THE UNIVERSITY OF MICHIGAN
INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

FOR OUR FUTURE ENGINEERS – MORE THEORY OR MORE PRACTICE?

Transcript of the Eighth Ann Arbor Industry-Education Symposium

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INTRODUCTION

The technical manpower problems of the future can be alleviated only by analysis and planning today. The eighth annual Industry-Education Symposium was dedicated to this purpose; speakers from government, industry, and education described, evaluated, and presented opinions on various facets of the present and future requirements of engineering education. Many helpful ideas were expressed by the audience as well.

Several of the talks, and all of the discussion, have been transcribed from tape; the oral style has been deliberately retained. Since this book has been printed primarily for those who attended the meeting, and copies will not be available for sale, please do not refer to it in formal publications. Thank you very much.

R E Carroll

OPENING REMARKS

J. L. YORK

Professor of Chemical and Metallurgical Engineering
and Assistant Director, Industry Program

Gentlemen, we would like to convene another of the spring symposia of the Industry Program. We are glad to have these symposia for the direct contact that occurs between faculty and industrial people. We usually find that the faculty has a certain amount of isolation, hard as they try to get away from it; and the industrial people, hard as they try to find out what we're doing, have a little problem doing that. This is a chance for you to tell us some of the things you have on your mind regarding these problems, the subject of engineering education. We would first like to have you meet our Dean, Stephen Attwood, who will say a few words to you.

Stephen S. Attwood

Dean of the College of Engineering

I'm very happy to have you here today and extend a welcome from the College of Engineering and the University to our industrial friends who have come to this Eighth Industry-Education Symposium. We have been very happy over the years with the relationship we have established between the two groups and we feel that it's truly a beneficial operation. Your assistance to us is very valuable, and I think that we are able to give you something in return. I think of it as a two-way street, each of us helping the other. A good deal is being said these days about industry and education getting closer together, and this is one of the mechanisms by which this relationship is being strengthened. So we're very happy to have you here. Especially interesting today is the fact that we're talking about an education problem which we have to live with all the time but in carrying out our responsibility along that line we are very much interested in what our industrial friends think about it. After all, our product gets into your hands; how we mold them, and how you continue the molding, determines the general effectiveness that our graduates have in carrying out the operations that you're responsible for. I want to extend my thanks to the planning committee which spent a good deal of time deciding on an appropriate topic, and arranging the meeting. I want to thank the speakers that you will hear today. I should mention in particular the very fine organizational work that Ray Carroll does to make the operation successful and interesting. I am sure you will enjoy the day and I hope some of our faculty will be able, from time to time, to drop in as the day goes on. We still have to teach students and I find that every time we ask a faculty man to drop out of a class he is very jealous of the amount of the time lost. He thinks his topic is the most important in the world and one hour less just doesn't give him the opportunity to get all those words across that he wants. So I hope that we will see more of them during the day and at lunch. Thank you very much for coming.

J. L. York

Thank you Dean Attwood. The decision on the topic, as Dean Attwood mentioned, was an interesting process, and I think some of you in the room were here during the discussion. It was one of those cases where we sit around to have lunch and try to decide what kind of topic would be a good one. People tossed out one or two things and a side discussion would grow up about, "You know that last engineer I hired from here had some problems that I think you fellows ought to try to correct." So this little side discussion started over in the corner pocket, and Ray, a kind of chairman of the affair, tried to get us back to the subject at hand. Before he could get that discussion squelched we had another one going in another corner, because someone else complimented us on the type of things we're doing to a man. We found that it was impossible to stay off the topic, so everybody thought about it awhile and decided that what we do to the raw material, in order to give it a partial processing before we deliver it to the industrial concern to put it to work, is a crucial part of the over-all operation. The resulting topic, then, is "What should we do for our future engineers?" We, in teaching, are very much aware that the students now in process at the University are going to be sitting in your chairs in a few years and they will still be practicing in the year 2000. Most of us feel a little dreamy thinking as far ahead at the year 2000, but we must plan on turning out people who will be leaders in their fields and valuable to the industrial concerns at that time. On the other hand, they must be able to earn their keep next month when you put them to work. So we have somewhat conflicting goals. Since we, in teaching, usually do a lot of the talking about what we think should be done, part of this program was developed to ask you to tell us what you believe we have been doing wrong within the framework that I just outlined. We have several speakers, all of whom are from outside the University. We have one professor on the program, however, but I guarantee he's not like the rest of us. We would like to get started on the subject by finding out where we are, where we've been, and where it looks like we might go. For this purpose we went to the man we thought could probably tell us more about the engineering trends and manpower problems of the nation as a whole and of the world as a whole than any man we could think of in the United States. He is a midwesterner, born in Minnesota, educated in Iowa and the University of Pittsburgh; he was a professor in the field of physics for over 20 years. In 1941 he went to work in Washington for the Office of Scientific Research and Development, worked for some time in the War Manpower Commission, and is now

Director of the Office of Scientific Personnel in the National Academy of Sciences. He can tell you something about the type of information he has at hand, the kind of research they do, the background that they have on engineers and scientists, in general. I'd like now to give you an opportunity to hear from Dr. M. Trytten.

SOME BACKGROUND ON TRENDS IN REQUIREMENTS FOR ENGINEERS

Dr. M. H. Trytten

Director
Office of Scientific Personnel,
National Academy of Sciences
Washington, D. C.

SOME BACKGROUND ON TRENDS IN
REQUIREMENTS FOR ENGINEERS

In a symposium whose subject matter is the proper balance between experiential courses and theoretical and scientific background fundamentals, a paper on requirements for engineers may be only partially germain. The issues, in my view, are definitely related.

Perhaps my first comment, therefore, is that the dichotomy of "more theory or more practice" in engineering is part of a larger question, that of the changing character of engineering required by the fundamental changes being brought about in our society and its economy by the pace of discovery in basic and applied science. But even this fails wholly to present the challenge because there are other changes in our society which have their own great implications for the future of engineering, which are not primarily technical.

J. Douglas Brown, Dean of the Faculty, Princeton, in speaking on the occasion of the dedication of the new engineering quadrangle at Princeton in October last, said: "It is my mature conviction based on these years of study (on the supply and demand of high-talent manpower) that the profession of engineering is now undergoing the most drastic revolution in purpose, responsibility and character that has occurred since its existence as a profession."

He goes on to make a few salient points which I shall epitomize. His first point is that changing times bring to the fore changing demands by society for types of people reflecting the changing areas of rapid evolution. In the early years of our nation, political leaders were needed. Now the accelerating growth of new science and its application completely reorients the balance of talents our society requires.

The result is that the engineering profession lies between science and executive and industrial leadership in the supply of talent available and in the demands on that talent once developed.

Furthermore, the demands are harder to meet because of the greater intellectual attributes now required for the mastery of engineering science.

In respect to the responsibility of the engineering profession he states: "The professional engineer must act as the moderator and the interpreter between the two worlds of science and the humanities." (Here by the humanities it appears that the non-scientific-engineering domain in man's activities is meant.)

To summarize in one sentence, what Dr. Brown seems to be saying is that the interaction of science and particularly engineering and the outer world is now so great that it must be recognized as a conscious responsibility of the engineering profession.

That this points to qualitative changes in requirements for engineers would seem to be the prime corollary.

As was noted earlier in this paper, the dichotomy in the title of this symposium is in reality not broad enough. The thrust inwards on the professions is far wider than merely that arising from the divergence between the character of the technological jobs to be done, on the one hand, and the traditional disciplines, on the other. The fact is that the problems arising and demanding solution spread out far beyond the science or engineering disciplines and involve human behavior in the social, economic and political environment.

The problems of transportation, highway, rail, air or what not, have steadily become more complex. The engineering component has become proportionately a less dominant element as far as straight technology is concerned. The problems of land use, urbanization, protection against hazards, occupational and environmental, problems of building construction, of communication, and even of space exploration, all are requiring more and more attention to the human behavioral components. The answer here does not lie at least primarily in developing persons of hybrid competence. It seems rather likely that the initial approach will involve migration into these areas of interaction from both types of disciples, primarily to bring from the quantitative sciences a contribution of research design, quantitative method, and techniques of relevant computation.

As a first generalization, therefore, the trend seems to be clear that the principles of the engineering approach will be needed increasingly in the future in problem areas now only partially or not at all considered part of the engineering domain.

Within the more traditional domain of engineering, it may be that the present trend towards a higher scientific content in the engineering curriculum will create problems for a category of employers of undetermined character and magnitude. There seems to be a consensus that the new emphasis in science is an admirable preparation for many of the newer types of industry or those using newer technology, including, of course, research and development. There are, however, employer categories which are more in accord with the output of the traditional engineering curriculum. The extent and nature of this more traditional demand is difficult to assess since its spokesman have not been too articulate. It is, however, apparently real and not negligible.

The assessment of overall demand has been at all times fraught with difficulty. Prior to World War II there was no vocal interest in this matter as an issue. Since World War II continuous attention has been paid to it by various groups and agencies in and out of the Government. Uncertainty and disagreement have never been quite dispelled.

Probably the most significant and comprehensive attack on the matter has been made by the Bureau of Labor Statistics. Their methodology is considerably more sophisticated and detailed than has been possible by any agency in the past. The next report should appear early in 1964 and will indicate a substantial requirement for engineers between now and 1970. A paraphrase of their findings reads as follows - as taken from an early draft:

"The demand for new scientists and engineers arises as a result of two major factors - growing technical manpower requirements of an expanding and more heavily technological economy, and need to replace scientists and engineers who die, retire, or transfer to other fields."

Projected 1970 requirements - underlying the projections of growth requirements prepared for the study are several basic assumptions:

1. That relatively high levels of economic activity and employment will be maintained over the decade and that gross national product in real terms will increase 50% between 1960 and 1970 (about 4% per year), a target rate agreed upon by the United States in discussions with the Organization for Economic Corporation and Development. (Economic Report of the President, transmitted to the Congress in January 1962)

2. That the national security expenditures will rise somewhat above 1962 levels.

3. That there will be a continuation of the scientific and technological advances of recent years and that research and development expenditures will continue to grow.

4. That economic and social patterns will be about the same in 1970 as today.

Other more specific assumptions which underly the requirements estimates, such as a continuation of current patterns of technical manpower utilization, although not included here, are discussed in the complete report.

On the basis of the above assumptions, and using the methodology to be described in detail later, the projections developed for the study indicate an increase in requirements for scientists and engineers in the United States over the 1960 decade of nearly 800,000 - from 1,157,000 employed in January 1960 to a projected 1,954,000 needed in 1970, an increase of 69%.*

In engineering, a growth in requirements of more than 550,000 is indicated - from 822,000 employed in early 1960 to the 1,375,000 needed by 1970, a 67% increase. For scientists as a group (including mathematicians), the increase projected is 75% or about 245,000 - from 335,000 in 1960 to 580,000 in 1970)."

"The projections further indicate that between 1960 and 1970 requirements for scientific and engineering personnel in several broad industry divisions will increase more rapidly than the 69% anticipated for the economy as a whole. These industry divisions include construction, colleges and universities, and manufacturing - where by far the largest number of scientists and engineers are employed. The industry divisions in which the rate of increase in scientific and technical manpower requirements is likely to be somewhat less rapid are government (particularly the Federal Government), mining (including petroleum extraction) and transportation, communication, and electric, gas and sanitary services.**

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* It should be noted that the figures for 1960 represent actual number of persons employed, whereas the 1970 figures were developed independently of supply considerations, and thus represent projections of needs under stated assumptions, rather than projections of actual employment levels.
** The heterogeneous division "other industries" is excluded from this analysis since it consists of a number of dissimilar industries. Included in this group are medical and dental laboratories, engineering and architectural services, "other" nonprofit organizations, miscellaneous business services, agriculture, forestry, fisheries, wholesale and retail trade, finance, insurance, real estate, and other service industries.

There will appear also early in 1964 a report of the demand survey by the Engineering Manpower Commission of the Engineers Joint Council. It will quite probably differ rather sharply from the BLS survey report, showing a lower projected demand. The difference is in considerable part a reflection of the psychological impact of the "economy" dialogues in the Congress and the Administration. The probability is that some figure in between these two poles is quite likely and closer to the BLS figures than those of EMC.

The issue is illustrative of a basic dilemma in the pursuit of reality in the question of our requirements for technically trained manpower. There can be no "correct" answer to a question of how large is demand. There are too many missing or slippery variables. As an obvious example we may ask how many engineers are needed in American universities. Counting classrooms with students but no teachers would probably yield a figure of zero. There appears to arise some sort of accommodation between supply and demand so that no conspicuous or clearly measurable situation presents itself. We generally "make do" with what we have. The hidden costs and penalties of inadequacy - be it lack of numbers or of quality - are exceedingly difficulty to measure. We have no way of measuring what might have been.

For an educator in the domain of engineering or the sciences it would seem realistic for a long time to come to assume that by no stretch of the imagination will our schools train too many in any discipline. As has been noted, our society will have an increasing need for engineer-minded persons to deal with social, economic, educational, and health questions in the future. These burgeoning issues become ever more pressing. Engineering can expect to lose more out-migrants into action-type activities such as business, public life, entreprenueurial activities, etc.

With these considerations in mind, perhaps it is worthwhile to inquire briefly into the matter of personalities attracted into engineering. First there is the fact that a substantial number of engineers do not enter the profession by way of a degree from a college of engineering.

A study was carried out in 1958 for the National Science Foundation by A. J. Jaffe, based on a small sample of engineers and men in certain associated occupations. The purpose of this study was two-fold, to experiment with an approach which could be used in the 1960 census and to analyze such substantive information as the sample might provide. The sample was chosen from the Census Bureau's monthly national sample.

The schedules of information were examined to determine if the respondents were actually in engineering jobs, this examination carried out by qualified referees.

The results showed that about three-quarters of the men were engineering graduates. On the whole about 2.5% held doctoral degrees; 7% had a master's degree; 66% had a baccalaurete degree as the top degree about 17% had one to three years of college and 5% had high school training of four years; 2.5% had less than high school. Of those with a B.S. degree about 9% came from other physical sciences, and a somewhat comparable number from other fields including schools of business.

In the B.L.S. study referred to above comparable figures appear with respect to accessions to the engineering labor force. That is, some thing over 20% of acquisitions do not graduate from engineering cirricula

Studies now under way by the N.S.F., the B.L.S., and the Census Bureau will most probably give us much more information on this quite important source of employed engineers.

In moving now to discuss the characteristics of engineering students, there is the obvious fact that by and large engineering students are a fairly able category as judged by the common indices of aptitude and achievement in an academic setting.

From the point of view of academic ability engineering students have generally compared very favorably with students in other categories. Chauncey reported that in the first Selective Service College Qualification Test administered by that agency in 1952, a larger proportion of engineering students achieved relatively high scores than did students in any other major field of study, closely followed by students in mathematics and physical sciences.*

Wolfle and Oxtoby reported about that same time that this same fact appeared in studies on recent college graduates.

One of the more interesting and significant findings on the population of engineering students relates to their socio-economic origins. Over the years several studies have seemed to agree that engineering students tend to come from somewhat lower strata on the socio-economic scale than do many other categories.

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*Henry Chauncey, Science, Vol. 816, July 25, 1952.

Glen Stice of ETS* studied 33,000 American high school seniors with respect to career plans. He found that among males in the top third of their high school classes, those aspiring to careers in engineering were more likely to be from "working class" backgrounds, (clerical, service, and manual) (32.4%) than were those aspiring to careers in natural science or mathematics (25%).

Martin Trow** reported results of a recent survey conducted by the Center for the Study of Higher Education, Berkeley, that winners and runners-up in the National Merit Scholarship Program show that over 50% of the future engineering students in that sample have fathers in manual and lower middle class occupations as compared with a little over a third of science and mathematics students. He reported that the findings of an as yet unpublished study (as of that time) are similar to those of the NMSC study. Half of the engineering students at Berkeley came from manual and lower middle class backgrounds as compared with about a third of the students in various natural and physical sciences.

Dael Wolfle (Loc. Cit.) reported in 1954 that engineering students were considerably more likely than most groups to have fathers employed in the skilled trades; the study gives no statistics but represents 10,000 graduates of 41 colleges.

In one sense these studies are somewhat imprecise in determining what defines a lower middle class origin. The findings from studies made by National Opinion Research Center are a bit more precise in identifying criteria for a judgment as to socio-economic origin. These studies were based on the graduates of colleges and universities in June 1961. The studies report in "Great Aspirations", University of Chicago 1962, covered 34,000 graduates from a broad representative sample of institutions and departments. Part of the results were based on a weighed sample of the returns of about 4,000 cases.

