technology in solving the problems and meeting the needs and desires of society" had occurred. By examining several engineering projects, this study identified fourteen "fields of understanding" encompassing the technical and nontechnical disciplines involved in engineering projects. Employers of engineers, when asked what degree of understanding engineers should have of each field, generally responded that engineers should have at least an awareness of the humanities, life sciences, behavioral sciences, political science and economics; at least a sensitivity for management, communication arts, ethics and physical science; and a proficiency in engineering science, design/application and engineering technology. For a more detailed discussion, see the "Societal Needs" section of the detailed discussion, in the body of this report.

b. Continued Education

As the societal demand for technology increases, so does the concern with the currency of an engineer's technical knowledge. Employers of engineers in responding to questions concerning the importance of continued education in engineering practice, indicated that about a third of them had continuing education requirements for their engineers. Fifty-six percent of them allowed their engineers to take these classes on company time. However, 48 percent stipulated that the courses taken must be directly job related. When so related, the companies were usually willing to pay 75-100 percent of the educational expense. Few were willing to pay any expenses for classes unrelated to the job.

c. Hiring

Industrial hiring policies varied substantially, but in general, companies were less interested in engineers with Ph.D.s. Over three-quarters of the respondants hired persons with a bachelor of science or master's degree, who lacked full-time engineering experience. Only half hired Ph.D.s with no full-time employment experience.

Overall, companies did not view engineering registration as an important hiring qualification. Only 37 percent sought registered engineers. Furthermore, only an average of 15 percent of the engineering staff of the responding companies were registered.

d. <u>Engineering Registration</u>

The responses generally indicated that engineering registration did not play an important role in engineering practice (probably because most practicing engineers are exempt from the registration law). Ninety-two percent of the responding companies stated that there was no pay differential between registered and non-registered engineers. Similarly, 69 percent of the companies did not believe there was a need for all engineering practice in California to be conducted by registered engineers, and 65 percent responded that they would oppose elimination of the existing registration exemptions.

Three-quarters of the companies supported the "grandfathering" provisions of the registration law. Sixty-three percent believed that experience-credit toward registration should be granted for formal engineering education. However, there was disagreement as to what the equivalence should be. Only 3 percent of the companies agreed that a straight equivalence should be granted.* Twenty-six percent would grant only 50 percent; a like percentage would grant a 25 percent equivalency.

Fifty-nine percent of the responding companies believed alternatives to registration would provide minimum standards of competence to protect public health, welfare, safety, and good. Forty-one percent favored a degree from an accredited curricula; 35 percent believed that certification by a firm's backing and reputation would be adequate; and 12 percent recommended certification by related engineering technical societies.

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*The engineering registration law currently grants four years experience-credit toward the six year experience requirement for engineering registration to graduates of a Board-approved engineering curricula. (The Board of Registration currently approves all engineering education programs accredited by the Engineers' Council for Professional Development.)

3. Summary

This survey indicated:

a. That most companies employing engineers recognized the importance of continued education and were willing to share the cost of it with their employees, as much as 75-100 percent, if the course or program were at least indirectly related to the employee's job;

b. That most companies were most interested in hiring graduates with a bachelor of science or master's degree with no full-time engineering experience than an engineer with a Ph.D. lacking similar experience; and

c. That engineering registration played no currently important role in industrial engineering practice.

APPENDIX H

INFORMATION FOR REGISTRATION AS A PROFESSIONAL ENGINEER DURING THE INITIAL (GRANDFATHERING) PERIOD

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INFORMATION FOR REGISTRATION AS A PROFESSIONAL ENGINEER DURING THE INITIAL (GRANDFATHERING) PERIOD

Bulletin 3-75

BOARD OF REGISTRATION FOR PROFESSIONAL ENGINEERS STATE OF CALIFORNIA

1. GENERAL REQUIREMENTS - Each applicant for registration as a professional engineer:

   (a) must be of good moral character.
   (b) must furnish evidence of nine years of qualifying engineering experience. Experience will be acceptable to the Board on a full-time basis except for equivalents as noted below.
   (c) is not required to be a citizen of the United States, nor a resident of California.
   (d) must submit an application identified for the appropriate branch together with the required filing fee.
   (e) except as provided under 2 (a) below, must have professional experience other than teaching, since a maximum of one years experience credit can be allowed for teaching experience.

2. EXPERIENCE EQUIVALENTS - Education or registration credit may be substituted toward the total nine year experience requirement only according to one of the following:

   (a) nine years' credit for current registration obtained by 16-hour written examination in another state in the same specialty in which you are applying.
   (b) seven years' credit for registration as a professional engineer in any state in any branch of engineering.
   (c) four years' credit for successful completion of an Engineer-in-Training written examination in any state in the United States.
   (d) five years' credit for a masters or higher engineering degree from a school whose undergraduate degree is accredited by Engineers' Council for Professional Development (ECPD). See note below.
   (e) four years' credit for a B.S. degree in an engineering curriculum accredited by ECPD. See note below.
   (f) two years' credit for a B.S. degree, or equivalent, in an engineering curriculum not accredited by ECPD or for a B.S. degree in an engineering technology curriculum accredited by ECPD. See note below.

(g) one-half year credit for each year completed toward a B.S. degree in an ECPD accredited curricula. See note below. NOTE - To obtain credit for education you must submit a copy of your degree, diploma, or transcript.

3. HOW TO APPLY - Obtain the application forms for the appropriate branch(s) from the Board's office located in Sacramento. These are available on request which may be made by letter or in person. Complete the application, and the two-part experience record, according to instructions. Attach your check, or money order, made payable to "Department of Consumer Affairs", and mail your completed forms to the Sacramento address, 1006 4th Street, 6th Floor, Sacto., CA 95814.
NOTE: All portions of the application must be typewritten except for your signature.

4. REFERENCES - The application process for registration as a professional engineer in California calls for each applicant to provide the Board with at least four references. These references should be engineers who have personal knowledge of your character and your engineering experience. At least two should be registered professional engineers (any branch, any state) and the remainder should have expertise in the branch in which you are applying. You should provide at least one reference for each significant engagement for which you seek credit. Additional reference forms are available from our Sacramento office upon request.

