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FACTORS AFFECTING THE SUPPLY OF GRADUATE STUDENTS\*  
IN ENGINEERING

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Introduction

My topic for discussion is the question, "What measures are likely to be successful in increasing the supply of graduate students in engineering?" Preliminary thinking about this topic led to the early realization that a comprehensive study which would arrive at the relative importance of the various factors and predict the possible quantitative results which might be achieved would be beyond the scope of my individual effort. This paper, therefore, will be limited to simply summarizing some of the more likely factors involved and commenting on some of the more obvious aspects of these. Our chairman has already sounded a call for a comprehensive evaluation of graduate education in engineering, and if this study is made, certainly the topic which has been assigned to me for discussion here today will be developed fully and quantitative answers arrived at.

Separating graduate-student manpower problems from the problems of undergraduate manpower is impossible. Accordingly

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much of this discussion may, on the surface, appear to be concerned with under-graduate problems. I think, however, the relation to graduate problems will be evident.

Presumably any program which leads to an increase in either the quality or number of high school graduates entering engineering colleges ought also to eventually increase the supply of graduate students in engineering.

Although current studies indicate a large and continuing deficiency of engineers educated at the bachelor's level, I think that economic returns to the members of the profession and benefits to society as a whole might be greater if we concentrate on improving quality more than increasing quantity. A normal and healthy increase in bachelor-engineers, consistent with increasing population and industry, is certainly desirable; but I doubt the wisdom of making every possible effort to "get all the engineering graduates that we possibly can".

The problem we face has been stated many times. Each member of our rapidly multiplying population demands more and better material goods in the face of decreasing natural resources and more complex social, economic and political problems to solve. At the same time we are faced with the prospect of inordinate technological expenditure of men and resources for war machinery to insure national survival. These demands can probably never be fully met. The only hope of meeting the minimum is to substitute more machine power or manpower. This will require increasing the supply and efficiency of brain power. We must increase the number

of young people capable of working with their brains and we must utilize these much more effectively than in the past.

In our search for an increased number of graduate students in engineering we must not overlook that the sciences and other intellectual fields will also be under great pressure for more brain power. Any practical answer to our problem must consider these requirements also. Our efforts in evaluating graduate education in engineering, especially as they relate to manpower problems, ought to be correlated with a general study of these needs for all of the sciences.

#### Factors Influencing Graduate Engineering Manpower Supply

Factors which might influence young people to follow graduate study in engineering appear to fall into two broad categories. The first of these appears to consist of factors which are clearly economic in nature. The second is not so clearly strictly economic but involves psychological considerations as well.

#### Economic Factors

Prospect of increased individual financial return.- The prospect of increased individual financial return is probably the most potent motive that could be introduced to stimulate graduate study. The greater this prospect, the greater would be the expected increase in graduate-study interest. Presently little difference seems to exist in the financial returns to persons with advanced degrees in engineering over those holding bachelor's degrees.

We have assumed that graduate study in engineering is valuable to society. If this is true, why have not supply and demand operated to create a comparable reimbursement. Perhaps the answers may be found partly in the facts (1) that most advanced-degree engineers have been employed in education, which is somewhat protected from the laissez-faire operation of economic law; and (2) that employment by industry of engineers with advanced training is generally relatively recent and that time will be required before persons holding these degrees mature, if they will, into higher paid brackets.

Control of engineering wage scales based on degree held or years of advanced study might be possible. If not by legislation, this could be accomplished by unionization. Pay increases in the education profession often result automatically as the result of no other qualification than possession of an advanced degree. This has stimulated graduate activity in education. Many people feel however that this artificially stimulated endeavor has detracted from the quality of advanced work in the educational field. I certainly do not favor any such drastic measures in engineering. The point is cited only for the record.

Increased financial return to better-educated engineers can probably only come about because of proven increased economic worth to industry or to the public of the individual concerned. This may be difficult, because intellectual achievement is sometimes not marketable to society at its true worth. Without doubt, however, resulting individual financial return to

advanced-degree engineers needs to be increased if graduate work in engineering is to be stimulated.