Additional information was reported in a more complete analysis of findings released in March 1963 and based on the same returns.

Table I shows the relationship between family income and career preference of the sample. It is striking that engineering students come

*Background Factors and College-Going Plans Among High Aptitude Public High School Seniors, Princeton, ETS, 1956.

**Some Implications of the Social Origin of Engineers. Scientific Manpower, National Science Foundation, 1959.

from homes of low family income. In fact, electrical engineers and physical scientists other than physicists and chemists have the lowest percentage of all with respect to family incomes over $15,000 annually. In contrast physics students are at the top in this respect, being exceeded only by one category, a small one numerically. At the other end of the scale electrical engineers have the highest percentage in respect to family incomes less than $7,500 annually. Only secondary education in the sciences ranks higher.

In respect to fathers' education and career preference, Table II shows corroborating evidence. Civil Engineers show the lowest percentage of fathers with four years of college, with the one exception of accounting. Certain educational specialties match them. Electrical engineers also rank low and next in line on a rising scale. In contrast, physics students rank quite high in respect to the percent of fathers with four years of college or more. At the other end of the scale almost half of all engineers have fathers with less than four years of high school. Table III shows approximately the same situation with respect to mothers' education.

With respect to place of origin the picture is not so clear-cut. Table IV shows the effect of community size. Electrical engineers tend to come from large cities and less from rural origins. Civil engineers are far less likely to come from large cities and much more so from farm or open country. Other engineers come from all types of environment in somewhat similar percentages.

One would expect the socio-economic level of the students to be a factor in drop-outs. Eichhorn and Kallas report* from a study of students at Purdue that socio-economic status is inversely related to drop-outs. Forty-two percent of those returning for a sophmore year were from high-status background, while only 30% of the drop-outs were. The definition of drop-outs in this case is not clear.

In the NORC study quoted above, which deals only with graduates and hence gives information only on shifts from and to engineering, and not drop-outs from university attendance of engineering students, no significant socio-economic correlation was found. The shifts, however, are of prime significance. The Table V shows us a representation of the statistical findings. It will be noted that among the 7,398 entering freshmen apparently bent on an engineering career, 3,038 defected to

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*Social Class Background as a Predictor of Academic Success in Engineering, Journal of Engineering Education, 52, 507, 1962.

the listed discipline headings. In addition, in this case, where one deals with shifts in enrollment as opposed to drop-outs, there is a significant positive correlation between high socio-economic status and shifting from engineering.

There have been clues in studies from time to time as to why such shifts occur. There seem to be few studies of a depth and competence to be of high apparent validity, but some appear to be indicative. One such study was carried out at Yale by Burnhave and Ramsey. The number of students studied was small, but of uniformly high ability, most in the 90 percentile. Upon matriculation their aims were 69% in science and engineering and 25% in other areas with 6% undecided. Upon graduation, however, the percentages were reversed with 37% in science and engineering and 63% in other subjects.

While there were a variety of reasons for shifting, the major one seemed to be the wider intellectual horizons in the new fields and the fact that these fields were broad enough to keep more avenues open for eventual commitment.

Perhaps a word or two about social characteristics is in order. Krulee and Nadler (ASEE Journal 1961) reported on a study at Case Institute of Technology of 1,600 undergraduates. They found that science students tended to be "men of action", placing much greater value on what is practical and directly applicable. This was much characteristic of mechanical engineers. Even electrical engineers who placed greater emphasis on theory than other engineers did so for practical reasons.

It may be of interest, too, that this study seemed to differentiate between science and engineering in other ways. Science students appear to seek more demanding courses, to be tolerant of courses of general educational purpose, and to desire freedom of choice in such courses. Engineers seemed to desire prescribed courses. Engineers also seemed to disfavor decidedly the trend towards more theory and less practically useable material.

Summarizing these findings, Table VI, correlation of freshmen choice, is shown. Academic performance index, it must be remembered, is based on grades which may be heavily influenced by the competition they are in, in this case other engineers, for much of their course work. The tendency of engineers to be uninterested in working with people is marked. Clearly they are interested in ideas and wish to be creative, to deal with problems, and to achieve mastery over the tools of their elected occupation and get on with a job.

One situation which I have always believed has been far less analytically examined than it should have been is the fact of high G.I. interest in engineering as a field of study. It was noted by the ASEE Committee on Engineering Manpower early in the nineteen fifties that the great engineering bulge which produced a peak graduating class of over 52,000 engineers in 1950 was primarily due to veteran enrollment. In fact, non-veteran freshmen enrollment, I believe, had begun its downward trend prior to this time.

Why did so many veterans enroll in engineering? There have been two plausible reasons given, neither of which seems to me adequately documented, as far as I know. One of these would seem to be borne out by the findings here presented that engineers come from somewhat lower socio-economic levels. At these levels the cost of education is a deterrent to ambitions for college education. It is at least reasonable that when the Veterans' benefits provided the necessary financial support this reason disappeared and provided the opportunity for the disproportionate interest in engineering in this stratum to manifest itself.

The other explanation arises out of the fact that military experience in the modern services deals intimately with hardware - electrical and mechanical gadgetry for the most part. This provided training of various degrees of engineering complexity to a large percentage of veterans. Perhaps it was, on the one hand, a spur to predilection and, on the other, a base upon which to capitalize. There may be here food for thought. There should be more effort to document the effects of military experience on career choice.

It would seem to me quite clearly indicated that whatever conclusions one might wish to draw from these findings, the fact would seem to be that typically engineering students, or at least students who are attracted to engineering, are differentiable from others. Trow comments* that even at Swarthmore College, which his group finds gives an extremely favorable impression of a high degree of intellectual life on the campus, engineering students go their own way and seldom participate in the general intellectual ferment, or share in the interest in ideas. They are "more like engineering students elsewhere than like Swarthmore students."

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*Trow loc. cit. page 73.

Remembering that no stereotype is universally valid, and that the stereotype may fit poorly in some engineering schools and better in others, one may nevertheless conclude that a sufficient number of engineering students fit the type to be worth some inferential comments.

In the first place, the distinctive feature of lower socio-economic origin taken together with the mounting costs of education may lead to the conclusion that engineering enrollments should suffer disproportionately. That this is occurring has, as far as I know, not been demonstrated. It may be worth exploring.

Secondly, the implication of all of these findings seems to be that one of the characteristics of engineering aspirants is a desire for upward mobility in the socio-economic sense. This would explain also their apparent single-mindedness in getting on with the business of acquiring their professional training, their seeming impatience with non-professional courses and their lack of interest in service functions to people as such.

But there are growing categories of opportunities for upward mobility in many competing fields at present, not least among which is the area of business education, business administration and the like, which obviously compete even after the student has begun his engineering training. Engineering is no longer a rather conspicuous path to upward mobility.

Then, too, the changing nature of engineering training may be altering the image of the profession in such a way that the high school graduate finds less compatibility between his own concept of the kind of training he wants and what he now sees ahead of him.

Trow expresses it somewhat in these terms. He visualizes the aspiring student as one who has come from a home where it has been necessary to focus on the essentials to get ahead and who carries with him the effects of this environment. Consequently he is not conditioned to the kind of open inquiring questing approach stressed in science teaching, but rather to the fixed assignment, the tasks to be done to gain knowledge and skill, and the acquisition of saleable professional expertise in his field.

Obviously this stereotypes both engineering and science teaching, perhaps outrageously. But crudely this is his point.

His further point, however, would seem to be valid, that the solution to the problem of ensuring adequate engineering enrollments is not merely a question of improved science instruction in the formative, preparatory years, in the pre-college years, but also depends on understanding the social conditions and forces which shape the aspirations of the fledgling student, and direct his ambitions. Of necessity the evidences that have been shown are only as yet indicative They do indicate that there is in the characteristics of engineers, their early environments, their natures and typical motivations, much that can be of value in the problem of interesting more young people in engineering as a career.

TABLE I

SOCIAL BACKGROUND CORRELATES OF CAREER PREFERENCES

(Ten percent Sub-sample)

(a) Family Income

Career	Less than $7,500	$7,500-$14,999	Greater than $15,000	Total Per Cent	Total N
Chemistry	60	35	6	101	52
Physics	33	33	33	99	36
Mathematics	42	47	10	99	38
Other Physical Sciences	62	33	4	99	24
Electrical Engineering	71	26	4	101	82
Civil Engineering	55	38	7	100	42
Other Engineering	50	43	6	99	124
Medicine	33	36	31	100	84
Nursing	50	40	10	100	40
Other Health Professions	52	32	17	101	60
Biological Sciences	52	40	8	100	60
Agriculture	50	40	10	100	48
Elementary Education	51	34	15	100	229
Secondary Education, Non-science	53	36	11	100	233
Secondary Education, Science	68	21	10	99	79
Edu. Administration	60	34	6	100	35
Housewife, teaching	42	43	15	100	60
Educational Specialties	65	29	6	100	175
"Clinical"	47	41	12	100	66
Social Sciences	33	42	25	100	84
Fine Arts	34	41	25	100	73
Humanities	48	36	16	100	106
Communications	39	26	35	100	77
Business	37	33	29	99	368
Accounting	56	33	11	100	93
Religion	69	24	7	100	55
Government	54	22	24	100	41
Law	31	36	33	100	113
Social Work	44	30	26	100	43
Housewife	49	20	31	100	39

			Total..........		2,659
			Not classified.		223
			No answer......		115
Total sample.........	42	31	15	88	
			Don't know.....	12	400
				100	3,397

TABLE II

(b) Father's Education

Career	Less than 4 years High Sch	High School Graduate or Part College	College Graduate or more	Total Per cent	Total N
Chemistry	30	45	24	99	53
Physics	30	35	35	100	40
Mathematics	34	27	39	100	44
Other Physical Sciences	38	38	23	99	26
Electrical Engineering	51	34	14	99	90
Civil Engineering	52	37	11	100	46
Other Engineering	43	42	15	100	137
Medicine	21	31	48	100	91
Nursing	45	40	14	99	55
Other Health Professions	37	39	24	100	75
Biological Sciences	39	40	21	100	70
Agriculture	43	41	17	101	54
Elementary Education	39	40	21	100	279
Secondary Education Non-science	40	39	22	101	264
Secondary Education Science	49	28	22	99	85
Education Administration	50	35	15	100	40
Housewife Teacher	34	42	24	100	84
Educ. Specialties	52	37	11	100	202
"Clinical"	41	35	24	100	78
Social Science	31	36	33	100	94
Fine Arts	26	28	46	100	92
Humanities	44	30	26	100	121
Communications	26	34	39	99	84
Business	35	38	27	100	405
Accounting	60	32	9	101	104
Religion	44	34	21	99	61
Government	33	31	36	100	45
Law	28	26	45	99	121
Social Work	25	37	37	99	51
Housewife	24	30	46	100	46
				Total.........	3,037
				Not classified	272
				No answer.....	88
Total sample	39	34	25		3,397

TABLE III

(c) Mother's Education

Career	Less than 4 years High Sch	High School Graduate or Part College	College Graduate or more	Total Per cent	Total N
Chemistry	30	53	17	100	53
Physics	37	42	20	99	40
Mathematics	21	49	30	100	43
Other Physical Sciences	40	48	12	100	25
Electrical Engineering	42	48	10	100	90
Civil Engineering	39	48	13	100	46
Other Engineering	37	51	12	100	137
Medicine	12	60	27	99	91
Nursing	44	44	13	101	55
Other Health Professions	28	55	17	100	75
Biological Science	39	39	23	101	70
Agriculture	33	50	17	100	54
Elementary Education	36	47	17	100	281
Secondary Education Non-science	29	51	20	100	268
Secondary Education Science	39	48	13	100	85
Educ. Administration	52	35	12	99	40
Housewife Teacher	24	60	16	100	83
Educ. Specialties	41	49	10	100	202
"Clinical"	29	51	19	99	78
Social Science	22	53	24	99	94
Fine Arts	20	50	29	99	93
Humanities	31	46	22	99	121
Communications	21	52	26	99	84
Business	28	54	18	100	403
Accounting	42	46	13	101	103
Religion	42	43	14	99	62
Government	28	46	26	100	46
Law	23	54	23	100	121
Social Work	18	57	25	100	51
Housewife	11	72	17	100	47
				Total.........	3,041
				Not classified	272
				No answer.....	84
Total sample	32	50	19		3,397

TABLE IV

(d) Place of Origin

Career	Metropolitan Area: Greater than 2,000,000	Metropolitan Area: 100,000- 2,100,000	Less than 100,000	Farm or Open Country	Total: Per cent	Total: N
Chemistry	28	36	21	15	100	53
Physics	32	40	15	12	99	40
Mathematics	34	27	23	16	100	44
Other Physical Sciences	23	31	35	11	100	26
Electrical Engineering	33	23	27	17	100	90
Civil Engineering	11	26	33	30	100	46
Other Engineering	17	33	27	23	100	137
Medicine	34	29	27	10	100	89
Nursing	11	24	40	25	100	55
Other Health Professions	14	30	36	20	100	73
Biological Science	16	25	29	29	99	68
Agriculture	6	17	18	59	100	54
Elementary Education	18	25	32	24	99	279
Secondary Education Non-science	17	32	31	19	99	268
Secondary Education Science	15	21	32	32	100	85
Education Administration	12	22	35	30	99	40
Housewife Teacher	8	30	37	25	100	84
Educational Specialties	7	16	34	42	99	206
"Clinical"	29	26	26	19	100	78
Social Science	21	46	25	7	99	93
Fine Arts	27	25	35	13	100	92
Humanities	21	28	26	25	100	121
Communications	14	40	29	17	100	84
Business	20	33	32	15	100	402
Accounting	15	27	32	26	100	104
Religion	8	25	44	23	100	61
Government	22	35	28	15	100	46
Law	33	24	31	12	100	121
Social Work	10	37	37	16	100	49
Housewife	19	38	32	11	100	47
				Total.......		3,035
				Not classified		272
				No answer...		90
Total sample	19	30	31	22		3,397

TABLE V

CAREER FIELD NET TURNOVER

Field	Educ.	Bus.	Soc. Sci.	Hum.	Bio. Sci.	Other Profs.	Law	Phy. Sci.	Med.	Engin.	None	Total Freshmen
Education.........	+3,959	+324	+121	+328	+87	+1,069	+71	+251	+228	+497	+983	12,619
Business..........	-324	+2,760	+12	+94	+19	+266	+82	+250	+224	+1,360	+777	5,763
Social Sciences...	-121	-12	+609	+58	+27	+96	+28	+118	+118	+140	+157	1,135
Humanities........	-328	-94	-58	+349	+13	+172	+52	+103	+107	+111	+271	2,953
Biological Sciences	-87	-19	-27	-13	+248	+101	-7	+80	+145	+29	+46	833
Other Professions.	-1,069	-266	-96	-172	-101	-486	+29	+135	+228	+346	+480	8,411
Law...............	-71	-82	-28	-52	+7	-29	+266	+72	+136	+235	+78	1,708
Physical Sciences.	-251	-250	-118	-103	-80	-135	-72	-414	+27	+449	+119	3,231
Medicine..........	-228	-224	-118	-107	-145	-228	-136	-27	-1,130	+50	+33	2,643
Engineering.......	-497	-1,360	-140	-111	-29	-346	-235	-449	-56	-3,038	+179	7,398

	Freshmen	Senior			
Cell entry = X - y	row occ	column occ	y	=	Net Turnover
	column occ	row occ	X		

N, Senior Career = ... 49,817
NA, NEC, Freshman Career..... 2,834
NA, NEC, Senior Career....... 3,560
NA, NEC, Both................ 453

Total Weighted N = ... 56,664

Shaded cell indicates row occupation had Net Loss to column occupation:
Diagonal = Let Change for the occupation vis-a-vis all others.