The best references are those from your immediate supervisors and other supervisors who are engineers, particularly if they are registered professional engineers. Engineering co-workers and other associates in your organizations who are familiar with your work are also quite acceptable. Less desirable and often not very meaningful are friends, acquaintances, professors from your college days, and others who have only a general knowledge of the kind of work you do. References from your subordinates should be avoided unless they are necessary to meet the requirements of the Board.

Blank reference forms are provided. Give these forms to the selected references and ask each of them to personally complete and sign the form and to forward it directly to the Board. The Board's address is 1006 Fourth St., 6th Floor, Sacramento, CA 95814. Ask each man to give the reference form his personal attention, and to return it to the Board promptly so the processing of the application may not be delayed. Your application may not be acted upon unless all references are submitted. This is an important part of the qualification process.

The Board asks the reference to provide information relevant to your experience based on his personal knowledge and to express his opinion on the questions asked. The information is confidential to the Board, and is not intended for any other use.

The Board will review your application after the required reference forms have been received. It is your responsibility to see that your references submit the completed reference forms. It is suggested that you furnish each of them with a stamped envelope, addressed to the Board, so as to expedite his reply. If the references have not responded within a reasonable period of time after receipt of your application, the Board will advise you of such fact. You should then follow up with a second request.

5. EXPERIENCE RECORD - The record is to be prepared in TWO parts. The first part is an engagement summary. The Board will provide standard Experience Record forms with the application. Please identify each engagement following graduation; or each engagement beginning with the first for which you claim professional engineer experience credit. If an intervening engagement is not qualifying--list it, show the enclosing dates, and identify it as non-qualifying. The total Experience Record should be complete up to the final filing date with no gaps. Each separate engagement must be summarized in inverse chronological order on the forms provided. (Your present engagement is #1.) Supplementary information may be appended in the form of letters, affidavits, exhibits, etc.

An engagement means one association with one employer in one capacity. If you change employers that means a change in engagement. If you are promoted or change job levels, you may show such a change as a new engagement even though you continue with the same employer. This kind of change implies a significant change in authority, responsibility, function, activity, etc.

The second part of the Experience Record must be prepared on 8-1/2" x 11" paper supplied by yourself. The Board will identify certain functional areas in connection with your particular engineering branch. Select those functional areas most appropriate to your own experience and develop each one separately. As an example: You may select from the master list such functional areas as: appraisal, operations research, and statistical analysis as areas in which you can show significant professional engineering accomplishment. You should write up in detail your experience in each of these particular areas. Your description should describe your activities, functions, accomplishments, levels of responsibility, job titles, projects, etc., that will demonstrate to the Board that you have had qualifying professional level engineering experience in each functional area identified.

Your total Experience Record will now be a linear calendar record listing in turn each engagement, plus a detailed description of those functional areas that demonstrate significant professional engineering achievement. If you cannot show significant experience in a function--do not attempt to build a false image--leave it out.

Qualifying experience for professional engineer registration means full-time employment or activity. It does not include part-time or short-time employment, overtime, trainee or orientation programs, technician or sub-professional levels of employment.

If you have experience in more than one branch, please refer to Board Rule 424 in the Engineers Act. If you plan to apply in more than one branch or have already used some of your experience to obtain registration in California, indicate clearly what portion of each engagement is applicable to each branch.

6. ELIGIBILITY - The Board will appraise each applicant according to his own achievements with respect to education and engineering experience. Each applicant will be notified of the official finding of the Board.

7. APPEALS - Applicants are referred to the current Board Rules for the avenues open to appeal actions by the Board that may be unfavorable.

8. REFUNDS - All application fees will be retained by the Board whether you are accepted or denied.

9. EXAMINATION - If you wish to apply for registration by examination, please contact the Board office in Sacramento for forms and information.

APPENDIX I

PREPRINT SENATE BILL NO. 17

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PREPRINT SENATE BILL NO. 17

Introduction

The Forum on engineering education and licensing was facilitated through the development of draft legislation that would make significant changes to the California Engineering Licensing Act. The draft legislation is included in its entirety.

PREPRINT SENATE BILL No. 17

Proposed by Senator Rodda

July 14, 1976

An act to repeal and add Chapter 7 (commencing with Section 6700) of Division 3 of the Business and Professions Code, relating to professional engineers, and making an appropriation therefor.

LEGISLATIVE COUNSEL'S DIGEST

Preprint SB 17, proposed by Senator Rodda. Professional engineers.

Existing law provides for the registration of professional engineers in various specialty branches and provides for the regulation of such engineers.

This bill would substantially revise such provisions. The bill would revise the definition of the terms "engineer," "professional engineer," "engineering," and "engineering practice."

The bill would eliminate registration in the various specialty branches of engineering.

The bill would add provisions regulating the conduct of professional engineers.

The bill would revise the membership of the State Board of Registration for Professional Engineers by eliminating representation from the various branches of engineering. The bill would require the board to maintain 4 standing committees, including an engineer-in-training committee, a registration examination committee, and an ethics review committee. The bill would also authorize the board to establish professional engineers investigation committees.

The bill would create an Engineering Advisory Committee which is advisory to, and appointed by, the board.

The bill would require any person practicing engineering, as defined, to be registered including any person professing to be an engineer or is in responsible charge of engineering work.

The bill would revise various existing exemptions from registration.

The bill would revise the qualifications required for registration of a professional engineer.

The bill would make other various changes in the law relating to engineering.

The bill would appropriate an unspecified sum from the General Fund to the State Controller for allocation to local agencies for reimbursement of costs incurred by them pursuant to the act.

Vote: ⅔. Appropriation: yes. Fiscal committee: yes. State-mandated local program: yes.

The people of the State of California do enact as follows:

SECTION 1. Chapter 7 (commencing with Section 6700) of Division 3 of the Business and Professions Code is repealed.

SEC. 2. Chapter 7 (commencing with Section 6700) is added to Division 3 of the Business and Professions Code, to read:

CHAPTER 7. PROFESSIONAL ENGINEERS

Article 1. General Provisions

6700. This chapter of the Business and Professions Code constitutes the chapter on professional engineers. It may be cited as the Professional Engineers Act.

6701. "Engineer," within the intent of this chapter, means a person who, by reason of his special knowledge and use of the mathematical, natural, physical and engineering science and the principles and methods of engineering analysis and design, acquired by engineering education and engineering experience, is qualified to practice engineering.

6702. "Professional engineer", as used in this chapter, means a person who has been duly registered and licensed, as a professional engineer by the board.