Meeting the high cost of graduate work to institutions of higher learning.- One important factor affecting the attractiveness of graduate work is doubtless the professional reputation, personal enthusiasm and inspirational quality of graduate teachers and leaders; another is the importance and support available for graduate research programs. Worthwhile graduate work is expensive and universities are faced with a decreasing unit purchasing power in the face of demands for increased mass education at the college level. Many schools have met this problem, to some degree at least, by venturing into contract research. This source of income helps pay professor's salaries, and furnishes assistantships and graduate research projects. Contract research is not without its difficulties, however, as those who are involved are well aware. These programs make additional demands on the already short supply of manpower capable of high-grade graduate leadership. Many research sponsors do not recognize the true costs to the institutions of these activities - staff time, facilities, apparatus, and administrative costs are often not allowed. These costs can be met only by decreased institutional services elsewhere. More liberal support of sponsored research is needed.

Industrial contributions to research in colleges has been stimulated in recent years by operation of the excess profit tax and by high corporate income taxes. Under these, each dollar

of research effort costs the owners only about 18¢. With the discontinuance of the excess profit tax and the decrease in the corporate income tax, the share per dollar of the cost now becomes about 54¢, thus effectively tripling the cost to the corporation of such research. Perhaps this may not decrease corporate sponsored research as much as the figures indicate, because the corporations will have a larger supply of cash at their disposal. We hope they may recognize the importance of investing continuing large sums in research on our campuses. Perhaps some preferential tax concessions on funds spent this way ought to be considered as a means of stimulating this source of income to the colleges and universities. This public cost could be justified on the basis of the value to the nation of the continuing research effort in colleges.

Contract research grants are helpful, but they can only partly answer the problem. Graduate schools need more adequate general financing. This is especially true of the smaller institutions, who find it increasingly difficult to employ and to hold the interest of really well-qualified professors necessary for graduate work. This is true both in engineering and in the supporting sciences. For the publicly-financed institutions some means must be found to make legislatures recognize the importance of investing public funds in graduate activity. Privately-financed institutions have an even more difficult problem of finding adequate financial support.

Increasing the number and value of fellowships and assistantships.- A very important factor in the supply of graduate students must be the availability and monetary value of fellowships and assistantships. Presently research assistantships are relatively easy to obtain. Fellowships are more difficult. Graduate work in engineering would be stimulated if more fellowships were available. The number of fellowships in engineering under the National Science Foundation is helpful but inadequate.

The subsidy to education under the G.I. bill operates essentially as a huge fellowship program. This subsidy has not only directly supported graduate students but has increased the number of graduate students by simply increasing the number of bachelor's degrees. If and when G.I. benefits are discontinued, something will probably have to take their place. Perhaps the idea of mass subsidy may be replaced by increased public sponsorship of young people of superior ability by the National Science Foundation, and by comparable agencies at the level of state, city and school district.

Special consideration in regard to military service for talented graduates.- Deferment from their military obligations of talented graduates who wish to pursue further study would be helpful. If our object is to be realized, public policy on this point should probably be liberalized. The problems involved are not simple and extend from current logistic considerations all the way back to our basic concepts of democracy. This aspect of our problem has already had a lot of consideration. It will have

to come in for considerable more if we pursue our proposed evaluation of graduate work in engineering.

Availability of graduate courses to young engineers in service.- Doubtless many young engineers who are employed full-time will elect to do graduate work on a part-time basis if such programs are readily available to them. These programs frequently utilize night classes. I have had very little experience with part-time programs and I will leave discussion of this point to someone else. Co-operation of industry and public agencies is vital to stimulation of programs of this nature. A conference on co-operative education at the graduate level was held at Troy in connection with the 1949 annual meeting of ASEE and the various papers presented have been published as a bulletin of the Graduate Division.

Competition with the sciences for graduate personnel.- All of the sciences are faced with impending manpower shortages. We can accordingly expect that competition for scholars of extraordinary ability will continue. Supply and demand will probably operate fairly well to establish equitable distribution among the various sciences and engineering, and I would not advocate an artificial program to divert manpower from one or another of these professions. What is needed is a concerted effort on the part of all to encourage talented youngsters to enter science and engineering rather than commercial or other less intellectual fields.



## Psychological Factors

Fortunately not all of the factors which influence young persons to enter a graduate career in engineering are economic. For lack of a better term, I have lumped these factors together and called them psychological factors. There are a great many of these of relatively minor importance, but which, nevertheless, ought to be exploited if we seriously undertake an effort to increase graduate activity. These factors include such items as (1) the opportunity to do creative work of lasting value, (2) the possibility of service to the public, (3) natural scientific curiosity; etc. Stimuli of this kind operate naturally in our favor. Probably ways can be developed to make them more effective.