TABLE VI

CORRELATIONS: FRESHMAN CAREER FIELD BY SEX, API, VALUES, AND BACKGROUND INDEX

Variable		Field									
		Phy. Sci.	Bio. Sci.	Soc. Sci.	Hum.	Med.	Law	Engin.	Educ.	Other Prof.	Bus.
Sex:	Male	+.301	-.190	-.177	-.438	+.508	+.730	+.977	-.730	-.246	+.521
API:	High	+.257	+.062	+.278	+.234	+.245	+.180	-.106	-.051	-.038	-.233
Values:	People	-.491	-.433	+.233	-.047	+.094	+.075	-.552	+.432	+.169	-.001
	Original creative	+.255	+.082	+.067	+.467	-.040	-.091	+.146	-.066	-.099	-.304
	Money	+.107	-.174	-.071	-.259	+.040	+.416	+.335	-.472	-.242	+.430
SES:	High	+.026	+.082	+.215	+.192	+.370	+.435	-.120	-.184	.000	-.014
City:	Larger	+.177	+.043	+.307	+.054	+.211	+.258	+.051	-.233	-.142	+.138
Religion:	Protestant	-.166	-.112	-.158	.000	-.231	-.401	+.017	+.168	+.197	-.137
	Catholic	+.156	+.073	+.002	-.014	+.049	+.297	+.019	-.140	-.146	+.151
	Jewish	+.082	+.128	+.335	+.031	+.400	+.331	-.100	-.145	-.220	+.013
Race:	Negro	-.330	+.361	+.327	-.263	+.076	-.306	-.428	+.240	+.235	-.398

DISCUSSION

J. L. York:

Thank you Dr. Trytten. One of the features of these symposia is to throw the floor open for discussion, and we always encourage questions -- as many and as embarrassing as you may care to make them. Of course Dr. Trytten's area is dealing primarily with where the facts are and where the people are, but if any of you have questions that you would like to put out on the floor for discussion, or comments that you would like to make, I'd like to have you start out.

A. R. Hellwarth
Question:

Dr. Trytten, would you estimate the possible increase in efficiency of the total manpower picture, if we had more technicians?

M. H. Trytten
Answer:

Well, I can only tell you what other people think about this, whose opinion I respect, and the picture as I see it is like this. We have less than one technician per engineer at the present time in our general setup in this country and we can undoubtedly use two or three technicians per engineer for maximum efficiency. For example, as you may know, DuPont has tried to solve this problem of bringing in the technician. I heard a presentation by the person in charge of this program at DuPont some months ago, some two months ago. They seemed to be quite successful. They started out using high school graduates and tried to make them over into technicians, but they found that this was too expensive and took too long. So they have gone now completely into the use of graduates from technical institutes. And they have also set up what I think is the key to the whole question -- a pattern of career advancement for the technician which is a recognized thing. They have done away to some extent with this status-seeking feature which is the real problem. I think on the one hand there isn't much question about it, that we need many more technicians or we could use many more technicians and would increase efficiency. The problem is how you get them.

J. L. York
Question:

Any other questions? I have one myself, Dr. Trytten. We know that there has been an increasing number or percentage of doctorates, showing the sharp increase in engineering and simultaneous decrease in chemistry -- I wonder if that implies that there is a transfer of people who might have otherwise gone into engineering. A broader part of the question might be, as you indicated in the beginning, we need 80 thousand engineers and we're getting some 30 thousand engineers. Where would they come from?

Answer:

This is the reason I brought in this material on the nature of engineering population; I think most of the social science analysts would conclude from this information that many of the people go into engineering as a path toward mobility in the socio-economic sense and that they did so in the past because this was probably the most attractive way to do it. I think what we need to recognize today is that there is another upward moving path, in the field of business administration, that may appeal to many of the same youngsters and that maybe some of the people who would ordinarily go into engineering go into these other fields. As to your question where are we going to get them from, I don't know. I think the change in the curricula may actually be, on the one hand, less attractive to people from the level of personnel who are trying for an upward mobile path. But it may be more attractive to the better quality student who can see a challenge in engineering which apparently in the past some have not seen. I have been puzzled, for example, why this tremendous surge out of engineering. This 3,000 loss seems to me to be one of the things that needs to be analyzed very carefully to find out why they changed. If you can keep them you would solve much of your problem. I haven't any answers for you; I've only got questions

A. R. Hellwarth:

Many of the people whom we admit directly into engineering from high school are still exploring their vocational choice, and our biggest loss comes the first two years. I talk with the ones who are considering leaving and trying to make up their minds whether they want to be in engineering college, or over in the Literature school. Those who change are charged as a loss to engineering. Actually I think the loss is not any higher than among those who plan to go into law or into business, when they first enter college.

M. H. Trytten:

This is true. I was just going to comment but I think the statement you made is that when they enter college with some commitment to engineering but not a final commitment to engineering that is, they're making up their minds. But they are doing that in all fields.

A. R. Hellwarth:

In other words, we have a two-year pre-engineering program.

M. H. Trytten:

If you can put a two-year pre-engineering program in a good high school, I think you will have something. Let me just throw out one interesting little item here that is a wholly different sort of thing, that has interested me very much. The Society for Professional Engineers carried out a series of interviews which was not sufficiently extensive for them to be willing to publish this as a finding, but it was carried out for the purpose of designing a study which I believe is going to go on. But one of the questions that came up on the part of high school seniors who had indicated a desire to go into engineering, who had thought about it at one time, and then decided not to go into it: Why didn't they? The reason they didn't,in many cases, was that the mathematics which is taught in high school at the present time has been changed so materially with the advent of the new look in mathematics, that they felt that while they knew more about mathematics, they did not possess the specific skills needed in engineering education. They were not ready for engineering education mathematics so they didn't go into it. I hesitate to bring that out because it's a pretty weak research design, but it's significant enough to be worthwhile mentioning.

Question:

Your remarks about two years of pre-engineering in high school - is that on top of the standard high school curriculum or is that to replace the junior and senior year in high school, what is your thinking about....... ?

M. H. Trytten
Answer:

No, I was thinking more of a course in high school which could be worked out with high school people satisfying high school requirements. But making sure that the individual had substantial mathematical and science training to be ready for engineering. Some sort of cooperation with the high school to insure the good preparation for engineering when the individual goes in and to get him thinking about engineering two years earlier, this I think is the important thing. To get him at least partially committed to engineering as early as the junior year in high school.

Question:

In other words, you would not put another semester or year in the high school?

M. H. Trytten:

Well, not presently, but I wouldn't rule it out. It might be possible some places but not as a first step.

J. L. York
Question:

One bit of information that I've heard you discuss, informally at least, is the percentage of the population which apparently has the mental capacity and background to go into the technical fields, the EMP group, and this is another interesting point. Can we get people, not by stealing them from other fields, but by upgrading them into a useful level of engineering education from areas where they are not now being used to their full potential?

M. H. Trytten:

I think the answer to that depends on what you state as your primary parameters there. I think the major problem we have in the United States is the fact that a great many small high schools are inadequate in size to do the kind of a job that the modern high school has to do. This comes out of some studies we are making on the doctorates in the country. We have for example taken the totality of doctorates in the years 1957-58 on whom we have information as to where they did their high school work, and have examined that in terms of several variables in high school situations. A large number of high school students in the United States are in small high schools where they don't have the equipment, they don't have the teachers, they don't have the course offerings, etc. And it shows up in the fact that these people do not go on to graduate school. The great weakness in our country is right here. This is one place where we could get a lot of additional personnel because when you take the over-all actual measurements or whatever other measurements you want, you do find that there is theoretically a possibility of answering their question in the positive. But whether you can do it under present circumstances, in present schools, then I think there is a definite limitation. Let me give you another curve here which comes out of our studies. Taking the population as a whole and putting them on any kind of a curve or graph you want to, let's take the Army General Classification Test as a measure of the ability of the population to do this kind of thing. It has certain drawbacks but on the whole is fairly statistically reliable as an indication. Then you take the people who have a doctoral degree, you get a curve about like that; if you were to take the engineering personnel it would come over somewhere about in there and you draw it like that, and you can determine that is the unused potential. Of course, these are on very different scales. If I were to draw these on the same scale it would come like this so that there is in here quite a large percentage. In the case of the doctorates, variation in terms of the I.Q., up here is the way high I.Q. About 1 out of 5 in the country is now obtaining a doctoral degree out of this group. If you take the median for doctorates it's about 1 out of 40 that is getting a doctor's degree, so there would appear to be quite a bit of talent available there although, of course, you have to remember the many other demands in the population for this kind of people, not only that one category. But if you do that for engineering you get the same sort of curve which shows that you probably could, under proper circumstances, get enough people with a high enough quality to fill your needs. But, on the other hand, time is in sight when that may not be true. The other part of this picture is what we get from abroad. This is becoming a more and more interesting question. Right here on the campus in Ann Arbor you have 1400 foreign students, about 230 from Europe, and in speaking to one of these people last night he told me he expected about half of those to stay in the United States, so that we can't forget the foreign component. This is probably going to be a substantial thing; these are very select people.

J. L. York:

Any other comments? Well, we hope that Dr. Trytten will feel free to bring into the discussion after the other papers anything that he thinks might be applicable to the subject.

J. L. York

Now that we have established a background of information as to the lack of engineers and had some discussion as to how we might arrange to get more of them, where we might find them, and what we might do to encourage more of them, we might look at another aspect of this problem. One big part is what happens to them after they leave the University: what industries do with these engineers, and what kind of training they should have to be of maximum usefulness to the company and to the nation and still satisfy their own ambitions. The next presentation and the first one after lunch are both along these lines, representing points of view from industries. The first of these is coming from one of those companies that some people call a "miracle-type growth industry," "a modern phenomenon," and so forth. It's one of the companies whose name changes just often enough and fast enough that many of us have trouble keeping track of their insignia and title, because they're growing fast by virtue of internal growth, mergers, etc. We have with us one of the men who was instrumental in that. The next speaker has responsibility as a Corporate Vice President and President of the Instrument Division of Lear Siegler. He has responsibility over the activities of a large number of engineers, physicists, as well as other scientific personnel. He himself came out of the ranks of business administration, where Dr. Trytten tells us most engineers who don't like us go. So perhaps he is one of the people who came back the other way, in a certain sense, although I'm sure that his engineering is at the moment engineering of people as much as engineering of things. He was with Engineering Research Associates, Kaman Aircraft, and Ford Motor Company in his earlier years. In 1955 he joined Lear, Inc., and rose up quite rapidly in that organization. It now is Lear Siegler as a result of a recent merger, and he is the Corporate Vice President of the organization and has responsibility for the Instrument Division, so we shall hear some comments regarding the balance between theory and practice in engineering training from Mr. Joseph Walsh.

MAINTAINING A BALANCE BETWEEN THEORY AND PRACTICE IN ENGINEERING EDUCATION

Joseph M. Walsh

President,
Instrument Division,
Lear Siegler, Incorporated
Grand Rapids, Michigan

MAINTAINING A BALANCE BETWEEN THEORY AND PRACTICE IN ENGINEERING EDUCATION

Thank you very much and it's certainly an honor for me to speak to you here today. As you can see an engineer put a noose around my neck again. For us business men this happens quite regularly. I think that my talk is going to be much more restrictive than Dr. Trytten's. I can't speak for all of industry because I am experienced in our own particular type of industry. We can give one company's view, a company which makes everything from space heaters for cabins to space equipment for outer space. I can speak mainly for the instrument division which as some of you know is located in Grand Rapids.

We are a highly technically oriented company of roughly 3,000 employees. Our products are aerospace equipment, in the gyroscopic, electronic sub-system, space system area. Recently, as the result of our association with the University, we acquired a laser company in Ann Arbor and we have a laboratory here, in addition to the laser activity. Our company has grown over the years; our employment of engineers, in strictly engineering pursuits, is about 180. Our total number of engineers is approximately 250. This points up some of the problem that was discussed earlier of the number of engineers that stay in engineering as such. We feel that the engineering graduate has a wider field than the normal classification of engineer. We require people trained in engineering disciplines, and it's necessary that they be well equipped to handle the determination of requirements by studying the total picture of new requirements in our particular fields: the new space systems, the new weapons systems, the actual conception of the equipment itself, the basic design and development, and then the translating of that into a manufacturing concept working with our manufacturing people to finally end up in the produced product, shipped, installed and operating in a major weapon or space system.

Of course a significant amount of engineering talent is required in our manufacturing engineering areas. These particular areas cover processing, tooling, industrial engineering, and plant engineering. In our quality control areas a high technical content is required and in at least the major spots in that particular area, engineering training is required. The work of our particular company has become increasingly more complicated. For example, about 10 years ago we had 5 products, while today we have approximately 300 products. And the products themselves have become much more complicated. This has required a widening of capability in the total area that we attempt to cover. The whole atmosphere of the company demands a greater knowledge of the technical disciplines. We have engineering people, engineering graduates, in such jobs as industrial relations, production supervision, staff positions, general management, and purchasing, which is a very interesting area. A few years back we could pretty well take a shop man who had a pretty good flair for haranguing with a vendor and give him a purchasing assignment. As our programs are now more complicated, and our components more sophisticated, an effective buyer must have a high degree of technical knowledge, and we have quite an interlacing of engineering graduates in our purchasing activities. Contracts administration and sales also have a significant technical requirement. Our products are complicated; the requirements we have to fill are highly technical in nature. And we also find within our marketing organization an increasing percentage of graduate engineers. We are able to translate our technical competence into the customer's requirement so we can combine our forces, engineering and marketing, to come up with a strong position on profitable terms. The foretest of our future product, which is a very important part of our effort, the new fields we must get into to continue our growth, indicate to us that the percentage of technically trained people with the organization will increase. The wide variety in the company, the wide variety of positions in which we use engineers, indicates that there is no simple answer to what we look for in a new engineering graduate. We do, however, have some general requirements. They may sound more specific to us, but in the light of the many specialities today it would probably seem general to most of you gentlemen.

We have in product engineering a strong requirement on the engineering employee to be able to come up with an accurate prediction of requirements. This requires the engineer to conduct a series of investigations of possible requirements, involving a significant analytical effort on his part to be able to define how we could fill these requirements, which means early evaluations of what type of equipment will be needed. You must be able to cross discipline lines, which was brought up earlier today.

Our company is often classified as a glamour electronic stock. Basically, however, our success has been electro-mechanical equipment. The gyroscope is basically a mechanical gadget. It does involve work with electronic and electrical areas. It also involves work in the areas of materials, meaning a careful study of the physical and chemical properties of the materials of construction of the various units we use. It also requires a knowledge of the environmental conditions under which it must operate. So we find that engineers specializing on the mechanics of gyroscopes can't produce for us a gyroscope to fit within a certain envelope to tie in and integrate with other products without having a strong appreciation for the other basic disciplines and an ability to work with them and understand them. Of course, a significant amount of knowledge in the particular field of design whether it be electronic, or whether it be mechanics, is certainly required. The engineer must be able to understand the total picture, and be able to visualize the total program to see how his particular part integrates with the work of other scientists that may have, for example, responsibility for an electronic package which can involve microcircuitry, or for a solid state display system. Our engineer must have this ability to respect, understand, and work with or integrate these particular efforts with his own.

It's also necessary that he be able to communicate fairly well, because an engineer today in our particular type of business has the responsibility for being part of a project team, and as he grows within the company, being leader of a project team, where he has strong responsibilities in addition to the technical disciplines. He must have a strong capability in the understanding of programming of programs; he must be able to manage diverse groups; be able to utilize properly services other than those under his specific control; he must be able to become part of the customer relations team, or the selling team in its early stages. He must also be able to participate effectively from the time of working with the theories of what the program is going to be, the total weapon system, the total space system, and maintain continuity until the day that he is working with the installation of that equipment. In other words, he must be able to work both with mechanics and program conceivers. And of course he must be able to make our system operate in the particular aircraft or spacecraft, as required, and in very many cases that last step is one of the most difficult to be able to integrate our particular piece of gear into this massive complicated system over which we have a very small control, and in some cases no control. We also have to recognize that we are operating in a profit economy. Occasionally we have the same old remarks that we're not non-profit, it just worked out that way. But we feel we have been successful in being a profitable company and a growing company partly because we continually work on training our technical managers, submanagers, and engineers to be significantly management oriented so that they can't live in a world unto themselves. And of course bookkeepers like myself keep the engineering organization fully aware of the total requirements of the company in order to continue operation in a profitable manner. They must understand and accept the profit motive. They must understand and accept time limits, cost limits, and incidentally we often hear criticism of management from technical people that we're trying to make them bankers. I disagree very much that we're trying to make them bankers. To be a good engineer I think they must keep thinking of these things because the cost limitations and the time limitations represent only an ability to understand the problem, to be able to plan it, including such things as understanding the material, and personnel requirements. If these are done the dollars fall out automatically. An engineer who cannot do that can't be expected to handle any significant program with any degree of success. It's inherent that he must know what talents he needs to call on, when he needs them, and how long it's going to take.