6703. "Engineering" is the profession in which a knowledge of the mathematical, physical and engineering natural, sciences gained by study, experience and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.

6704. "Engineering practice" and "engineering work" within the intent of this chapter chapter shall mean any service or creative work, the adequate performance of which requires engineering education, training and experience in the application of special knowledge of the mathematical, physical and engineering sciences to such services or creative work as consultation, investigation, evaluation, planning and design of engineering works and systems, planning the use of land and water, and the inspection of construction for the purpose of assuring compliance with drawings and specifications; any of which embraces such services or work, either public or private, in connection with any utilities, structures, buildings, machines, circuits, equipment, processes, work systems, projects, and industrial or consumer products or equipment of a mechanical, electrical, hydraulic, pneumatic, nuclear, aero-dynamic, or thermal nature, insofar as they involve safeguarding life, health, property, public welfare or public good and including such other professional services as may be necessary to the planning, progress and completion of any engineering services.

A person shall be construed to practice or offer to practice engineering within the meaning and intent of this chapter who practices any branch of the profession of engineering; or who, by verbal claim, sign advertisement, letterhead, card, or in any other way represents himself to be a professional engineer, or through the use of some other title implies that he is a professional engineer or that he is registered under this chapter; or who holds himself out as able to perform, or who does perform any engineering service or work or any other service designated by the practitioner which is recognized as engineering.

6705. "Area of competence" is that area of engineering in which a person is, by training and experience, fully competent and proficient.

6706. "Engineer in responsible charge," within the intent of this chapter, means the individual who determines technical questions of design, development application, certification or construction, or personally supervises engineering work.

6707. A subordinate is any person who assists a registered professional engineer in the practice of professional engineering without assuming responsible charge of work.

6708. In order to safeguard life, health, property, public welfare, and public good, all engineers in responsible charge shall be licensed as professional engineers. Only persons registered under the provisions of this chapter shall be entitled to take and use the titles "professional engineer," or "registered engineer," or any combination of such titles.

6708.1. "Public welfare" involves the general well-being of the public.

6708.2. "Public good" involves the utilization of public resources.

6709. The safeguarding of life, health, property, public welfare, and public good is dependent upon the engineer's knowledge of the technical and nontechnical parameters that must be considered in his area of competence in engineering practice. These parameters are:

Physical science	Business administration
Engineering science	Economics
Design/application	Law
Engineering technology	Political science
Multidisciplinary engineering	Social and behavioral science
Professional ethics	Biological systems
Communication arts	Humanities/history
Systems management	

Article 2. Rules of Conduct

6710. In order to safeguard life, health, property, public welfare, and public good, and to establish and maintain high standards of moral conduct in the profession of engineering, rules of conduct are set forth in this article. Each engineer shall be completely knowledgeable of these rules and the board shall strictly enforce them.

6710.1. The engineer shall at all times have the highest regard for life, health, property, public welfare, and public good and shall always regard his duty to the public as paramount. If his engineering judgment is overruled in circumstances where life, health, property, public welfare, or public good are endangered, he shall inform his employer or client of the possible consequences and shall notify the board and other proper authorities this action.

6710.2. The engineer shall not complete, sign, seal or stamp plans, reports, specifications or other engineering documents that are not in accordance with his duty to safeguard life, health, property, public welfare, and public good. Should the employer or client insist on such unethical conduct, the engineer shall notify the board and other proper public authorities and withdraw from further service on the project.

If the employer or client chooses to proceed with the project, the engineer shall notify the board and other proper public authorities of this action.

The engineer shall be granted the same immunity as is granted to a public employee pursuant to Article 3 (commencing with Section 820) of Chapter 1 of Part 2 of Division 3.6 of Title 1 of the Government Code.

6710.3. (a) No employer shall discharge or in any manner discriminate against any employee because such employee has filed any complaint or instituted or caused to be instituted any proceeding under or related to this chapter or has testified or is about to testify in any such proceeding or because of the exercise by such employee on behalf of himself or others of any right afforded by this chapter.

(b) Any employee who believes that he has been discharged or otherwise discriminated against by any employer in violation of this section may, within 30 days after such violation occurs, file a complaint with the board alleging such discrimination. Upon receipt of such complaint, the board shall cause such investigation to be made as it deems appropriate. If upon such investigation, the board determines that the provisions of this subdivision have been violated, the board shall bring an action in any appropriate court against such person. In any such action the court shall have jurisdiction for cause shown to restrain violations of subdivision (a) of this section and order all appropriate relief including rehiring or reinstatement of the employee to his former position with back pay.

(c) Within 90 days of the receipt of a complaint filed under this section the board shall notify the complainant of his determination under subdivision (b).

6710.4. The engineer shall undertake to perform engineering assignments only when qualified by education or experience in the specific area of competence of professional engineering involved.

6710.5. The engineer may accept an assignment requiring education or experience outside of his own field of competence, but only to the extent that his services are restricted to those phases of the project for which he is qualified. All other phases of such project shall be performed by qualified associates, consultants or employees.

6710.6. The engineer shall not affix his signature or seal to any engineering plan or document dealing with subject matter to which he lacks competence by virtue of education or experience, nor to any such plan or document not prepared under his direct supervisory control.

6710.7. The engineer shall express an opinion on an engineering subject only when his opinion is based upon adequate knowledge of the facts in issue, upon a background of technical competence in the subject matter, and upon honest conviction of the accuracy and propriety of his opinion.

6710.8. In a group discussion, public forum, or publication of articles, the engineer shall insist upon the use of facts in reference to engineering projects.

6710.9. The engineer shall not issue statements, criticisms or arguments on matters connected with public policy which are inspired or paid for by private interests, unless he indicates on whose behalf he is making the statement.

6710.10. The engineer shall conscientiously avoid conflict of interest with his employer or client, but, when unavoidable, the engineer shall fully disclose the circumstances to his employer or client.

6710.11. The engineer shall inform his client or employer of any business connections, interests or circumstances which would influence his judgment or the quality of his services.

6710.12. When in public service as a member, advisor, or employee of a governmental body or department, the engineer shall not participate in considerations or actions with respect to services provided by him or his organization in private engineering practices.

6710.13. The engineer shall not solicit or accept an engineering contract from a governmental body of which a principal or officer of his organization serves as a member.

6710.14. The engineer shall not accept compensation, financial or otherwise, from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed to, and agreed to, by all interested parties.