Another point which would appear to have some influence on a person choosing a profession is the quality of professional status enjoyed by members of that profession. Everyone seems to agree that there is room for improvement in this regard in engineering. A great deal of effort is presently being made by leaders of the engineering profession in an attempt to improve this status. The success they achieve will probably be reflected in some measure in the success of our recruiting efforts.

Engineers, being practical people generally, are apt to mistrust or fail to appreciate persons who have specialized in highly technical subjects at the expense of field experience. This tendency decreases with time as more rigorous technical efforts become increasingly necessary. Perhaps, better general understanding of the place and value of the engineer with

advanced education might eventually add to the attractiveness of this kind of career.

There have been some expressions that graduate school administrators do not fully appreciate the desirable features of advanced work in engineering. Most administrators of graduate work are apt to be recruited from the so-called "pure" sciences. I suppose most of the misunderstanding centers around the classical concept that the purpose of graduate work is to conduct research of fundamental nature. Development of the most useful graduate curricula in engineering ought to improve the attractiveness of these programs. They should be free to develop without being fettered by traditions or by preconceived ideas based on what may be desirable for programs having different objectives.

I have briefly mentioned a few "psychological" factors. I have little notion of their relative importance. Some of them may prove to be trivial. I have in mind, however, two factors which seem to me to be of primary importance in producing graduate students. These are (1) improvement in pre-college preparation for engineering and the sciences and (2) more inspiring scientific leadership especially in the secondary schools, but also in the undergraduate colleges. I shall discuss these together because it is difficult to separate them.

Improved secondary education in preparation for science and engineering.- Secondary education has suffered criticism because of a tendency toward superficial treatment of science and pre-science work and its neglect of the talented student. I do not

wish to enter into a discussion of the justice of this criticism but merely to place the problem before you.

There is certainly evidence that many objectives of our secondary education program are not conducive to the intensive scholarship habits which young adolescents ought to develop if they are to become effective scientists or engineers. There seems to be good evidence also that preparation in the sciences and mathematics is too often omitted altogether or is of inferior quality when it is included. Habits and interests are pretty well moulded in young people by the time they reach 18 or 19 years of age. If the charges laid at secondary education are true, we are not only wasting valuable, formative years; but losing capable people simply because they have developed other interests without ever having a chance to become acquainted with science or engineering. The apathy of young people toward science and mathematics courses in high school probably could be overcome by better and more inspiring leadership in these fields and by reduction of conflicting interests.

The entire problem of secondary education as it relates to preparation for an engineering or scientific career needs a great deal of thought and study. Mass education must be recognized as a powerful force in realizing the American Dream, yet it apparently has the serious and growing deficiency of neglecting the basic education of our potential intellectual leaders. The problems of overcoming these deficiencies and still maintaining the desirable objectives of mass education are not simple. These

conflicting objectives and points-of-view have resulted in verbal brickbats being exchanged between scientists and educators recently. It is time that scientists and engineers sat down with conscientious leaders of secondary education and did something about (1) determining just how serious these alleged shortcomings are and (2) finding some way to improve the situation with as little sacrifice to all desirable objectives as possible. This responsibility falls upon engineers and scientists as much as on high school leaders and teachers. Our assessment of graduate work needs to include this task.

Intellectual leadership in the college and university.- There is no substitute for the talented, enthusiastic and inspiring teacher and scientist-engineer who stirs the spark of curiosity, skepticism and imagination in his undergraduate students. You all have met these fellows. The only trouble is that we don't meet them often enough. Perhaps some thought ought to be given to where these fellows come from and how we can keep them in contact with our undergraduate student bodies.

#### Summary

In trying to make an outline of what factors might be exploited to increase the supply of graduate students in engineering I have considered several which stem principally from economic considerations. Other factors, though in part tied to economy, involve principally other motives and for lack of a better term I have taken the risk of calling them "psychological". Without detailed

surveys, any statement about the relative importance of these various factors would be speculation. All that seems possible at the present time is to present them for further discussion and possible future evaluation.

In considering these various factors I could not help but be impressed by the fact that generally the factors which might increase graduate enrollment are also those which would contribute to building strong and effective graduate schools.