Another consideration is that we must come up with products; we must be able to integrate them into current requirements. The ability of a technical person to design a piece of equipment for producibility is an extremely important element with us. To be able to prove a phenomena in a laboratory is of course a first step; it is absolutely essential that our engineers have the ability to translate basic phenomena into a workable piece of equipment which can exist under particular environmental conditions. The third requirement is the most difficult for our new graduates -- an ability to design hardware which can be produced, can be built, by people not as talented as the engineers or technicians. These are some of the abilities which we hope will develop rapidly in our new graduates and in our new engineering employees. Another requirement in our engineering organization, is that our new engineers must be able to accept changes and emphases. The constantly changing program, the radical changes in decisions of the strategy in the new space and weapons programs, result in a constantly unpredictable type of operation. We have to be flexible within our company to move with these changes; this is one of the real difficult problems we have with new people. We can sit around and decide it's unfair that 3 years ago our plant was dedicated to the idea that it would be full of Zeus anti-aircraft missile guidance platforms this year. Mr. McNamara, the man who took care of that problem for us, was worried about having too much business. That program was solved by the fact that we build it in a closet today. However, our efforts had to switch to new flight control programs on other major programs so that we could continue our existence and progress. One of the things that we require of our new technical people as well as our present employees is the fact that they have to recognize that the formal education on the campus is not terminal. The rapidly changing technology that we are facing is such that our people are constantly having to go for new educational programs, some organized and some on an individual basis. This is extremely important. We were discussing it out in the hall. Many people, many new students, new graduates, feel that when they have graduated from a well-recognized college with a sufficiently high degree that their problem is largely solved but we can't quite accept that particular position because the needs of our company are not necessarily identical with their basic training, with their specialized training. And they have to be able to be flexible, to shift with changing requirements. This makes the engineering business more difficult. Certainly the requirement of patience during the trials and tribulations of initiating new programs is also a great requirement.

There seems to be, also, a feeling by some organizations that we are not getting enough imagination from our new engineering people. We don't have that experience; our problem usually is that we have too many ideas to afford or to be able to handle intelligently. We do have a real problem, however, in that the dedication of an engineering or technical person to carry a program through to completion is a major requirement. And sometimes a task becomes very tedious and looks like there's no end to it, but our company has been able to be successful in every program that we ever took in spite of errors in original calculation, in spite of failures during the development program, during the production program. We like to think we are an enthusiastic organization and I think one of the reasons that we are is the fact that this is a major requirement on our new technical people. We don't have the same atmosphere as a research lab possibly can have; we require that the purpose for which we set out must be accomplished, and accomplished within the envelope of time and cost. In production engineering, an area of our manufacturing, many of the same requirements exist. In addition, the engineer in that particular area must have a strong feeling for working with the production worker himself. In sophisticated technical products, a close relationship between engineering, manufacturing engineering, and the production worker is required. We have short lead times, we have tremendously technical requirements, and this ability to work with a much less talented person, to show him the techniques and processes to establish adequate processing, to build these particular instruments into a high quality standard in a short time, requires a certain type of person. This is certainly required in our production area. We also, of course, with the voluminous number of products and many changes we face, the many new requirements on environment and specification that we face, we must have a tremendous capacity and interest in detail. And this capacity should not restrict the ability to understand and see the total program.

Our most competent people in the design of equipment are those who have a great respect for detail and still have the talent to understand the total program, and manage it. Quality engineering is also an important part of our engineering responsibilities. This particular type of person must have a bent for analysis and constructive critical evaluation; this might even be a separate type of creativity -- the ability to criticize from a constructive standpoint and follow up constructive recommendations.

In our total company structure, we do of course have some kinds of work in what we might call non-formal engineering areas. In our industrial relations and our programming areas, and our marketing areas, they are probably more interested in how something is done than what is done. They work more with intangibles than tangibles. We feel, in a nut shell, that engineering is a practice of theory and are looking for men that are capable of doing just that, of having the theoretical background and being able to turn it into practice.

Up to this point I feel fairly competent to tell you about the particular kinds of engineering skills and abilities we require, because of our type of products. We know how to produce our products; we know how to design and develop them. Now what are the means that we can use to get the type of people that we require? Here I'm not too well qualified. I'm not an educator and I can't say that I am very well versed in the total academic philosophies, approaches, and practices. However, I have experienced the educational process myself, although with what level of success there has been serious question, and I certainly have some appreciation for the total effort. Our company has also attempted to provide continual education by working with the universities in our state, and we certainly have some respect and appreciation for the problems of the universities and the techniques they employ to develop and turn out raw material which we must use, which are the engineers. We have certainly had the opportunity to work with thousands of people who have gone through the educational process and are able to evaluate their success in accomplishing our needs and this success in large part is due to the training they had, disciplines they gained, and the motivations they gained while going through the educational process. We have formed some opinions about what educational processes produce what type of people and these are opinions that I will be very happy to share with you. Again I would like to point out that they are restricted from my standpoint by the type of company we are, the size company we are, and the problems we face. I do feel that we have been able to accomplish a great deal in a highly complicated, highly technical field, in spite of the fact that we are supposedly working in the wrong atmosphere.

the wrong environment, the wrong business environment, etc. We can't agree with Dr. Terman that the geniuses are on the East and West coast and the idiots hammer hardware in the center of the country. We feel our company has grown and is one of the more respected in the aerospace field and this wasn't by accident. We feel that the conditions that are supposedly preventing others from doing it are overstated, and perhaps there is often less dedication to the real problems than to the conditions surrounding them.

We expect that the engineers coming into our organization through the years will have come through an educational process which includes first of all an extensive exposure to mathematics. This is being required more and more in our non-engineers as well as being an absolute necessity in engineers. An extensive exposure to the basic sciences is certainly required, a heavy exposure to basic concepts rather than specialized techniques, and I'm sure there has been plenty of controversey in this particular area. There are certainly benefits in specialized techniques in some areas. In our type of business, where the requirements are changing constantly, the state of the art is constantly changing, we feel that too great a specialization is not the most beneficial thing to us. We find that the best people today that are in our area, who are successful in the new field of microelectronics, for example, are the people who have been basically sound, competent, and capable in electronics, working from the vacuum tube to the transistors. They are the ones who are accomplishing the greatest things and insuring our success in this new field. Certainly an extensive exposure to the practice of communication is essential. Here again we have probably different requirements than many of the other activities and research laboratories and the like where there is more opportunity for a one-man show. We require the ability to communicate accurately within the organization, and of course good communications with customers is absolutely essential. We certainly feel that some theory of the humanities, psychology, sociology, history and the like, are required. The theory of economics is valuable -- some attempt to gain the fundamentals in this area are required. The control of an organization, the organization itself, how industry operates, how investments are required, how you determine return on investment, what has to be done to accomplish it, these are fundamentally not very complicated problems. We feel it is more advisable to have some of this training before they come into the company because often the company's motivation is questioned when it is found that the company wants to make a profit. We do have other duties and other responsibilities but without the profit we won't accomplish any of them. I think there is a need for simplification in the presentation of the economics of modern industry to developing engineers, so they at least have a chance to understand. I feel that many of our approaches to teaching economics to students engaged in other fields has gotten far too complicated. I think there is someone here at the University, an economics teacher, who said he had no problem in using the same exam every year because he changed the answers. I feel it is necessary to put in a simplified explanation. It isn't complicated, business isn't complicated in its basic fundamentals; it is complicated in various applications and approaches. As our programs have become more complicated and more sophisticated and cover wider areas, the ability to program is absolutely essential, to sit down and think a program all the way out. And I've seen great efforts put on programming to a gnat's eyebrow, taking so much time and so much effort that we finally never accomplish a successful approach. We feel that a good sound program covering the major areas, subject to change, with clearly defined beginning points, is what we are really after. The final answer is important, but we have to have the milestones laid out, and the approaches laid out. In this program planning, the engineer must utilize his full analytical capability, working problems in many areas over and above the straight development of a particular product, using his specialty or his technical background in a very narrow area. We must be able to move out to the ability to take logical approaches and understand overall relationships. To summarize our total picture, I've tried to give you an idea of what we have in the way of various kinds of requirements for engineers. Requirements inside our company, indicating the type of things that may be done within the University to enable us to accomplish these, and I think that we can conclude by saying that the person who completes an engineering degree should be capable of putting theory that he has obtained into practice. Thank you very much.

DISCUSSION

J. L. York:

Thank you Mr. Walsh. Any comments or rebuttals or questions? Ideas that have been stimulated or discouraged or anything of that kind?

Question:

Mr. Walsh, when you hire a new employee, is he hired for a specific job in your organization, or does he go into a program where he can move around for six months or a year before he finally settles down to one job?

J. M. Walsh
Answer:

Usually the graduate is hired under a program where we bring in a group, varying with the particular year and the amount of business we have, of somewhere between ten and twenty engineers who are quite competent and who are then assigned to various parts of the company. We don't have a strong requirement for them at the moment. Now, our engineers that are experienced usually come in, after they have been gone from the campus a few years, to a specific job where we have the basic need. We also have been very effective with a program of bringing engineers into the company during the summer and over the sophomore and junior year to fill in for vacation people in our laboratories and shops. We have had an amazing success in having these people come back with us. We put them in and see how they work out. We don't have a formal program of bouncing them around from place to place except in some special cases.

L. N. Holland
Question:

Could I ask what type of mortality rate you have on graduate engineers say in one year or two years?

Answer:

Last time I looked at the numbers I think the record showed that 70% of the people that finished two years stayed with the company, and of that number, somewhere between 60 and 70% of the people were still with us after 5 years. We have been very fortunate and we think our particular location on the west side of the state has attractions so that our turnover rate is low compared to others in the defense business or, in fact, compared to most businesses employing technical people.

A. R. Hellwarth
Question:

What percentage of your employees are at the bachelor's level?

Answer:

I don't have the percentage but I could take a guess. I would say about 25% of our employees have bachelor's degrees-now I'm talking about across the board.

W. G. Dow
stion:

I find a little vagueness here. At the end of your talk you were describing certain things - exposure to mathematics, basic sciences - and these all are things related to the mind. Now in the earlier part of the talk you didn't talk about things that had to do with the mind; you talked about things that had to do with the adjustment to living. I'm talking about the matter of acceptability of change, the matter of following through to completion, and the matter of being able to work as a team in an operation. Engineering students come to us but we don't have much influence as to what their motivations are. We can have a lot of people who are exposed to basic sciences, exposed to upper mathematics, and do beautifully at it. They like it and may even be good at the practice of communication, but they may be very poor at the acceptance of responsibility and willingness to adjust to the necessity of the economic motive and things of this kind. What I am talking about is the importance of the professional spirit in the undergraduate education. I have a feeling that there is less emphasis on this in many areas now than there was many years ago. We can't create that emphasis but I can tell you the way it can come. It can come from conversation, from people who are looking for students. For years we've been told, "We don't want you to teach people to be able to build this, that, or something else. We want you to teach people to think." I've been trying to figure out what they meant by that, I think I know now. I'm not sure but what, more than that, they need people who are willing to carry their share of the world's responsibilities. They have enough to do; sure they must have mathematics, sure they must have physics, sure they must have these things. It seems to me they must also have the willingness to accept responsibility in the world of professionalism. I think that industry should, through its brochures, say what it tells its recruiters to say and to get the message around, "We want people to carry loads." I think that industry can help a great deal in creating the right kind of professional motivation on the part of our graduate students. That's how we make distinctions. I've got a new word for it: use the word synthesis. Fifteen years ago the work design was a marvelous word. Fifteen years ago it was in a stellar position. Let's use a new word. Instead of talking about design, let's talk about system synthesis. That carries a different conotation. It encourages - it says, "We want you to think, not just sit."

Answer:

All right, first of all I'd like to make a comment or two. From the standpoint of recruiting approaches, our company, our division, has never gone into the program of coming out to your place, sitting in a little cubby hole, and talking to a lot of people, the president of the class and the like. Possibly we have done it in past years before I was aware of it. We did come upon the other approach, where the people come in to see how we work, what we do, see what we expect of an engineer, and see what visibility we give within the plant to a product engineer and his crew. We think we accomplished the idea of accepting the responsibility. I don't feel that the young engineers are reluctant or don't want to accept responsibility, I think that they feel they can't. Now we have fought the idea of a big bull pen of engineers. We have them broken up into smaller groups; this is particularly fortunate for our business because our business is a series of boxes that fit into a total system. And we will emphasize that in our area they are seen by the management of the company, and the programs are monitored that way. We feel this has accomplished, in our particular case, a significant development of the engineer ... the engineer over and above the straight school type.

W. G. Dow
Question:

Professionally, as an apprentice, serving under the eyes of a master of this profession?

Answer:

Yes, sir. And it is really important that the younger people who make significant progress get visability from the total company, in their successes. Too often it's buried and we're fortunate in having a type of product so that we can avoid it. I think we are quite successful at it, and I think that is why our turnover is low. We don't lose people for ten dollars a week, or to a recruiter in the Morton House. In fact I've asked the Morton House to give us 10% of the rental fees because there is always someone over there trying to get our people but we still have been successful in combating this. Certainly the second point on the ability to think out the total system, the total program, and the total operations that the engineer is going to carry out, is something we will carry out. We've gone from the bull-of-the-woods type of product and production to a complicated widespread number of programs and products. Without a well thought-out effort from the conceptral stages through the introduction of the product into the shop and the introduction of the product into use, we couldn't possibly be a success. We certainly stress that, and I think it needs to be stressed more in all technical organizations.

W. A. Turunen
Question:

In mentioning the low mortality I think you used the figure 70% twice. This was after 2 years and after 5 years, is that correct?

Answer:

Of the students who stayed with us 2 summers?

Question:

Two summers.

Answer:

Seventy percent of those came to work for the company. And of these, at the end of 5 years, 65-70% of them were still with us

Question:

So half of the people that came to work for you during the summer are there yet?

Answer:

Yes sir. And over the years these have developed into some of our top people. Again, since we have a large number of individual products, it is possible to give many of these engineers a chance to move much quicker, to be a manager of an area, and to represent us with a customer and with the shop.

Question:

Is this always maintained by expanding the business?

Answer:

Yes sir. That's the only way I know. Ford Foundation doesn't help me at all.

L. R. Baker
Question:

What sort of selection standards do you use in your recruiting? Do you select from the top end of the class as one criterion? What criteria do you use in your selection procedure?

Answer:

We don't take a 10% or 5% criterion. We like to see fairly good grades, and we like to see good grades in certain areas in particular the more analytical subjects. We have an interesting situation in that we have quite a few senior engineering people who never did get their bachelor's degree, so we don't feel we should restrict ourselves to just the top 10% or 5%.

Question:

You still are looking at people who have good grades in certain areas?

Answer:

Yes sir.

Question:

Areas of interest to you, so you really are looking for top people in that particular instance?

Answer:

The good passing grade. The marginal students we will hire on occasion.

Question:

Is this an average student, for example, at the University here with a grade point average of 2.0?

Answer:

I'm not up on the numbers.

J. L. York:

It would be a student who would be acceptable to our graduate school.

M. Brown
Question:

You are talking in terms of grade point average of something like 2.6, or approaching 3; you're looking at the top end of the class. I think the point I'm making is, in many instances we're talking about this supply of engineers in number, quantity of engineers, and I think that this quality factor is exceedingly important, also. And I think also that one looks at the number of engineering graduates, and looks again later on as to where they are after graduation. I think there is a factor that enters in, that people are selected for engineering jobs, and those who are not selected for these engineering jobs then go on to other areas.

Answer:

I think Manley was using the standard that we have for the engineering areas as such. Our manufacturing engineering, which we classify under manufacturing area, or our purchasing trainees, our industrial engineering groups and the like, have different standards, and usually we're looking for someone who has proved himself, but maybe isn't really basically intereste in the sophisticated development of engineering. But the back ground is quite important to us. And another strange thing is that some of the fellows that have come in that way and work very well in the shop, on processing, tool design and the like are really important to us, and do first class, important work In working with the design engineer in putting new units into production, he will eventually work into engineering and a fairly responsible position.

Question:

And I would like to ask a question. What percentage of students graduate from engineering with a bachelor's degree with less than a 2.5 average?

J. L. York:

Dean Hellwarth, would you like to comment or give us some statistics on Ann Arbor?

A. R. Hellwarth
Answer:

That's about the median of those who graduate. The median of our graduates currently is about 2.6. Because, you see, about one half of those who start don't graduate.

M. Brown
Question:

My point is, the point I'm trying to get at is, that when we talk 2.5, 2.65, we're not being terribly selective, we're getting down fairly far.

Answer:

You are comparing all the kids who are born to this group of highly selected ones.

Question:

No, I'm comparing them with the kids who graduate from your Engineering school.

Answer:

There have been a great many screenings....

Question:

But they're still your graduates and they are the ones we have to choose from.

W. G. Dow
Answer:

A lot of these boys that come up with 2.2 are pretty good boys. I'm rather negative against the idea, as used in broad engineering employment, of putting too severe a filter on a grade point average. There is a great deal more to it than that. One of our graduates who came out about 2.5 or 2.4 20 years ago has a $50 million budget right now, and he's doing very well; and there's a large element of fundamental science and his use of it, in his job. But there are elements of motivation that develop later in life, and one needs to look for these things too. So I think the strict grade-point-average screen can cos you a lot of good people. We have no other screen in the grad uate school; we can't use anything, but you fellows can.