6710.15. The engineer shall not solicit or accept financial or other valuable considerations from material or equipment suppliers for specifying their products.

6710.16. The engineer shall not solicit or accept gratuities, directly or indirectly, from contractors, their agents, or other parties dealing with his client or employer in connection with work for which he is responsible.

6710.17. The engineer shall not offer to pay, either directly or indirectly, any commission, political contribution, or a gift, or other consideration in order to secure work, exclusive of securing positions through employment agencies.

6710.18. The engineer shall not knowingly associate with or permit the use of his name or firm name in a business venture by any person or firm which he knows, or has reason to believe, is engaging in business or professional practices of a fraudulent or dishonest nature.

6710.19. If the engineer has knowledge or reason to believe that another person or firm may be in violation of any of the provisions of this article, he shall present such information to the board in writing and shall cooperate with the board in furnishing such further information or assistance as may be required by the board.

Article 3. Administration

6711. There is in the Department of Consumer Affairs a State Board of Registration for Professional Engineers which consists of 11 members appointed by the Governor.

The Governor may remove his appointments for misconduct, incompetency or neglect of duty.

6712. Each member of the board shall be a citizen of the United States. Each member, except the public members, shall have been licensed for at least four years and shall be of good standing in his or her profession. Each member shall be a least 30 years of age, and shall have been a resident of this state for at least five years immediately preceding his appointment.

Three of the members of the board shall be public members, who are not registered under this act or licensed under the Land Surveyors Act.

Each member shall hold office until the appointment and qualification of his successor or until one year shall have elapsed since the expiration of the term for which he was appointed, whichever occurs first. No person shall serve as a member of the board for more than two consecutive terms, but this provision shall not apply to any member in office on November 23, 1970.

6713. Each member of the board shall receive a per diem and expenses as provided in Section 103.

6714. The board shall have four standing committees comprised of board members. The committees are the Engineer-In-Training Committee, the Registration Examination Committee, the Education Qualification Committee and the Ethics Review Committee.

6715. Each standing committee shall consist of five board members of which one member must be a public member.

6716. (a) The Engineer-In-Training Committee shall supervise the engineer-in-training examination.

(b) The Registration Examination Committee shall be responsible for the formulation of the registration examination.

(c) The Education Qualification Committee shall evaluate curricula and major factors affecting curricula in order to determine qualifying education programs.

(d) The Ethics Review Committee shall review violations of Article 2 (commencing with Section 6710) and recommend to the board what action should be taken.

6717. The board shall appoint an executive secretary at a salary to be fixed and determined by the board with the approval of the Director of Finance.

6718. The secretary shall keep a complete record of all applications for registration and the board's action thereon and, between July 1 and December 1 in each even-numbered year, shall prepare a roster showing the names and addresses of all registered professional engineers. Between July 1 and December 1 in each odd-numbered year he shall prepare a supplemental roster showing changes in and additions to the roster.

A copy of the roster and the supplemental roster shall be filed with the Secretary of State and a copy of each shall be furnished to each professional engineer registered under the provisions of this chapter. Copies of

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each shall be available on application to the secretary, at such price per copy as may be fixed by the board.

6719. The board may adopt such rules and regulations as are not inconsistent with law and as are reasonably necessary to govern its action. Such rules and regulations shall be adopted in accordance with the provisions of the Administrative Procedure Act.

6720. The board shall hold at least two regular meetings each year. Special meetings shall be held at such times as the board rules provide. Notice of all meetings shall be governed by board rule. A majority of the board constitutes a quorum.

6721. Any member of the board may administer oaths and may take testimony and proofs concerning all matters within the board's jurisdiction.

6722. The board shall adopt and have an official seal which shall be affixed to all certificates of registration.

6723. (a) In carrying into effect the provisions of this act, the board may subpoena witnesses and compel their attendance, and also may require the submission of books, papers, documents, or other pertinent data, in any disciplinary matter, or in any case wherever a violation of this chapter is alleged. Upon failure or refusal to comply with any such order of the board, or upon failure to honor its subpoena, as herein provided, the board may apply to a court of any jurisdiction to enforce compliance with such order.

(b) The board may in the name of the state to apply for relief by injunction in the established manner provided in cases of civil procedure, without bond, to enforce the provisions of this chapter, or to restrain any violation thereof. In such proceedings, it shall not be necessary to allege or prove, either that an adequate remedy at law does not exist, or that substantial or irreparable damage would result from the continued violation thereof. The members of the board shall not be personally liable under this proceedings.

(c) The board may subject an applicant for registration to such examinations as it deems necessary to determine his qualifications.

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each shall be available on application to the secretary, at such price per copy as may be fixed by the board.

6719. The board may adopt such rules and regulations as are not inconsistent with law and as are reasonably necessary to govern its action. Such rules and regulations shall be adopted in accordance with the provisions of the Administrative Procedure Act.

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6721. Any member of the board may administer oaths and may take testimony and proofs concerning all matters within the board's jurisdiction.

6722. The board shall adopt and have an official seal which shall be affixed to all certificates of registration.

6723. (a) In carrying into effect the provisions of this act, the board may subpoena witnesses and compel their attendance, and also may require the submission of books, papers, documents, or other pertinent data, in any disciplinary matter, or in any case wherever a violation of this chapter is alleged. Upon failure or refusal to comply with any such order of the board, or upon failure to honor its subpoena, as herein provided, the board may apply to a court of any jurisdiction to enforce compliance with such order.

(b) The board may in the name of the state to apply for relief by injunction in the established manner provided in cases of civil procedure, without bond, to enforce the provisions of this chapter, or to restrain any violation thereof. In such proceedings, it shall not be necessary to allege or prove, either that an adequate remedy at law does not exist, or that substantial or irreparable damage would result from the continued violation thereof. The members of the board shall not be personally liable under this proceedings.

(c) The board may subject an applicant for registration to such examinations as it deems necessary to determine his qualifications.

Article 3.5. Investigating Committees

6725. The board, when it deems necessary, may establish professional engineers investigation committees to assist the board in the investigation of claims of violation of any provision under this chapter. Each committee shall report its findings and recommendations to the board. Any member of such a committee may act as an expert witness at a hearing conducted by the board when the hearing is conducted as a result of the committee's investigation.

Each committee shall exist so long as the board deems that it is necessary.