Question:

For students who have come up to a 4-year program and have had questionable achievements during that four years, if you expect us to select, out of those, the ones that are going to make the grade, why can't you also in your graduate school develop similiar techniques?

Answer:

I'm not sure that we don't. Actually we're not as completely inflexible as you might think. The guys that work on it will finally get a Master's degree even though they wouldn't have been admitted to graduate school right after their bachelor's degree. We're not as inflexible as my initial reaction indicated, we have a gray area too.

J. M. Walsh
Question:

I don't feel that the screen is as restrictive as one might think. There are other positions that they do take and, of the people that develop later, some do move into engineering if they're inside the total structure.

A. R. Hellwarth
Answer:

One of the criteria should be to determine what the student does with his time. We have students that are working 15-20 hours a week to support themselves. Statistics point out very strongly that many of our engineering students have to work if they are going to get a degree. At a panel at Wayne University, one of the members pointed out the great importance of what the student does with his time. Some are active in extra-curricular activities, for example. The young man who is running our Engineering Open House will some day find himself a manager and do an excellent job.

M. Brown
Question:

What grades is he getting?

Answer:

He's putting a lot of time on this job, and has a 2.6 average. Getting back to the panel at Wayne University, one of the boys got up after we had gone through this discussion, and with a very serious expression on his face said, "What would you say about me, I'm married and have 3 children?" One of the members responded, "It's pretty obvious what you've been doing with your spare time."

G. V. Edmonson

I know another area you oughtn't to forget. Al Hellwarth came in the other morning with a record on a student, the first semester as I recall, I may be slightly in error here, but I think he had 3 E's and 1 D for the first semester; 3 E's and 1 C-, or 2 E's a C- and a D for the second semester. The C- of course he had repeated. I acknowledge that and Al said, "What do I do?" And I said, "Well, I think you ought to call him in." On a second look I saw the record was made back in 1957. I said, "Alright, tell me the rest of the story." The rest of the story runs something like this as I recall it: he received a straight A record on his return, after being out several years. The fact is that some of these students have a degree of immaturity that is awfully hard to believe, but in a rather short time, under the proper conditions, you find you have an honor student instead of a failure.

A. R. Hellwarth
Question:

This boy spent 4 years in the Marine Corps and has two children. What do you think of that?

J. M. Walsh
Answer:

In the area of those who develop and start late, I think they become motivated by working in an area of industry in which they become intensively interested. The opportunity is there, I think. We don't have a selection system which automatically rejects someone just because he had a poor grade at some point in his life. I don't see that in business, at least not in ours. Incidentally, we've hired technicians who had flunked out of school, and who have done an outstanding job for us, and who have started again at extension courses and have come along very well. But there has to be a strong motivation. I don't think industry or the graduate school or anyone else is getting to go down into a pile of people who don't care and pull out those who might have talent. This is a really important thing in all education; how do we get through, how do we get through in a company, to develop the motivation to do an outstanding job? I think a lot of us have worried about the fact that just doing a job seems to be satisfying enough, instead of doing the best job we are competent to do. This motivation is something that is a real problem we never talk about, or talk about in very general terms, and I certainly have no solution.

G. V. Edmonson
Question:

I believe there are graduates, however, that we know are on the other side of the fence. In making a selection, they do put a company high on the scale when they think there is a great probability that this company will expect unusual things from them, challenging things, rather than just a job.

J. M. Walsh
Answer:

I think that in the engineering area, of all these statistics that you see, there are too few graduates for the number of opportunities, and I think this offsets the problem of being to selective; we just don't have the choice.

W. G. Dow
Question:

Yes, there's another one. A lot of people have to do the work You don't want all of the people to be the kind who are going to be unhappy unless they get to be chief engineers. Some people who are successful but not brilliant, learning relative early in life -- as one of my former students said to me 25 ye later, "Bill, I know my limitations." He had a good steady jo He hadn't been the company president, but at the age of 50 he was content with a reasonably successful life. I'll tell you a little yarn which amused me. About four years ago a recruit came to the office and wanted to get acquainted with me. He said, "I'm a stranger here, but I engaged a couple of your bachelor degree candidates about 2 years ago and I'd like to get some more like them." "Well," I said, "let's look at who they are." So he gave me their names, and I looked up their file and found they were both on probation.

Answer:

I think you can over-emphasize the amount of restriction on the people who mature later, by early screenings. We have projects inside our company where people come to the fore-where they have advanced remarkably - regardless of what they did before.

Question:

These things are not absolute at all; you set up a general standard and statistically adhere to it. That is, you sit down and talk to a prospective employee whose personality appeals to you, and you consider some of the things in his background, and the degree of interest he has in your product. You balance these things against his grades and try to find out whether he has been this bad all along, whether he was bad in the beginning, and if he's been improving. You try to sort out what he's poorest in, what he's best in, and then you take a certain number. You have to gamble on fellows who are below your standards. Sometimes you win and sometimes you lose, you also win and sometimes lose on the ones that meet your standards. You have to play it as it comes.

J. L. York:

There should be a broader measure used by the University than that of grade points alone. In an interview you have rather a short exposure to this prospective engineer to make all these judgments; maybe you could ask to have some other yardsticks supplied. There are a few students interviewed where 3 or more people know the interviewees, can say where they stand on their ambitions and possibilities. Sometimes the use of this system is quite limited. Maybe we should attach more importance to them.

J. M. Walsh
Answer:

I don't know if we in industry have ever gone back and made any real studies to see who ended up successfully.

J. L. York
Question:

My point is that the University has had the student for four years and now in 15 minutes or one half hour he may get an interview. How can you make a judgement? Several studies have been made on success in industry. Studies made by the Bell System which relate success to position and salary indicate that grades are significant; also the extracurricular activity in which the student has some "management" responsibility.

W. G. Dow

Let's remember that's Bell Laboratories, too.

Answer:

Right, that's an entirely different set of problems from what we have.

Question:

They have one in process now which may produce some valuable information. They have picked out probably 500 to 700 graduates hired over a three-year period, then five years later they will check their progress. Unfortunately, there are thos who pointed out that most of these studies have been accepted as statements of individual progress. Many organizations also make great progress.

Answer:

I think any study of an organization like Bell is a very selective thing.

W. G. Dow

Selective, maybe, but not biased. I think acceptance of our 2.0 level is a pretty good one. I think anybody that we give a Bachelor's Degree to at the University of Michigan is likely to be a pretty good guy. And I'm rather negative to various kinds of external fill-ins. They say, "Well, of the 100 fello from you we will take only the ones that are above a certain point." Everybody accepts it. Then the nation as a whole loses a very valuable pool of responsibility-oriented and pretty well-trained people. And so I think it's too bad if everybody says, "We aren't going to hire you unless you've got better than a 2.5 average." I think these other fellows are pretty darn good if you put them in the right place. I'll put in a plug for them.

Question:

Undoubtedly you have answered my earlier question. What is the minimum grade level that a person can have and receive a degree?

W. G. Dow
Answer:

Two point zero.

Question:

Two point zero, so as I say, by reaching down to 2.5 or 2.4 I get down fairly close to the bottom.

Answer:

But half of them are below 2.5 or 2.6. It's a skewed distribution.

J. L. York

And our incoming freshmen have been well screened to the point where they come from the upper 25 or 30%, so really the discussion of relativity of graduates is basically one of how rich is the cream. Then the distribution of the people who graduate, as Professor Dow says, is quite skewed to the left, so that a man with a 3.0 average is in the upper 15% of his class, and 4.0 is attainable but not common, therefore, the peak rounds about 2.5 or 2.6.

G. V. Edmonson

At a large engineering school, we must also recognize the fact that a student rarely sees the same instructor twice. This would mean that he has been evaluated by actually as many instructors and professors as he has had courses in getting his degree.

J. M. Walsh

I don't believe the problem is as great as we're saying. We have certain standards we'd like to meet, we have certain requirements we have to meet, and tha analysis we went through this morning on the availability of engineering graduates shows that the number available has fallen short. We have to move down a notch or two and basically our standard is not that firm. It's not an Act of Congress that we don't move to either side, or that we don't take into consideration these other things. There are more jobs for trained engineers opening up than there are trained engineers graduating. Some of us have to change our standards or select certain other ones below what we would like to have for that ideal standard but there is the problem.

M. H. Trytten

I want to make two or three comments. One of them is that we wrote some time ago for the very special purpose of getting the names of some very bright Ph.D. prospects. We wrote to one institution and suggested they send us the top 10% - nominate the top 10%. This distinguished institution wrote back and said essentially that perhaps we didn't realize it but all of their people were within the top 10%. This reminds me of the remark that was made. On this business of selection I think you might be interested in this. We are very carefull studying this whole selection process in connection with our fellowship opportunity. We receive 15,000 applications a year for graduate fellowships. Our panels make the selection and we think that this is, on one hand, a responsibility to see what we can find out about the selection process. Secondly, that we for the first time, probably in history, have enough people to work with so that there is statistical validity in the things that we find out. Consequently we are following up the people. These are at pre-doctoral level, which is not quite the same thing, but I think still revelant. We follow up a certain category every year, and write to the people who know most about them: superiors, and colleagues and what not. We get an evaluation of what they're doing, and then compare that with the criteria that we're using as selection. We've done this now about 3 or 4 times, and we're beginning to build a body of information that I think will be significant. We're not publishing much of it yet because we want to have more tim and more opportunity to study it before we issue any final statement. I think we find this, that grades are important, definitely. But they are not the prime thing. That is, these people are human beings after all, and human beings are quite variable; grades are, after all, only one measure of the competence of the individual. The thing that we find that correlates best with the criteria used in selection are the comment of the people who know them well on the job as compared with the comments of the people who knew them well and wrote to us about them when we were selecting. In other words, the subjective judgment of people who have been in a position to observe these people stands up the best. Grades are the next significant thing, but definitely less significant. Then, finally, at the third level are the tests which we give, the verbal and quantitative, and the field test, those come down in the third category. And that would leave me to suppose here that the grades are important in selections of this kind. I'm sure of that. But I would think also that the professors who work with these people for 4 years probably have a pretty shrewd idea of whether there's real promise in this guy or not regardless of his grades.

W. G. Dow

May I comment on that. You are talking about the group of students who will be known by their professors.

M. H. Trytten

That's right.

W. G. Dow

There are two kinds of people the professor gets to know. One is the guy that is real good, the other guy that's real poor. The great bulk of people in between you really don't get acquainted with.

M. H. Trytten

This shows up in our work too.

W. G. Dow

You are working with a limited set about which you do have subjective information but these other people are dealing with samples where information is very difficult to get. You may know more about the man in a 15 minute interview talking to him as a recruiter.

M. H. Trytten

This even shows up in our work because you take a graduate student in chemistry like at the University of Illinois where they have graduate students by the hundreds -- it's harder to get an adequate evaluation. The same situation holds there.

The last comment I want to make is that there is a study which has been carried out by the Educational Testing Service. I don't believe they have published this yet. It was carried out some time ago, but it has relevance here and I think they have not published it because they're not quite sure of what they found. One of the things they found related to what Mr. Walsh said a bit ago, that success on the job on the part of these engineers (they studied quite a large number) seems to be less related to academic records in college than it does to their ability to communicate, their ability to work with people and some things of that kind that are not technical at all. I think one reason why there is some skepticism here may be just what you alluded to, that in many large organizations it becomes difficult for the person who is making the evaluation. This is because of compartmentalization and the fact that these people work in boxes. It is a little hard to evaluate a man's technical competence from a little ways away from him; but you can much more easily spot the man who is a good communicator and a good guy on the team, and a good person in human relation

J. L. York

This afternoon we will start off again from the industrial viewpoint. This one will no doubt be a little different from Mr. Walsh's; we wanted to have speakers with different points of view. As I indicated, Mr. Walsh represents one of the - how do you use the phrase - glamour industries, or something of that kind, that grows rapidly and does a wide variety of things -- has electronic and physical and mechanical backgrounds in it. Now our first speaker this afternoon is going to come from what Michigan would call the backbone of the state, the traditional type of engineering operation, in fact he calls it the "nuts and bolts" engineering business. So he has a point of view here that is related very much to his own background, and he'll be prepared here to tell us something about it and answer questions, and defend it if necessary, I assume. He has a background which gives him plenty of authority for discussing this point of view. He was trained as a mechanical engineer. Right after he got out of school, in about 1927, he went to work for Cadillac, and he has stayed in the General Motors family ever since. I gather that he is one of the men who is primarily responsible as an engineer for the automatic transmission that the General Motors Corporation has, so on that basis if you don't like the way your gears mesh you can ask him about it. He went up through the ranks from draftsman, until in 1957 he was made Chief Engineer of Buick, and then switched over to the Defense Systems Division, and now has the position of being engineer in charge of the passenger car development program. Perhaps he can explain that in more detail. I'm not sure what kinds of titles these are. But anyway Mr. Oliver Kelley is going to discuss with us the application of theory to obtain more accurate prediction in the practice of engineering, Mr. Kelley.

THEORY--A NECESSITY FOR ACCURATE PREDICTION IN PRACTICE

Oliver K. Kelley

Director of Development Engineering,
General Motors Corporation,
Engineering Staff,
Warren, Michigan

THEORY--A NECESSITY FOR ACCURATE PREDICTION IN PRACTICE

Thank you, Dr. York, ladies and gentlemen. I'd like to make it clear that my speech will be very much more narrow than the entire area of the mechanical engineer's role in the automotive industry, in which I have served to a somewhat significant degree. And without any generalization of any kind I'd like to just get right down to the engineer as a working engineer.

We have 14,000 of them in the automotive side, besides the ones we have in the research laboratories and the Defense Systems Division, and I'm excluding the more exotic type of engineers and getting right down to the nuts and bolts engineers' roles in our operations. I would say that the education of an automotive engineer must be primarily in mechanical engineering; he must thoroughly understand forces, moments, stresses, and deflections. He should not have to go to a handbook to look up the formula that he needs in these areas. He should be also instinctively conscious of the linear, square, and cubic relations in dimensions, stresses, and deflection, and be able to reproportion a simple design on the slide rule without making a project out of it. In other words he must have, in his feelings, proportions and managing of stresses and deflections. Everything we build deals with these phenomena and unless he thoroughly understands them without our doping it out to him by formula he isn't going to be of much use to us. He should be equally sure-footed in dealing with acceleration, masses, and forces, up to the point where he looks for $f = ma$, everywhere he sees motion. He should have a clear understanding of energy, power, and momentum and understand the significant difference between mv and mv^2. And you'd be surprised how many graduates we get who really don't understand the difference. And he should need no handbook to help set up his equations to get numbers on these phenomena either. Then besides, he should be exceedingly aware of the fact that every part of a moving piece of machinery has an inherent tendency to go into resonant vibration. He must know the relationships of mass and spring rate to the resonant frequency. He must understand harmonic balancing and damping. If he has reliable information on the materials he uses and knows all these fundamentals well and can use his slide rule quickly to establish a design dimension, and then if it works out the way he said it would, he's already a usable mechanical engineer. Those are the basics. When he has them straight he has command of a great deal of useful theory possessing the power of accurate prediction. And that is what engineering is all about.

I can't over-emphasize the value of remembering the most frequently required formulae and the ability to run simple computations on the slide rule. Of great additional value would be to remember simple examples from which he can scale up or down for quick comparative evaluation. For instance, torsional stress produced by 1,000 ft.-lb. of torque in a one-inch diameter shaft is approximately 61,000 lb/sq. in. Remembering this and knowing that the strength of the shaft is in proportion to cube of the diameter, it is very easy to establish a shaft diameter for any stress under any torque in a single easy-to-read slide rule setting. The briefer the computations need to be, the less chance there is for mistakes, and too many mistakes are made by many potentially good engineers in simple mathematics. This led me, a long time ago, to believe that one of the greatest things in engineering is the ability to add and subtract correctly.

There are other important areas in mechanical engineering that have to be taught in college also. But in my opinion statics and kinematics properly taught lead in importance over all others. They also have an inherent fascination for the student who knows that he wants to be an engineer regardless of any actual product he will be working on as a design engineer. These are the true physical characteristics of it. You just can't tackle the design of any mechanical device without them. This is the area, in my opinion, where the student should first learn the application of theory in practice. Simple laboratory or even class-room aids can demonstrate the truth of the theory in all these areas, and can establish a valuable confidence in the student's mind that he has now learned something new which enables him to predict accurately what is going to happen, if he does so and so. A good engineer wants to be an inventor, a creator of new things, and how is he going to be able to do it if he can't put actual numbers on his design picture so that he can then build it and test it to see how it comes out. After a thorough brainwashing in statics and kinematics the curriculum should include thermodynamics and combustion, flow of fluids and gasses, hydrostatics and hydrodynamics. They are perhaps the next most important, with fairly well-established theory possessing the power of accurate prediction.

Power, energy, momentum and the ever-present $f = ma$ can be conveniently translated into $v = \sqrt{2gh}$, which is effective in these domains also. Students should look for it in order to digest the full meaning of the kinetic theory of heat and to understand hydrodynamics. They should find $f = ma$ in explaining how the rotor on a helicopter and the wing of a bird as well as the wing of an airplane must accelerate a mass of air downward in order to balance the gravitational force.

Equations based on empirical constants tend to hide the true $f = ma$ in left-over drag coefficients for airplane wings or propeller blades, but the same laws of nature in kinematics are ever present here also. I would like to say once you have found them never let them go. An engineer must necessarily want to be practical but by this he should mean that he wants to be able to use all the theory he has that possesses the power of accurate prediction. He should want to acquire as much of it as possible, just as much as college can teach him, and before many years on the job he'll wish that he had more. The fundamentals of mechanical engineering thoroughly digested so as to really be able to see things will help tremendously in rearranging or redesigning more or less standard practice items in automotive engineering. But the destiny of engineering is not just to shuffle the old stuff around but to constantly strive for the new knowledge of materials and techniques that will open new horizons beyond today's limitations. Opening new frontiers of knowledge is a job for science. When new knowledge has been sufficiently verified, systematized, and formulated into theories possessing the power of accurate prediction, it can be called - Science Ready for Technology. This is the kind of science and theory we should teach to our future engineers in advanced classes, right up to the latest theories there are in the area of students' specialization. Science Ready for Technology is an inseparable part of engineering; not to be up-to-date in it is to be an out-of-date engineer. For instance, automotive electrical engineers must understand transistors, diodes, thermistors, and solid state transducers in order to design today's automotive electrical equipment, air conditioning system controls and so on. A few short years ago these names were unknown in the automotive industry.

Structural materials present another field which is very important to automotive engineers. New alloy steels and irons, and aluminum and magnesium alloys, besides copper, tin and lead, are the working metals in automobiles. Design engineers are severely handicapped if they are not up-to-date in their metallurgy, physical and chemical properties, heat treat and new fabrication procedures. It is not possible to be a good automotive engineer without a good coverage in this area. The same can be said to be true for nonmetallic materials like rubbers, synthetic polymers, teflon, nylon, delrin, various vinyls, insulators, ceramics, and also organic and inorganic friction compounds which are all used extensively in many automotive components. It would be valuable to have more than a general knowledge in this rapidly growing field. Metallurgical and chemical advancements will be made; teflons and delrins will be old names. What will be the new ones five years from now?

Other materials are also important: paints, enamels, lacquers, protective waxes, rustproofing coatings, sealing compounds and cements, anti-freeze solutions for engines and windshield washers, various greases and lubricating oils compounded with friction modifiers, detergents, anti-oxidants, anti-foaming agents, viscosity index improvers for engine and automatic transmission oils -- all present important material for science technology studies. Though mastery in this field is not a typical automotive engineering requirement, most automobile companies need staffs of experts covering it. A fair general knowledge in this field should be included in a well-organized engineering curriculum. Any new developments in fluids and gases, hydrostatics and hydrodynamics, are as important as they are in thermodynamics and combustion. Automatic transmissions have hydrodynamic drive units and hydraulic controls; all modern cars have hydraulic steering and hydraulically operated brakes; most engines use hydraulic self-adjusting valve lifters, and centrifugal pumps, with their cavitation and power loss problems, as they circulate the cooling fluid through heat exchangers. Cooling fans, heater and air conditioning system blowers present noise and horsepower loss problems. Fuel pumps, vacuum pumps, transmission and oil pumps, may well be improve for reliable efficient and quite operation. Carburetion, the control and distribution of air-fuel ratio, under all temperature variations at all speed and torque conditions, are challenging problems in modern automotive engines. Exhaust silencers and the elimination of unburnt hydrocarbons that produce smog present a real challenge in the near future. Any new developments in transparent materials better suited for structural use also would be very welcome. A better way of making a pneumatic tire or a new kind of wheel possessing the necessary tolerance for road roughness would be a boone to the industry. Woven fabrics cut and sewn the same old-fashioned way to upholster the seats are still our best bet for seating comfort in automobiles. Science advances in these areas can be expected to add important knowledge or technology in the future; it cannot come too soon to suit the automotive industry. Additional studies in these areas will be welcome improvements in the education of automotive engineers. Much needs to be done to advance the art in many, many places in our modern motor cars. How much of this can be inspired and started in the minds of students in automotive engineering?

In addition to strictly technical subjects, courses in the correct use of English, plenty of practice in self-expression, and concise report writing, should be included as compulsory. If anymore liberal education is required, it is evident that less of this general technology can be taught and that fairly early limited specialization is required in the four or even in the five year course. I would regret to see the loss of an opportunity of acquiring as much as possible general technical education in automotive engineering for those who want to make it their career. All of this is directly use-able in their career advancement in the industry. As things are today the engineer has to pick up a lot of this later and never gets the chance to get enough of it after he starts his career. In the mean-time the industries are held back by an insufficient number of thoroughly qualified engineers really needed. Learning new technical art is a tough proposition while you're working and supporting a family. Perhaps it would be better all around if the student spent most of his time on technical courses in college; it would be easier for him to supplement his cultural education by reading, by selecting the most worthwhile TV programs, attending symphonies and operas, etc., and as much as possible sharing part of this development with his family.

We are living in a tough competitive era which is highly materialistic. I'm not one to ignore the implications of the commu-nist educational program. We may just have to get equally tough with ours; when you sup with the devil you use a long spoon. The communists know and we know that of all the world scientists who have made a noticable ripple in the affairs of mankind, some 90% live today. The advance of man's knowledge is on an accelerated scale now. Nations which wish to advance their technology need engineers who will greet the new knowledge not as a stranger but as one who is already tuned in on the same wave length because of his comprehensive technical education. Our country must be on the ball for the sake of its self-preservation alone, to say nothing for the necessity of demonstrating a higher standard of living for the rest of the world. The automotive industry has a role in both of these areas; one of the most important adjuncts of higher standard of living is the freedom of personal locomotion provided by the private passenger car. The automotive industry has great growth potential in this country as well as in the rest of the world. The ultimate limit of the number of personal trans-portation units will be reached when every licenced driver has not just one but as many different kinds of automobiles as he wants. It is up to us to produce better designs that can be produced more economically so that more people can afford to own them. Automation alone is not the answer. Product design is a most important part of it; it is up to us to develop the most ingenious arrangements by designing them clever-ly and fully exploiting the known laws of mechanical engineering and constantly supplementing this knowledge with everything pertinent that new science brings out in usable theories ready for technology.

And now, a few summary remarks. The nuts and bolts engineering covers a great deal of territory. An automobile today is not what it was 30 or 40 years ago, just an engine, wheels, and drive shaft. Today's competitive technology automotive engineering (you still call it mechanical engineering) needs the resources of many other branches, other disciplines. Although one may not need a Ph.D. degree in all of them, a working understanding would be the most valuable thing you could give our future engineers. The general technological education, and general up-to-dateness in the sciences plus a working familiarity with theories that possess the power of accurate prediction, should be taught to our engineering graduate students as much as possible.

Theory *per se*, until it reaches this point of accurate prediction, is not too much of interest to us. It makes good conversation, but brother, when it gets to the point where we know it works we want to know it fast, and we can't afford not to know it fast. Things are developing so fast -- within a ten-year or twenty-year period after college -- unless a man has well-founded fundamentals, he just can't keep up. So I would re-emphasize the need of instilling a fundamental understanding of the laws of nature into these students, starting with just a simple plain $f = ma$; it's surprising in how many places it solves your problem if you really know what it actually means, as well as mv and mv^2 . Things of that kind are so fundamental but are so frequently not absorbed by the student into his consciousness. Here is where I think we are falling short in teaching our students to be real engineers, needing no handbooks, so that they already know what's going on and derive from there quickly by understanding things completely.

If you get down to the theory of electronics, you'll find these same basic things there, but described in a different language. The respect for the laws of nature as we know them and the new ones that have not yet been written down must, as soon as they evolve into theories with power of accurate prediction, become required knowledge in Mechanical Engineering majors if we are to take the fruits of our science of the future and use them in our technology. This is a transition point when, from the science, the theory has been properly formulated and expressed so that it possesses the power of accurate prediction. I repeat that we then want it fast. So the theme of this meeting was supposed to have been Teaching Theory or Practice, in which there was a division between the two. I'd say practice without theory is almost useless. You must have the basic theory first, you must be able to say, "My problem is to make a beam to span this gap and carry a 100-lb. load. I need a piece of steel with this certain cross-section, because I know the formula for section modulus and the bending moment and I can figure it out with a slide rule in nothing flat. I can put it in there, put my 100-lbs. on top of the steel beam and I know how much it will deflect because I also remember deflection equals $SL^2/3Ec$," and by golly it works, and when it does I feel real good.

Now I know something as a student. And taking this thing further and further in education step by step using theories that have the power of accurate prediction, taking thermodymanics, and then hydrodynamics, they all work. A kid learns those things and he gets enthusiastic and he says, "My gosh, I know I can do a good job because I can put things together and see them work." I say, that's where the practice in education is most valuable because it's the only way of cementing the theory into his mind in permanent form so that he will always have it.

And now take even the most sophisticated areas clear up to how does a laser work, and how do I make one, I'd say that's equally as important. Right up to the frontiers of our today's science, the understanding "why" - why a solid crystal seeks its lowest level of energy and what are the excitations of the three levels of atoms, the engineer should understand the basic reasons for it; if he does he will not be afraid of the new theoretical advances. He's already tuned in on the same wavelength with the fundamentals, and he can quickly learn, without going back to college, what it's all about if he understands fundamentally in the first place. But the guy must understand that he has to understand, not just take somebody's word for it. The engineering student, then, should have enough practice mixed in with the theory so that the fundamentals can be throughly appreciated, and really understood. Thank You.

DISCUSSION

J. L. York
Question:

I might ask a question as to how we put all of this material in an ordinary engineering curriculum. I gather that you wouldn't object to a longer period of time and you also indicated that you felt we should leave out some of the cultural things and the humanities, hoping he can get them after he leaves school.

O. K. Kelley
Answer:

I was just suggesting a trade. I would speak from my own observation of many of our graduates besides my own personal experience. The more ammunition you have in your mind when you enter your job the quicker you advance. So if college teaches you things you can use in your business that's worth money to you. I can also quote Kipling who I like very much, and I know something about Rembrandt and Shakespeare, and I know the history and geography of the world; that's helpful and interesting but it's not important on the job. The most important single thing in this job is to know as much technology as possible. The engineer is going to work harder than heck, not on Shakespeare but on technology, if he wants to advance in the automotive industry and the more he knows the easier his work will be, and the quicker he will advance. Now, how the average students would take that proposition I don't know, but I think that those that really want to be engineers will say "Amen, give me the stuff."

H. Norder
Question:

You indicated the growing depth of specialization in the physical sciences which indicates that the field is becoming narrower to the engineer as far as specialization goes. How do you maintain your horizontal communication with the other physical sciences?

Answer:

By using the fundamental understanding, the underlying understanding that goes across many of the new sciences. You get that and then your touching acquaintance with a new thing is so much easier that you will take a minimum amount of time to understand some new proposal that has in it a strange theory that you have not even studied before. But you must get that level of fundamental knowledge into the kids' minds, and I'm quite sure that's a tough job in 4 years. At least do it, for mechanical engineering, in statistics, kinematics, thermodynamics, and then fluids. Let them digest and understand those areas; that doesn't take a long time if you go at it fundamentally. Make them look for the $f = ma$ every place where there's motion until they understand what it means. It results in mv^2 and mv and you've got to know the difference. So that those fundamentals first of all would make a mechanical engineer sharper. And it would be easier for him if in his post-graduate years he'd go after fundamental understanding of the newer sciences. An electrical engineering minimum is a must item for all mechanical engineers, and to extend the electrical engineering into solid state physics is not very hard; fundamentals of that could be taught, and some chemistry is absolutely essential also. And I should think that the theory of Polymers and plastics and composition, and the fundamental expected characteristics, would be rather easy to teach, and also those are very important, ceramics, the same way. There will be many engineers in automotive companies who must understand all of these areas, perhaps not on a Ph.D. level but so that they will not get lost in it. So you can't talk them out of anything in these areas. They must know enough about them and understand them. The requirements are tough if you want to graduate real top-notch engineers. Perhaps you can't cover them all but you can perhaps divide them into two or three areas and cover 1/3 of this group of subjects in 5 years. Specialization is surely needed; it takes more than one post graduate year to learn all these things.

H. Norder

I want to comment on the complaints that we constantly listen to -- the fact that engineers find it more and more difficult to keep abreast of the sciences in other than their own specialty. It appears to us that this is becoming more and more difficult to accomplish because the science tends to organize more and more in depth, less horizontally as time progresses

O. K. Kelley

One of the reasons for difficulty is that the engineer doesn't even have the courage to try. I had my own personal experience for two years in our Defense Systems Division, the first year and a half of it together with a bunch of real smart Ph.D.'s who taught me an awful lot in a short time. In a fairly short time I had no trouble in talking their own language and arguing with them, and that was a far cry from running the Buick Engineering Department a few months previously. But it can be done if you have any kind of a fundamental understanding in your mind in the first place. So if we could please somehow get more fundamental thinking into our kids' minds so that they could catch on to another branch of laws of nature and feel at home there rather quickly. Am I asking for too much?

J. L. York
Question:

Would you be willing in getting this to trade-off depth in specific areas of your own field?

O. K. Kelley
Answer:

Yes, definitely.

Question:

We always have the problem that some industries, some types of engineering people, are expected to be immediately productive in earning their pay, right after they graduate.

Answer:

That may be true in certain areas, but not in ours.

Question:

Other organizations will say, "Well, you teach him the basic fundamentals and we will teach him the details of our engineering operations." And this is a part of the problem; where do we draw the line? This is one of the reasons why master's degrees are becoming more and more common as an engineering degree, because the man wants to get a little bit more, he wants to get a little deeper in his own field. The more we give him in other fields, the more time it takes him to get deep in his own particular subject

Answer:

My guess would be, Dr. York, that if the students have had a completely thorough and well-digested grounding in the phenomena of statics and kinematics, and thermodynamics and hydrodynamics, then the specific courses dealing with these phenomena, in the student's chosen own field in machine design or design of engines, would be duck soup, and it wouldn't take very long to fully understand these phenomena and how to specifically apply them. To know the names of the phenomena and not to understand them is saddest thing that ever happened. I think you should start definitely with the understanding part first before you go to specific applications anywhere. Make sure that the students do understand that you have to understand. It's not hard to understand if someone just shows you what really goes on.

Question:

I'm reminded of a meeting I sat in a couple of years ago, but in the field of mathematics; since I'm not a mathematician I can speak of this with authority. This was the question: what kind of mathematics training should we have available to engineers? There were representatives there from every one of the degree programs in the University. The engineering professors sat down with the mathematics people and each of them was quite positive that all the math that was necessary beyond calculus for a graduate program in his field of engineering could be taught in two or three courses, providing he was allowed to select the material that went into those courses. When we got through going around the table we found that the listing of what each group wanted in the courses constituted a complete list of all courses in the mathematics curriculum. This meant that we were back in the same situation and I wonder if we may be up against the same problem, where do we draw the line?

Answer:

I'd look at it this way; I would start even before calculus to teach the kinematics and statics because you can understand them in terms of algebra very well. As you go into kinetic theory of heat and thermodynamics you do have to have an extra shot of mathematics. But I'd use mathematics as a tool to understanding, and not as a basic thing by itself. Tailor it to the subjects where you need a certain advanced knowledge of mathematics before you can really say that now I do understand it.

J. L. York

Well, we hope we use it that way.

O. K. Kelley

Most mechanical engineering theories do not require any advanced mathematics to understand them. Yes, sure, it helps to use calculus to develop the polar moment of inertia but you can demonstrate its value by algebra just as well.

J. L. York

Well, I think this is the basis for much of our experimental work, in the education field. Perhaps we might get a discussion on some of the ideas that are being developed in the engineering programs as a result of some of this. There are several of us here who have had some experience with it. We don't want to steal any thunder here from Professor Carpenter; he has a few ideas on these lines, so I believe we will ask him to make a presentation now, and then we can discuss the whole thing as a package, how would that be?

O. K. Kelley

That would be very interesting.