6726. Each member of each committee shall be appointed by the board and shall serve at the pleasure of the board. Each committee shall be composed of no more than five members.

6727. At least one member of each investigating committee shall be a public member.

6728. At least two members of each investigating committee shall be an expert in the area of engineering that the committee is investigating.

6729. All the members of each committee shall serve without compensation but shall receive per diem and expenses provided in Section 103.

6730. Each member of each investigation committee shall be granted the same immunity as is granted to a public employee pursuant to Article 3 (commencing with Section 820) of Chapter 1 of Part 2 of Division 3.6 of Title 1 of the Government Code.

Article 3.7. Professional Engineers Review Committees

6731. The board, when it deems necessary, may establish professional engineers review committees to hear all matters assigned by the board, including, but not limited to, any contested case which is assigned by the board. Each committee shall exist so long as the board deems that it is necessary.

6732. Each review committee shall consist of no fewer than two registered professional engineers and no fewer than one public member. Appointments shall be made by the board. Each member of a committee shall have the same qualifications and shall be subject to the same rules and regulations as if he were a member of the board.

6733. Each member of each committee shall be appointed by the board and shall serve at the pleasure of the board. Each committee shall be composed of no more than five members.

6734. All members of each committee shall serve without compensation but shall receive per diem and expenses as provided in Section 103.

6735. Each member of each investigation committee shall be granted the same immunity as is granted to a public employee pursuant to Article 3 (commencing with Section 820) of Chapter 1 of Part 2 of Division 3.6 of Title 1 of the Government Code.

6735.5. Except as otherwise provided in this article, all hearings which are conducted by a committee shall be conducted in accordance with the provisions of Chapter 5 (commencing with Section 11500), Part 1, Division 3, Title 2 of the Government Code.

If a contested case is heard by a committee, the hearing officer who presided at the hearing shall be present during the committee's consideration of the case and, if requested, shall assist and advise the committee.

6736. At the conclusion of any hearing which is conducted by a committee, the committee shall prepare a proposed decision, in such form that it may be adopted by the board as the decision in the case, and shall transmit it to the board. The proposed decision shall be subject to the same procedure as the proposed decision of a hearing officer under subdivisions (b) and (c) of Section 11517 of the Government Code.

6736.5. The board may adopt, amend, or repeal, in accordance with the provisions of Chapter 4.5 (commencing with Section 11371) of Part 1 of Division 3 of Title 2 of the Government Code, such rules and regulations as are necessary to implement this article.

Article 3.9. Engineering Advisory Committee

6737. The intent of this article is (1) to provide for the exchange of views among those concerned with the practice and education of the engineering profession (2) to identify the major needs and concerns of the people of California as they relate to the engineering profession (3) to examine educational programs and licensing requirements in light of such concerns and (4) to make recommendations to the board based upon the advisory committee's examination of educational programs and licensing requirements.

6737.1. There is hereby created an Engineering Advisory Committee which shall be advisory to, and appointed by, the board.

6737.2. The Engineering Advisory Committee shall be appointed by the board and shall consist of the following representatives:

(a) One engineering educator each from the University of California, the California state universities and colleges, the California community colleges, and the independent California universities and colleges;

(b) Two engineering students with upper division standing;

(c) Two recent engineering graduates that have been out of school no longer than three years and have been actively employed as engineers, two senior experienced engineers having practiced engineering for at least 10 years, and two employers of engineers. These persons shall be appointed by the board and shall be selected from the following areas of engineering practice: high technology, consumer products, consulting, construction, and government or public works. The board shall appoint at least one person from each of these areas of engineering practice;

(d) The chairperson of the Engineering Liaison Committee of the Articulation Conference;

(e) A member of a California professional engineering society;

(f) The President of the Board of Registration for

Professional Engineers shall be an ex officio member of the Engineering Advisory Committee.

6737.3. Except for the members first appointed, the terms of the committee shall be for two years.

6737.4. The terms of the committee shall be staggered. The terms of the first appointed members of the committee shall be as follows:

(a) The California state universities and colleges and California community college educators shall be appointed for two years and the University of California and the independent colleges and university educator for one year.

(b) One student shall be a junior and the other a senior. Each student appointed thereafter shall be a junior.

(c) One recent engineering graduate, one senior experienced engineer and one employer of engineers shall be appointed for one year. The remaining three appointments shall be appointed for two years.

6737.5. The advisory committee shall be assigned personnel and services as needed.

6737.6. The advisory committee shall meet at least twice a year. Additional meetings shall be held as requested by the board.

6737.7. The engineering advisory committee shall:

(1) Identify major needs and concerns of the people of California as they relate to the engineering profession. Examine existing and proposed professional education programs in light of these concerns and submit their observations to the Education Qualification Committee;

(2) Develop recommendations for program evaluation criteria and submit these to the Educational Qualification Committee;

(3) Define job market parameters which affect future engineering manpower requirements and submit these observations to the appropriate standing committees.

(4) Develop criteria for staff analysis of engineering education programs to be submitted to the Education Qualification Committee;

(5) Formulate counseling criteria for the four

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segments to increase student awareness of the education and practice requirements of a career in engineering. Submit the criteria to the Education Qualification Committee;

(6) Provide recommendations for basic minimum requirements for engineering practice and submit these recommendations to the board;

(7) Assist the EIT and Registration Exam Committee in the formulation of exams;

(8) Establish a close liaison with professional societies;

(9) Take a leadership role in the promotion of professional development of registered engineers, evaluate programs, methods of funding and service delivery systems and techniques;

(10) Improve communications with registered engineers; and

(11) Undertake periodic surveys to maintain current demographic information pertaining to the registered engineers.

Article 4. Application of Chapter

6738. In order to safeguard life, health, property and public welfare, and public good, any person, either in a public or private capacity, except as in this chapter specifically excepted, who practices, or offers to practice, engineering, in this state, shall submit evidence that he is qualified to practice, and shall be reigstered accordingly as an engineer by the board.

6738.5. It is unlawful for anyone other than a professional engineer registered under this chapter, to stamp or seal any plans, specifications, plats, reports, or other documents with the seal or stamp of a professional engineer, or to in any manner use the title "professional engineer," or "registered engineer," or any combination of such words and phrases unless registered hereunder.