J. L. York

The clean-up man on this team, maybe he won't like that phrase, is a man who has been in the engineering teaching business for quite a few years. He happens to be a structural engineer, author of a couple of textbooks in the field. He's also a mid-westerner in spite of his address. At least he came from the mid-west, as a graduate of Ohio State University. He has been at Swarthmore since 1935 and has been doing consulting during that entire time: quite a bit of work in the field of building structures, bridges, floating structures, wind loads and things of this kind. He is Chairman of the Division of Engineering at Swarthmore. He has received a certain amount of publicity recently because of some of the comments he has made, and we believe he will add a few points here regarding some of the newer thoughts in engineering education. Professor Samuel Carpenter.

EDUCATING ENGINEERS FOR THE FUTURE

Samuel T. Carpenter

Chairman,
Division of Engineering,
Swarthmore College
Swarthmore, Pennsylvania

EDUCATING ENGINEERS FOR THE FUTURE

Thank you, Professor York, Dean Attwood, Mr. Carroll. As you see, I came prepared to be the last person on the program. I have actually found that the previous speakers have stolen my thunder. It was mentioned that I'm the clean-up man, and at this point since "Engineering Education" happens to be my favorite subject, I should turn philosopher and probably draw my theme from the titles of Shakespeare's plays, with apologies. For example, "The Tempest" On the Campus, "Much Ado About Something"; "As You Like It", Theoretical Or Practical; and "All's Well That Ends Well", a Reliability Statement.

I commend the three speakers for their knowledge of this subject. I find it very easy to agree with most or many of their points, for I've usually said that the only practical thing to teach in college is theory, but it ought to be taught by a practical man. Most people miss that point. I know that there's a great deal to the learning process in the classroom and I think it's all right to teach some practice in the classroom. I think it's a part of the learning process. Theory can be awfully dull unless there is some real problem in mind.

You are probably aware that at this time engineering education is certainly passing through a momentous period of concentrated evaluation. The debate and controversy concerning the philosophy of curriculum planning is nearly in the mode of a revolution. A revolution which has been created certainly by the impact of all the scientific advances we've heard about here today, and the increasing complexities of the engineers' field. I think there's little doubt but that we're really moving into a new period in engineering education. There are many factors and forces. Now some of these forces come from our professional societies. The American Society for Engineering Education is a tremendous force in this re-evaluation. A new three-year, 300,000 dollar national survey of curricula by this Society is now just starting. This will explore the undergraduate base of engineering education, graduate study, and many other facets. The Engineers' Council for Professional Development is a powerful factor, with their accrediting function in this new period in engineering education. The National Science Foundation with its grants for curriculum and course improvement, the Ford Foundation grants for improving the undergraduate base and the graduate base for engineers, the Sloan Foundation, and Commission on Engineering Education -- these are tremendously vital forces.

Within the time allotted me here this afternoon, I can describe only some of the educational problems that we face in coping with modern technology, some of the pros and cons of educational philosophy, and the trends in some of the emerging plans, with subsequent comments bearing on these points. I have a wide open title, there's no question about that, Engineering Education for the Future. I should say at the beginning that most of my remarks will probably apply to the under-graduate base for the reason that the bulk of my teaching has been at the undergraduate level. The basic issue is how are we going to educate the engineers that will come up to the demands of tomorrow's world. I believe that new generations of engineers must function in a continually expanding field of technology in which nothing will remain stable for very long. And I know very well from my own work as consultant that industry certainly does not wait very long to put a new scientific advance into action.

For many years technology was stable; a gradual refinement of a stable set of principles brought on the handbook period in engineering. The engineering professor's job was solely to teach the new generation how to solve the same old problems. Industry used these engineers as draftsmen, technicians, supervisors, third and fourth levels of management. Now with the impact of the last several decades of new technology, that type of educational base will just not do and we are giving increasing attention in engineering education to the why instead of the how. I also think it would be a mistake if we in engineering education provided only for those going into research and development. We have to realize that the operational phases, design phases, and management phases must be taken into account. Our practical problem in the colleges is how do we strike a point of equilibrium or balance in our programs between some desirable theory and perhaps some desirable practice and also take care of the inevitable individual differences in the needs of our students.

We have been going through a very profound period of rethinking on just what is engineering. If we could answer that question objectively we could outline the sound educational objectives and content of an engineering education. This rethinking is all to the good because it has taken us into so many pertinent questions. Among the questions which we ask - Are there any differences between the necessary educational base for the scientist and the engineer? If so, what differences? If none, then why not just teach science, or conversely, engineering? Where is the dividing line between engineering and science? Professor Rankine, (you will remember him for his column theory and Rankine Cycle) answered some of these questions when he accepted a professorship at the University of Glasgow in 1856. This is what he said more than one hundred years ago. "In theoretica science the question is what are we to think when a doubtful point arises for the solution of which either experimental data are wanting or mathematical methods are not sufficiently advanced? It is the duty of philosophical minds not to dispute about the probability of conflicting suppositions, but to labor for the advancement of experimental inquiry and of mathematics and await patiently the time when these shall be adequate to solve the question." Rankine goes on in this quotation, "But in practical science the question is: What are we to do? In a question which involves the necessity for the immediate adoption of some rule for work, we cannot allow our machines and our works of improvement to wait for the advancement of science. And if existing data are insufficient to give an exact solution of the question, that approximate solution must be acted upon which the best data attainable shows to be the most probable. A prompt and sound judgement in cases of this kind is one of the characteristics of a practical man in the right sense of that word." I think you'll observe that even in Rankine's day of over one hundred years ago this question of differences was apparently a leading question.

If we can decide the differences between an engineer and a scientist then we stand a chance perhaps to get at some of the basic bodies of fundamental knowledge and the concepts which are relevant to engineering practice.

We have given much thought to what would be the common disciplines in an engineering education, something that all engineering students should have. The most important issue of all is, "What is the best educational base to prevent the technological obsolescence of the engineer." Not in 5 years, but in the 25, 30, 35 years in a practicing career. The major question is, "Is engineering a profession, and is engineering education a professional education?" I begin to wonder sometimes. This morning as I opened up my new shirt, it said right on the shirt bag, "This shirt has been <u>professionally</u> laundered." We're really using this word overtime.

Let's return to some of the questions. What is Engineering? The Engineers' Council for Professional Development definition is as good a place to start as any. The definition that they give is this: "Engineering is a profession to which knowledge of the mathematical and natural sciences, obtained by study experience and practice, is applied with judgment to develop ways to utilize economically the materials and forces in nature." You should note that ECPD defines engineering as a profession. It implies that the engineer utilizes economic solutions to current problems. In my opinion at least, the engineer is a problem-solver. By the means available, the engineer must contrive, analyze, design and build a system to meet an objective. As such he is a synthesizer, an inventor, an applied mathematician, an applied scientist and an economist. And in the end I would say that the engineer has to be a practical man.

We have graduated from the handbook age. No question about it -- we are dealing now with phenomena that we had not even heard about 5 or 10 years ago. Supersonic, hypersonic, semiconductors, electronics, solid state principles, complex interacting systems, and one of the speakers this morning mentioned lasers. Are there any differences then between the scientist and the engineer? Yes, the scientist is primarily interested in discovering what we never knew before and the engineer is interested in doing something that has never been done before. The engineer is a middlema between science and social needs. Engineering and science, though very different in their ultimate goals, do nevertheless have many things in commo The engineer must be able to understand what the scientists have to say or have already said, and we also must understand, as Rankine stated in the quotation, that an engineer is not necessarily limited to scientific findings alone. There probably will continue to be art in engineering but when we fully understand the processes the art may be perhaps limited. In my own field we have the science of soil mechanics applied to foundations. Without this science we might be 3,000 per cent off but with the science it is my hope that we are only 300 per cent off. In many situations it has been theory catching up with practice. That is, the engineer with the empirical data, and judgment, has anticipated the theory. The theory has in many cases helped to explain the true form of the art and has removed many limitations imposed by the art alone.

Engineering education, although we are talking about it here for the future, must also serve the needs of the present. Any good educational plan must first identify the essential fundamental bodies of knowledge which will enable an engineer to continue his development, and prevent technical obsolescence. We are finding in this critical restudy what the fundamentals are. We are now identifying many significant areas which cut across the traditional lines of civil, electrical, mechanical and chemical engineering, as we know them; areas in which physical phenomenon bears extremely close resemblance -- we could give many examples; field theory, fluid flow, heat conduction, etc. I believe that one direction in which a change in engineering curricula can develop is in the providing of more interdisciplinary areas, or core areas for all students, possibly unified through common mathematical solutions and related physical phenomena. We will have to do this because there are only so many slots in the curriculum, and to conserve time, as time is at a premium in a college course. These bodies of knowledge will certainly encompass the old as well as the new and I think they will be taught with a more rigorous mathemathical base. If we're going to get all of this into our program we'll have to do a little surgery on what we have been doing. We will perhaps cut out some or most of the vocational courses we've had in the past. Whether you know it or not engineering drawing or mechanical drafting - machine drafting as we used to call it - is going. Many engineering schools now are down to just one course, perhaps in graphics. I think we should retain it because I'm sure that graphics provides a very valuable education in 3-D visualization.

Now let's take a look at current curriculum philosophy in engineering. One group of engineering educators believes that mathematics, or rather those common aspects of mathematics which describe a family of physical phenomena, would be the key. They say teach the mathematics, for example the LaPlace equations, and we will have the solution to heat conduction, flow of water in a porous media, electrical fields, etc. They talk in terms of the mathematical model, and they also feel that one common electrical analog may suffice to describe and solve the problems of many varied phenomena. Another group believes that a fundamental understanding of the physical phenomena or concept is to be gained only by observing the phenomena. Once observed and experimental evidence is at hand, it may be described mathematically. This group recognizes the engineering problem created by a phenomenon. A great deal of good can come from this in thinking about interdisciplinary courses and what we call the common denominator courses. We must watch out for an over-emphasis on solely abstract mathematical solutions of isolated parts of the problem without a good knowledge of physical concepts. We must also watch out for a deficiency in dealing with the disciplinary aspects of design, and by design I mean something different than the routines that most of us had in college. We must also be aware that if we don't watch out we might have a piecemeal approach to separate phenomena which would fail to deal with the over-all problems of the system as a whole.

Getting back to the surgical point of view, I mentioned that mechanical drawing was going -- I think you should realize that descriptive materials courses which told you how to make steel, how to make cement, are essentially gone. They have gone out in favor of what we call materials science based on the atomic structure of matter. The old steam power plant courses have been gone for many years. We now provide fairly good solid courses in thermodynamics, but they're going, in favor of statistical thermodynamics and molecular thermodynamics. Old "strength of materials" is now "mechanics of solids." I think we have a danger in our educational plans; if we don't watch out we will be concerned only about the needs of military space technology, and neglecting our civilian technology and the basic mission of engineering. I think another danger exists in that we may no longer be educating engineers but only scientists and researchers, and design will not be attractive to these men. To be sure we need the scientists and researchers, but the needs of our industrial civilian economy and our environmental needs must also be satisfied.

There are many factors in building a future engineering curriculum. One factor is the better preparation of the incoming student, the steady improvement of high school work to collegiate standards. I am often asked by my friends who are not in education,"Are the students as good as we were?" And I say, "Look, fellows, they're better." I don't say that they are more intelligent, but they are better prepared. Earlier introduction of fundamental courses in college is possible because of the better mathematical base. Some of you may remember studying your mechanics in your junior year; I did. We then moved it into the sophomore year. It is now moving into the freshman year. You ought to be aware that freshman physics now introduces Einstein's equation $E = mc^2$, when in my day and age it was rumored that not more than 7 people in the entire would understood Einstein's theory of Relativity. We should realize that engineering education has not remained static. Material which we would have thought, 20 or 25 years ago, to be solely for graduate instruction is now in the undergraduate curriculum. We also ought to take into account in planning our engineering program that many of the classical areas of physics are being abandoned by the physicists, in favor of his new concentration in the nuclear field. These classical areas will probably have to be taken over by the engineer. The engineer must know modern physics, but in talking to one dean about this problem about one month ago, he said, "I am sure that within a period of 10 years we will not have a single Ph.D. physicist who will be interested in teaching a freshman course of physics." And then he said, "I think the engineers will teach this."

There are many interesting and promising educational plans emergi and every day you hear of something new. I will mention a few. Johns Hopkins University has merged nearly all the departments of engineering int one engineering science department. They plan to give a bachelor of engineering science degree without designation in the traditional fields, in four years. Some universities will award, from now on, a Bachelor of Arts in engineering in four years, and a Bachelor of Science in engineering in 5 years. At Yale there is a unified undergraduate plan with professional specialization at the graduate level; at Dartmouth, 4 years plus one more for the specialized traditional work. At Case Institute there has been a merging of essentially all of the departments. They will permit, after a thorough coverage of what we think to be interdisciplinary knowledge, a concentration in some of the traditional fields. A trend today on many campuses is towards the creation of centers: computer centers, design centers, material centers, system centers, set up to provide a closer collaboration between the faculty who may have varied disciplines. With all of these curricular pressures being asserted it does not appear to me that you can do all this in 4 years. I believe that 5 years will be required to cover the advanced professional courses that modern engineering education must provide for.

We believe that there can be a stronger and more extensive basic core of engineering science on an interdisciplinary basis, including a firm foundation in applied math, plus physics and chemistry. I do think, however, that 4 years will be enough for a large majority of our students since these men will undoubtedly have a better education and will fulfill many of industry's demands in such challenging fields as production, service, and sales. To accommodate all these purposes there will be an increase in the educational time spent on basic courses of fundamental content. The basic trend is towards a probable decrease in professional content in the four year program. It seems to me that if we go about this right that we can devise course offerings that can be made so fundamental that they will include the areas of modern physics and chemistry in themselves. Unless we as engineering educators can devise engineering science courses which will enlarge the scope of basic science for the engineer then we will have no other recourse but to let the physicists or the mathematicians teach these fundamentals. If we don't meet this challenge head on, we will then relegate these efforts to the pure scientists and lose the opportunity to teach the engineering approach as we teach the content. Any increase in educational time for the basic courses must necessarily mean a trimming of the vocational courses. Industry for years has said, "You teach them the fundamentals and we will teach them the rest." You are certainly going to get your wish. You should clearly understand that you will have to teach them more, not less, but on the other hand you will gain. As a matter of fact, we think these graduates can continue to grow.

I hasten once more to emphasize, as an educator, that I am a firm believer in some means of concentration in the field of the individual student's interest. I think you would find that an engineering program composed entirely of core courses would be very dead. We are dealing with human beings and we are dealing with students who have wishes and desires for the future. This lad may desire to work in the field of electricity, or he may want to be a mechanical engineer, and I believe it would be a mistake to keep him away from some of the media of concentration in his field of interest. I think he would be a more responsive student. I, for one, trust that the advanced areas of specialization such as civil, electrical, mechanical engineering, will remain although minimized, as in no other way can we circumvent the dangers attendant to the solely sophisticated mathematical analysis which we are apt to find in a straight engineering science course, without some latitude of election in an area of current interest. This will enable us to maintain the role of the engineer as distinguished, after all, from the pure scientist. I believe that the undergraduate concentration will be less, and the bulk of the concentration on professional specialties will be at the graduate level. To maintain the prime and distinguished educational goals of engineering education, namely, design and synthesis, I believe we must encourage the introduction of systems engineering into the engineering curriculum from the freshman year on. It is in design that the emphasis shifts from facts to the interpretation and evaluation of these facts, and much creative thought, I believe, must be given to the solution of this problem. Many educators are working on it; no real solution has been shown.

I believe we are going to find modifications in laboratory instruction in college. When I studied hydraulics we pumped 100,000 gallons of water over a weir just to study the theoretical principles of the weir. We're not going to have much more of that. I think we're going to have more on the planning of experiments, unified treatments where much of the laboratory instruction will be done in common for civil, electrical, and mechanical engineers, with a creative effort required on the part of the student. The newest gimmick that is coming into laboratory instruction is the take-me-home experiment. A student is given an opportunity to obtain all the parts necessary to build an oscilloscope, and he can take his oscilloscope home after he has built it and paid for the parts.

I'm also old-fashioned enough to believe the major ingredient in education is still the teacher. I also feel that never before has the engineering educator had such a real responsibility to foresee that any future trend in curricula toward engineering science is not the dangerous thing it could become. I think we want to preserve the function of the engineers within the framework of our greater emphasis on basic principles, and we must remember or recognize that what we're trying to do is to increase the flexibility of the engineer. We can cut across traditional and professional boundaries and enhance his ability to cope with changing technology and his ability to recognize the problem. In doing this, I feel the engineer must not lose his utilitarian goals. I am very confident that engineering education will emerge much stronger in this evolution towards the future. It will probably emerge, in my opinion, as one of the greatest educational developments in our time. And I'm sure in my mind that engineering very effectively ties together the forces of nature and the forces of modern society, present and future.