6739. It is unlawful for anyone to stamp or seal any plans, specifications, plats, reports, or other documents with the seal after the certificate of the registrant, named thereon, has expired or has been suspended or revoked, unless the certificate has been renewed or reissued.

6740. Any person practices engineering when he professes to be an engineer or is in responsible charge of engineering work.

6740.5. All engineering plans, specifications, reports or documents shall be prepared by a registered engineer or by a subordinate employee under his direction, and shall be signed by him to indicate his responsibility for them. In addition to his signature, he shall show his registration number or the stamp of his seal. The registered engineer shall use together with his signature or seal, the title "professional engineer."

6741. Nothing in this act shall be construed to prevent the practice of any other profession, the practice of which is defined by law.

6745. (a) This chapter does not prohibit one or more engineers from practicing or offering to practice engineering through the medium of a partnership, firm or corporation; provided:

(1) An engineer is the partner, member, or directing officer in charge of the engineering practice of the partnership, firm or corporation.

(2) All engineering plans, specifications, and reports are prepared by or under the direct supervision of a registered engineer in the appropriate area of competence, who shall sign or stamp with his seal such plans, specifications, and reports.

(3) The partnership, firm or corporate name shall not contain the name of any person who is either not registered by the board as an architect, or of any person who is not registered as a geologist under the provisions of the Geologist Act (Chapter 12.5 (commencing with Section 7800); provided, that any holding out by such partnership, firm, or corporation of any individual or individuals to the public as a member, or members, of such partnership, firm, or corporation, other than by the use of the name or names of such individual or individuals in the partnership, firm, or corporate name, shall clearly and specifically designate the license status of such individual or individuals.

(b) Nothing herein shall authorize the offering to practice or the practice of engineering by any persons, either as a member, officer or employee of any partnership, firm, or corporation, who is not registered as a professional engineer.

(c) This chapter does not prevent or prohibit an individual, firm, company, association or corporation engaged in any line of business other than the practice of engineering from employing a registered engineer to perform the corresponding engineering services incidental to the conduct of their business.

6748. Officers and employees of the United States of America practicing solely as such officers or employees are exempt from registration under the provisions of this chapter only insofar as their activities in no way affect the life, health, property, welfare and good of the citizens of California.

6749. A subordinate to a professional engineer registered under this chapter, or a subordinate to an engineer exempted from registration under this chapter, insofar as he acts solely in such capacity, is exempt from registration under the provisions of this chapter. This exemption, however, does not permit any such subordinate to practice engineering in his own right or to use the title, "professional engineer" or "registered engineer."

6752. This chapter does not affect Chapter 15 (commencing with Section 8700), relating to surveyors, except insofar as this chapter is expressly made applicable.

6753. This chapter does not require registration for the purpose of practicing engineering, by an individual, a member of a firm or partnership, or by an officer of a corporation on or in connection with property owned or leased by the individual, firm, partnership, or corporation, unless the engineering work to be performed involves the public health, welfare, safety or good, or the health and safety of employees of the individual, firm, partnership or corporation.

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Article 5. Registration

6755. An application for registration as a professional engineer or certification as an engineer-in-training shall be made to the board on the form prescribed by it with all statements therein made under oath, and shall be accompanied by the application fee fixed by this chapter.

6755.5. An applicant may become registered through any one of the following three alternatives:

(a) Experience and examination.

(1) The applicant shall have four years of engineering work experience.

(2) The applicant shall successfully complete the engineer-in-training examination.

(3) The applicant shall have two additional years of engineering work experience.

(4) The applicant shall successfully complete the registration examination.

(b) Graduation and examination.

(1) The applicant shall graduate from a board-approved education program.

(2) The engineer-in-training examination is waived upon graduation from a board-approved education program, with a minimum grade point average to be determined by the board.

(3) The applicant shall successfully complete the registration examination.

(c) Comity.

(1) The board shall grant registration to engineers registered in states where registration requirements are similar to or more exacting than California requirements.

6756. Each year of study completed without graduation in an engineering school or college where the curriculum has been approved by the board shall count as one-half year of experience, except that applicants for engineering registration shall not receive credit for more than four years of experience because of undergraduate educational qualifications. The board may at its discretion consider graduation in a nonaccredited engineering curriculum, as equivalent to not more than two years experience.

6757. The board may consider the professional experience and education acquired by applicants outside the United States which in the opinion of the board is equivalent to the minimum requirements of the board established by regulation for professional experience and education in this state.

6757.5. The board shall by rule establish the criteria to be used for approving curricula of schools of engineering.

6758. With respect to applicants for registration as professional engineers, the board may:

(a) At its discretion give credit as experience not in excess of one year, for satisfactory postgraduate work in a school of engineering where the curriculum has been approved by the board.

(b) Consider engineering teaching, if of a character satisfactory to the board, as engineering experience.

6758.5. All applicants shall be given equal credit for engineering experience in the armed forces of United States as with any other comparable engineering experience.

6759. Examination for registration shall be held at such times and places as the board shall determine.

6759.5. (a) The registration examination shall consist of two eight-hour sections and shall be of the nature that engineering experience on the part of the applicant will be required in order to pass both sections of the examination. The two sections of the examination shall be:

(1) Section I: Computational engineering concepts—tests for proficiency in engineering technical areas;

(2) Section II: Professional practice—comprehensive examination of the application of technical knowledge within technical and nontechnical parameters of engineering practice.

(b) The purpose of the registration examination is to establish minimum qualifications for a registered engineer. Both sections of the examination shall be equally weighed and the applicant must pass both sections in order to become registered. Each section shall be at least eight hours in length and both sections must be taken within a reasonable period of time to be established by the board.

6760. An applicant for certification as an engineer-in-training shall, upon making a passing grade in the examination relating to fundamental engineering subjects, be issued a certificate as an engineer-in-training. No renewal or other fee, other than the application fee, shall be charged for this certification. Such certificate shall become invalid when the holder has qualified as a professional engineer as provided in Section 6755.5.

6760.5. An engineer-in-training certificate does not authorize the holder thereof to practice or offer to practice engineering or to assume responsible charge of engineering work, in his own right, or to use the title specified in Section 6738.

6761. An applicant failing in an examination may be examined again upon filing a new application and the payment of the application fee fixed by this chapter.

6761.5. The board, upon application therefor, on its prescribed form, and the payment of the application fee fixed by this chapter, which fee shall be retained for the board, may issue a certificate of registration as a professional engineer, without written examination, to any person holding a certificate of registration issued to him by any state or country when the applicant's qualifications meet the requirements of this chapter, as specified in Section 6755.5, and rules established by the board.

6762. A temporary authorization for the practice of engineering may be granted, for a specific project, upon application and payment of the fee prescribed in Section 6773.5 for a period not to exceed 60 consecutive days in any calendar year; provided:

(a) The applicant maintains no place of business in this state.

(b) The applicant is legally qualified to practice that branch of engineering in the state or country where he maintains a place of business.

(c) The applicant demonstrates by means of an individual appearance before the board satisfactory evidence of his knowledge of the application of seismic forces in the design of structures or adequate knowledge in any of the other phases of professional engineering for which the applicant proposes to practice under the temporary authorization.

(d) If the applicant can satisfy the board that for the completion of the specific project for which the authorization is granted, will require more than 60 consecutive calendar days, the board may extend the authorization to a period not to exceed 120 consecutive days.

Upon completion of these requirements as necessary, the secretary on direction of the board shall issue a temporary authorization to the applicant.

6762.5. In determining the qualifications of an applicant for registration, a majority vote of the board is required.

6763. Any applicant who has passed the examination and has otherwise qualified hereunder as a professional engineer, shall have a certificate of registration issued to him as a professional engineer.

6763.5. If an applicant for registration as a professional engineer is found by the board to lack the qualifications required for admission to the examination for such registration, certification, or authorization, the board shall, notwithstanding the provisions of Section 158 of this code, refund to him one-half of the amount of his application fee.

6764. Each professional engineer registered under this chapter may, upon registration, obtain a seal of the design authorized by the board bearing the registrant's name, number of his certificate, and the legend "professional engineer."

6765. A duplicate certificate of registration to replace one lost, destroyed, or mutilated may be issued subject to the rules and regulations of the board. The duplicate certificate fee fixed by this chapter shall be charged.

6766. An unsuspended, unrevoked and unexpired certificate and endorsement of registry made under this chapter, is presumptive evidence in all courts and places that the person named therein is legally registered.

Article 6. Disciplinary Proceedings

6770. The board may receive and investigate complaints against registered professional engineers, and make findings thereon.

By a majority vote, the board may reprove, privately or publicly; or may suspend for a period not to exceed two years, or may revoke the certificate of any professional engineer registered hereunder:

(a) Who has been convicted of a felony, arising from or in connection with the practice of engineering, or of a crime involving moral turpitude, in which case the certified record of conviction shall be conclusive evidence thereof.

(b) Who has not a good character.

(c) Who has been found guilty by the board of any deceit, misrepresentation, violation of contract, fraud, negligence or incompetency in his practice.

(d) Who has been found guilty of any fraud or deceit in obtaining his certificate or violation of any provision of this chapter.

(e) Who aids or abets any person in the violation of any provisions of this chapter.

(f) Who violates any provision of this chapter.

6771. The proceedings under this article shall be conducted in accordance with Chapter 5 of Part 1 of Division 3 of Title 2 of the Government Code, and the board shall have all the powers granted.

6772. The board may reissue a certificate of registration, certification, or authority, to any person whose certificate has been revoked if a majority of the members of the board vote in favor of such reissuance for reasons the board deems sufficient.

6773. A plea or verdict of guilty or a conviction following a plea of nolo contendere made to a charge of a felony is deemed to be a conviction within the meaning of this article. The board may order the certificate suspended or revoked, or may decline to issue a certificate, when the time for appeal has elapsed, or the judgment of conviction has been affirmed on appeal or when an order granting probation is made suspending the imposition of sentence, irrespective of a subsequent order under the provisions of Section 1203.4 of the Penal Code allowing such person to withdraw his plea of guilty and to enter a plea of not guilty, or setting aside the verdict of guilty, or dismissing the accusation, information or indictment.

Article 7. Offenses Against the Chapter

6775. The board shall have the power, duty, and authority to investigate violations of the provisions of this chapter.

6776. It is the duty of the respective officers charged with the enforcement of laws and ordinances to prosecute all persons charged with the violation of any of the provisions of this chapter.

It is the duty of the secretary of the board, under the direction of the board, to aid such officers in the enforcement of this chapter.

6777. Every person is guilty of a misdemeanor and for each offense of which he is convicted is punishable by a fine of not more than five hundred dollars ($500) or by imprisonment not to exceed three months, or by both fine and imprisonment:

(a) Who, unless he is exempt from registration under this chapter, practices or offers to practice engineering in this state according to the provisions of this chapter without legal authorization.

(b) Who presents or attempts to file as his own the certificate of registration of another.

(c) Who gives false evidence of any kind to the board, or to any member thereof, in obtaining a certificate of registration.

(d) Who impersonates or uses the seal of any other practitioner.

(e) Who uses an expired or revoked certificate of registration.

(f) Who shall represent himself as, or use the title of, registered or professional engineer, or any other title whereby such person could be considered as practicing or offering to practice engineering, unless he is correspondingly qualified by registration as an engineer under this chapter.

(g) Who, unless appropriately registered, manages, or conducts as manager, proprietor, or agent, any place of business from which engineering work is solicited, performed or practiced.

(h) Who uses the title, or any combination of such title, of "professional engineer," "registered engineer," or "engineer-in-training," or who makes use of any abbreviation of such title which might lead to the belief that he is a registered engineer, without being registered as required by this act.

(i) Who violates any provision of this chapter.

Article 8. Revenue

6780. Certificates of registration as a professional engineer, and certificates of authority expire at 12 midnight on June 30 of each even-numbered year, if not renewed. To renew an unexpired certificate, the certificate holder shall, on or before June 30 of each even-numbered year, apply for renewal on a form prescribed by the board, and pay the renewal fee prescribed by this chapter.

6781. Except as otherwise provided in this article, certificates of registration as a professional engineer, and certificates of authority may be renewed at any time within five years after expiration on filing of application for renewal on a form prescribed by the board and payment of the renewal fee in effect on the last preceding regular renewal date. If the certificate is renewed more than 30 days after its expiration, the certificate holder, as a condition precedent to renewal, shall also pay the delinquency fee prescribed by this chapter. Renewal under this section shall be effective on the date on which the application is filed, on the date on which the renewal fee is paid, or on the date on which the delinquency fee, if any, is paid, whichever last occurs. If so renewed, the certificate shall continue in effect through the date provided in Section 6780 which next occurs after the effective date of the renewal, when it shall expire if it is not again renewed.

6782. A suspended certificate is subject to expiration and shall be renewed as provided in this article, but such renewal does not entitle the holder of the certificate, while it remains suspended and until it is reinstated, to engage in the activity to which the certificate relates, or in any other activity or conduct in violation of the order or judgment by which it was suspended.

6783. A revoked certificate is subject to expiration as provided in this article, but it may not be renewed. If it is reinstated after its expiration, the holder of the certificate, as a condition precedent to its reinstatement, shall pay a reinstatement fee in an amount equal to the renewal fee in effect on the last regular renewal date before the date on which it is reinstated, plus the delinquency fee, if any, accrued at the time of its revocation.

6784. Certificates of registration as a professional engineer, which are not renewed within five years after expiration may not be renewed, restored, reinstated, or reissued thereafter. The holder of such certificate may apply for and obtain a new certificate, however, if:

(a) No fact, circumstance, or condition exists which, if the certificate were issued, would justify its revocation or suspension,

(b) He takes and passes the examination, if any, which would be required of him if he were then applying for the certificate for the first time, or otherwise establishes to the satisfaction of the board that, with due regard for the public interest, he is qualified to practice engineering, and

(c) He pays all of the fees that would be required of him if he were then applying for the certificate for the first time.

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The board may, by regulation, provide for the waiver or refund of all or any part of the application fee in these cases in which a certificate is issued without an examination pursuant to the provisions of this section.

6785. The department shall receive and account for all money derived from the operation of this chapter and, at the end of each month, shall report such money to the State Controller and shall pay it to the State Treasurer, who shall keep the money in a separate fund known as the Professional Engineer's Fund. This fund shall be expended in accordance with law for the payment of all actual and necessary expenses incurred in carrying out the provisions of this chapter.

6786. The department may make refunds of all fees in accordance with Section 158.

6787. The amount of the fees prescribed by this chapter shall be fixed by the board in accordance with the following schedule:

(a) The fee for filing each application for registration as a professional engineer at not more than sixty dollars ($60), and for each application for certification as engineer-in-training at not more than forty dollars ($40).

(b) The duplicate certificate fee at not more than six dollars ($6).

(c) The temporary registration fee for professional engineer at not more than twenty dollars ($20).

(d) The renewal fee for professional engineer shall be fixed by the board at not more than twenty dollars ($20).

(e) The delinquency fee for a certificate which expires after June 30, 1961, is an amount equal to 50 percent of the renewal fee in effect on the date of its reinstatement.

SEC. 3. The sum of ______ dollars ($______) is hereby appropriated from the General Fund to the State Controller for allocation and disbursement to local agencies pursuant to Section 2231 of the Revenue and Taxation Code to reimburse such agencies for costs incurred by them pursuant to this act.

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APPENDIX J

FIVE-YEAR PLAN FOR POSTSECONDARY EDUCATION

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FIVE-YEAR PLAN FOR POSTSECONDARY EDUCATION

The necessity for coordination and planning in postsecondary education has been given attention in the formation of public policy. The California Education Code and the Five-Year Plan for Postsecondary Education: 1976-1981, contain the necessary impetus for the formation and adoption of the engineering Advisory Committee. The following Code provisions relate to the Commission on Postsecondary Education:

- ". . .To assure the effective utilization of public postsecondary education resources, thereby eliminating waste and unnecessary duplication; and to promote diversity, innovation and responsiveness to student and societal needs through planning and coordination."

- ". . .to facilitate 'participation of faculty members, students, administrators, and members of the general public in carrying duties and responsibilities.'"

The Code has further defined Commission functions and responsibilities under Section 22712. Those sections most applicable to the concept of the Engineering Advisory Committee are presented herein:

"The Commission shall have the following functions and responsibilities in its capacity as the statewide postsecondary education planning and coordinating agency and adviser to the Legislature and Governor:

"(2) It shall prepare a five-year state plan for postsecondary education . . .. In developing such plan, the commission shall consider at least the following factors:

(a) the need for a location of new facilities,

(b) the range and kinds of programs appropriate to each institution or system,

(c) the budgetary priorities of the institutions and systems of postsecondary education,

(d) the impact of various types and levels of student charges on students and on postsecondary educational programs and institutions,

(e) appropriate levels of state-funded student financial aid,

(f) access and admissions of students to postsecondary education,

(g) the educational programs and resources of private postsecondary institutions, and

(h) the provisions of this division differentiating the functions of the public systems of higher education.

"(8) It shall serve as a stimulus to the segments and institutions of postsecondary education by projecting and identifying societal and educational needs and encouraging adaptability to change.

"(9) It shall develop and submit plans to the Legislature and the Governor for the funding and administration of a program to encourage innovative educational programs by institutions of postsecondary education.

"(11) It shall periodically review and make recommendations concerning the need for and availability of postsecondary programs for adult and continuing education.

"(12) It shall develop criteria for evaluating the effectiveness of all aspects of postsecondary education.

"(21) It may undertake such other functions and responsibilities as are compatible with its role as the statewide postsecondary education planning and coordinating agency."

The Engineering Advisory Committee would enable the Commission to fulfill more effectively its broad responsibilities and perform its varied functions as outlined in the California Education Code. The proposed system would also make possible the accomplishment of State goals for postsecondary education found in the Five-Year Plan for Postsecondary Education in California: 1976-1981. These include:

- Encourage the increased effectiveness of accreditation of postsecondary education institutions in the State;
- Encourage postsecondary education to develop a comprehensive system of valid measures for knowledge gained both inside and outside formal academic programs:

- Encourage the establishment of educational requirements for licensure that are appropriate and reasonable in certifying occupational competency and the development of means for meeting these requirements including both educational programs and competency testing; and

- Work toward public understanding of the nature and significance of academic degrees, including their strengths and limitations as a measure of ability and skills.

Finally, under Section 22710.5, Chapter 5.5 of the California Education Code,

> "The commission may appoint such subcommittees or advisory committees as it deems necessary to advise it on matters of educational policy. Such advisory committees may consist of commission members or non-members or both, including students, faculty members, segmental representatives, governmental representatives, and representatives of the public."

Thus, the California Education Code contains the elements necessary for the establishment of the Engineering Advisory Committee within the Commission.