I know that industry has a stake in this venture. Your needs for engineering manpower should be known now. You should also think in terms of the future. Science is always taking one more step forward, and so is engineering education. Engineering practice will also need to step forward. Nevertheless, no one can accurately predict the problems that will need solutions five or ten years from now, nor the type of industry yet to come. We certainly do have a heavy responsibility to the young men coming to us. Many years ago I was apt to draw all my curves with a French Curve through all the data points; everything was either all black or all white. Fortunately in the subsequent years I have given up drawing my curves with a French Curve. I now get myself a 6-inch-wide brush and paint my curves. This allows for the scatter and also for a broader interpretation.

DISCUSSION

J. L. York

Thank you, Professor Carpenter. Now we have really two views of engineering education. They are not in direct conflict; there are points that may be in disagreement, but there are also many points of agreement. I think several of us will have questions to bring up.

O. K. Kelley

I would just like to say that I'm fully in agreement with Mr. Carpenter, especially regarding the emphasis on basic fundamentals.

J. Stievater
Question:

There seems to be some disagreement between the last two talks about where the humanities comes in and I was wondering if either of the gentlemen would care to comment on it? Should they come within a four or five-year period? (The exposure to sociology, economics, or psychology)

S. T. Carpenter
Answer:

Well, I think this depends somewhat on what school we are talking about. It has to be remembered that I come from really the smallest accredited engineering school in the country. We are built, steeped, in the traditions of a small liberal arts college. We represent 10 percent of the student body. We believe that a lot of the humanities, liberal thinking, rubs off because they're rubbing elbows with their classmates. Ninety percent are not taking engineering. We think that is a great help to them. We know that most students learn a great deal in the bull sessions in the dormitories. And if he is pretty much equal intellectually, he can talk philosophy and economics with the economics and philosophy majors, and this makes a big difference. Well, why do we have to wait for this balance? This is life. I agree that he has to know his job, I'm 100 percent for what he has said. But I think we are going to have to find some room somewhere for some of this too. Someone spoke today about communication.

Who do you communicate with? When engineers start talking, you know how they talk - pencil, paper - do you agree with me on that? I'm sure you do. Since I'm an engineer, give me a piece of paper. Well, of course the other engineer must have his pencil and paper too. It's like having two computers talking to one another, isn't it? This question of communication is pretty deep. If you believe that engineering has a chance of becoming a profession you're going to have to sell the ideas right down the line to a lot of people And sometimes you sell things by not trying to sell things. I believe in it myself and I'd like to have somebody speak up that disagrees. I'd like to argue the point.

O. K. Kelley

Professor York, would you permit me to voice myself on that? Well, I can say that in my presentation I was trying to drive a hard bargain knowing full well that I would not quite buy it myself. The reason was my anxiety to emphasize the high value of technological background, first of all. But the humanities are absolutely essential -- to teach or to acquire by communication with fraternity brothers. But how much do we really have to have is a big question. Can we minimize it to just a speaking acquaintance? Do we have to know the Battle of the Iso's 333 years before Christ or don't we? How throughly do we have to know the geography of the world and know where Caracas really is? Could we just give ourselves a general over-all speaking acquaintance of these humanities and classics that our curriculum always has to contain? And add just a little bit more to the technological side. However, I would not sell short the development and practices of self-expression because it is so very true that you may know more than anyone else about something, but if you cannot penetrate other people's heads with your words, then you are lost. You must understand how the other fellow thinks and you must be able to phrase your knowledge into the language that penetrates his receiving end. You must understand his point of view, not being an engineer, and it is difficult to clearly acquire without living a long time to really get it. But the alerting of the student of the necessity for it would be highly essential; don't expect the other guy to be another computer when you talk. I don't know whether I know where the dividing line is. If we had nothing but billions of students it would be simple. You would get a lot of this stuff across in a short time. If we had nothing but people from fine families with a lot of educational and travel experiences back of them, high culture in homes, it would be simple. But when we have to start with the average cross section I'm just sort of glad it isn't my job to solve the question. Dr. York, it's your turn.

B. G. Johnston

It seems to me that current experiments here in the Ann Arbor High School show that a tremendous improvement can be made in teaching humanities at a high school level if we really all get behind that sort of thing.

S. T. Carpenter

Yes, I agree with you very much.

B. G. Johnston

Yes, I think, too, because they are living in a college community (university community). They might as well carry on, there's no point in having a four-year lag, because the more they know the better.

S. T. Carpenter

I think overspecialization is a real danger. What worries me sometimes is that we might be like the surgeon who came out of his operating room and was talking to his colleague and said, "Whooh! That was a close one! Half an inch either way and I'd have been out of my speciality."

G. A. Baird
Question:

Professor York, I find it very hard to argue with Mr. Carpenter. In fact, in my opinion the clean-up man hit a home run. If you'll let me I will present here my summary of the four speakers we've had here today, or my reaction--what I got out of their message. As far as Dr. Trytten's talk is concerned, he tells us pretty much that fewer people are studying engineering even though the demand is higher. I think this presents a problem right away to the universities. What are they going to do about it? We in industry say we need more engineers and he also, in some of his charts, showed that those who are in engineering are going in for more advanced education, so this means as far as we in industry are concerned--there's going to be a longer time before they are available to us to use. And Mr. Walsh's story-- First, he was describing primarily what engineers do and what is required of them today by management; maybe that's not quite fair but that is the general impression I got. He also stated some things that I certainly agree with. A lot of people who have engineering education get into other fields. Even with this increased need for engineers some are going to sales, to purchasing, to manufacturing, and also into management. He did say that he doesn't feel that specialization is what he's looking for. So he wants more basic concepts Then some of Professor Dow's comments here show, and this may not be fair either, that most of the Bachelor-degree students from the University of Michigan do not qualify to enter their Graduate School and you might say that everybody should at least be trained to enter graduate school. Mr. Kelley says we must have theory to be able to do a better job with the practice and I certainly can't argue with that. My impression is that he wants trained engineers ready to go to work. And generally I would say design engineers. With a good knowledge of materials, and all the various technology required to actually do design work and create things, fairly shortly after they leave college. A quick summary of that might be that he wants a designer with a good knowledge of physics. Culture and humanities are more of a hobby than a requirement in Mr. Kelley point of view. The real answer could be in fundamentals. I was most encouraged by Mr. Carpenter's talk -- that universities are well aware of the change in needs, of what industry wants, and they are actually doing something about it. Because part of the conclusion I have come to before was that we want probably more people with engineering science education. Now one of the things that the universities may have to do here is to possibly pay more attention to some of the drop-outs because many of these people are capable of doing some of the jobs that engineering requires. And I think that the University possibly has been doing a lot of training for industry rather than educating. And this is partly our fault: those of us in industry expect people to come out and go to work right away. I think you might be able to summarize this by saying the engineer today is tomorrow's technician, because the requirements that we're going to have a few years from now are going to be quite different from what they have been in the past. So as I said I'm quite encouraged with what you are presenting here from the standpoint of some of the universities. This sounds more like a speech than a question.

J. L. York
Answer:

Thank you. I think we needed such a summary. There are a couple of points there, that you phrased as questions, that I might try to answer, but let's see if someone else has comments on it.

G. A. Baird

Well, I don't know, we have so many statistics on it today to look at we have a hard time sorting them all out. But this question of where these freshman who would have entered engineering are going, is quite a problem. There are a number of figures you could probably add. It figures up any way you want to. But in putting it together, several people have discovered this; whereas we might have thought we were losing to physics, chemistry, mathematics, we actually haven't. We can't account for even a major part of the total loss to those areas. There has been an increase in the number of people in physics and quite a number in the field of mathematics. On the other hand there have been fields that have gone down. Geology, for example, for one. Areas of that type. So actually it still doesn't explain it. I think I hit on one of the explanations this morning from the charts, from the first speaker which I thought were very good. It's this question, and I think I agree, that so many of our freshman engineers come from families where the father has been the blue-collar worker, a very, very qualified man in his field, and this is one step up for the young man when he comes to take engineering. The cost of our engineering education is getting so excessive that we may be putting it out of the reach of some of these people. The University of Pennsylvania, for example, charges a boy more tuition if he's going to study engineering than if he's going to do into the field of elementary teaching. And there are differentials creeping in like that over the country. We don't feel its really so much but the large school is really feeling this and the state universities will feel it. I'd like to have the answer to this question myself. How can we encourage that 80,000? But I don't see how we're going to do it right now.

J. L. York

One comment I might add. You spoke of the cost. A Michigan resident coming to the University here as an undergraduate engineer will spend just under $2000 per academic year, depending on how high he lives. If he is a graduate student or if he is an out-of-state student this price will be somewhat higher, particularly if he's out of state. It will cost him an extra $700 per academic year to come. So we have put the price up a fair amount over what it used to be. I can well remember as a student, not in this state, but attending a state university, when we had almost a revolution on the campus because the fees were raised from 20 to 25 dollars. That was a fantastic 25 percent increase in one year. There has been an inflation in cost, I'm not sure there has been a serious inflation in purchasing power. Education is still a pretty cheap commodity considering what it is worth to each individual. As Professor Carpenter indicates, you can't account for them all by transfers into other fields.

G. A. Baird

I think that another factor tends to drive them out of engineering. I'm a physicist, not an engineer. I can account for some of the experiences in physics and that is that the young fellows take a look at physics and the fact that they are going to have to go to school for eight to ten years before they're gainfully employed, so they immediately switch over to business administration. I think that as the engineering curriculum is built up and the demand for advanced-degree people by employers increases, you're going to lose a lot of them who just won't want to wait until they're 25, 26, 27 years old to start earning a living. I think that this may be an influence on your declining enrollment.

J. L. York

That could be a factor.

G. A. Baird

This could be in decline as well.

R. C. Juvinall

I heard a comment with regard to the economic aspect of engineering education. It's a little bit on the other side of the fence. The comment was rather shocking at the time but this was at a meeting we were having in the University discussing visitations to the high schools in order to carry the message to the high school counselors as to what engineering really was and for the information that might be passed on to their students. The comment was made by one of the very knowledgeable people who had been out to the various schools, that there is no need wasting our time going to Bloomfield Hills, Birmingham and Grosse Pointe, because in these suburbs of Detroit at the top economic level the kids are not going to come to study engineering. This is beneath them; they are coming to business administration, the literature school, medicine, law, but not to engineering. And I think Mr. Russell agrees that this should not be, and it's a rather alarming state of affairs, and how can we correct a situation like this.

J. L. York

I think that Dr. Trytten's figures this morning confirm that; he indicated that the income of the families from which engineers come is at the very bottom on the average list. If you looked at the rest of the diagram, you found that those who go to medicine and law come from very high income families. In fact, I've made the statement, as Professor Carpenter has, that the man on the production line encourages his son to become an engineer so he'll have a better job than he had. But the son's son is running around with doctors and lawyers, and that's where he is going to go to school, he's not going to be an engineer. His old man has already convinced the boy, because he sees what kind of a job Dad has and he doesn't want any more of it, so perhaps we don't encourage our own sons to do this often enough.

S. T. Carpenter

I think he spoke about these drop-outs. You spoke about what we might do about the number of drop-outs. That's a very, very tough question. I had a freshman in the other day who told me he was transferring out of engineering next year, and I said, "What into? Math, or Physics?" And he said, "No, classics." Well, he wants to study Greek and he's always had an interest in Greek, and he thinks that is what he wants to do. He might develop into an anthropologist this way, or something. "Well," I said, "look, if you're interested in classics, stay around a while. We're going to have a lot of classical physics, chemistry, classical mechanics." And he says, "Is that true?" I said, "Sure, we have our classics too."

G. A. Baird

Part of my point here, with the drop-outs, is that I think we're coming up with a lot more tools that will help some of the problems. As an example, at Burroughs we don't make slide rules, we do make computers, and some day I think most of Mr. Kelley's jobs will be done by computers and not by the physicists with their slide rules. So possibly some of these drop-outs can only get to a certain level in their education. They can then start pushing the right button on the computers.

O. K. Kelley

May I just offer a comment on that. I didn't mean to imply that General Motors Engineering does not use computers a great deal; I think we are IBM's biggest customer. However, the slide rule is a very valuable invention and if you can read it in one setting there's no way of making a mistake, you only have to add or subtract in many cases, and I think slide rules are here to stay. Not as a complete answer by any means but for the quick evaluation of results. I would like to say one more thing - perhaps this has something to do with the tough time we're having in getting more people into engineering courses in colleges. Too many people know that engineers work pretty hard. Just yesterday the Assistant Vice President at the Tech Center asked me, "What is your normal quitting time?" It was about 5:30 then. I told him, well, it's just about like this pullman porter during the 1932-33 depression. A gentleman taking his first ride in a pullman train didn't know what the average tip was so he asked the porter, and the porter said, "It will be one dollar, sir." So the fellow gave him the dollar, and the porter said, "Thanks very much, you are the first to come up to average." So our quitting time is later than 5:00. And our night work is necessary in solving all our problems. Engineers are a hard-working lot. If they want to advance they have to be. As a result you see, in our General Motors Corporation, our managers are all engineers They do study business administration, they do study plain hard-working engineering. They are drafted to these positions because they have been a producer, they've been the conscientiou hard hitters. Engineers are a bunch of sons of Martha. Very clearly, for those who have the money in their families to begin with, that sort of a hard working prospect is not so tempting. It should have some glamour or some professional recognition or honor added to it, you know, in order to make the thing attractive to those capable of hard work but who wouldn't volunteer to choose it if there was an easier way out. That's what ruins it for some of them. Kids that I know of very well go to Yale to study law; Princeton, medicine; but not to Engineering. That's for the birds, you have to work too hard.

J. L. York

As Professor Carpenter mentioned, Yale is not teaching engineering as an undergraduate program any longer, and Harvard long ago abandoned engineering as an undergraduate program. Many of those schools are treating it only as an applied science. Maybe this is their philosophy, I don't know.

W. A. Turunen

I wish Professor Carpenter would expand a little bit on his thoughts of the engineering curriculum going more towards a science orientation.

S. T. Carpenter

There were a couple of things that perhaps I didn't say too clearly. As you know, many elements of classical physics and chemistry will always be a part of engineering. I'm sure you'll all agree with that, and that the engineer, I think, is going to be left responsible for that field. I think the physicists have moved on. The Ph.D. physicists will always need to know some classical physics but they also want to deal with the really sophisticated frontiers in physics. I think what's going to happen is that the engineer is going to be left to husband those very basic principles. How can we work out these interdisciplinary courses? Several speakers pointed out the advantage of a man being able to cut across disciplines. I think you're going to get at this problem by having what I would call an interdisciplinary type of instruction, where the principles are widely applicable; for example, wave theory which cuts across a good many fields and physical phenomena. That is what I mean when I say we are going to study science by more of a fundamental approach than we have in the past. I think too, that when we think in terms of science our engineers must have what we call the modern physics area today. It is my hope that our engineering instruction can develop in such a way that we can husband those areas of science within these engineering sciences that we've been talking about. And we can abstract from these science areas the very, very best. That's what I really meant.

Many schools are experimenting with how to classify physical phenomena from the standpoint of just mathematics and theoretical treatment. Many phenomena could be dealt with on what we would call a lump parameter basis; there are other aspects with which we can deal on a continuous system basis, or say the media basis. What I really also said is that I think you've got to understand the physical concepts. For example, the same equation might handle condition, as say, flow of water through a porous medium, but the physical interactions that an engineer would have to guard against is different. I think we've got to have a real good understanding of physical concepts.

I wouldn't want you to think that these freshmen that we lose are only our poorest students, since many times they are our best students. This is too bad, because we often haven't furnished a sufficient challenge in our schools. As the engineering curriculum tightens towards a more scientific base there are dangers connected with this. We cannot lose the basic mission of the engineer, namely, that of design. I think we are interested in what we can do to challenge our young people to see in engineering at the very beginning that there is a lot of experimentation and creativeness in design. For example, in one of our freshman courses the instructor walked in and said, "Here, I want you to design a machine that will make a Scripto lead pencil in a production basis, now go to it." Well now, of course they had to make sketches, they had to conceive of the materials and everything, but they were getting at the idea, some of the ideas or some of the disciplines an engineer must have. He's got to be interested in a problem. We are doing a whole host of things like that as early as we can to try to show these students what we think engineering is.

H. Benford
Question:

I think it was Dr. Carpenter who mentioned the arrangement whereby some schools have a four year program leading to a bachelor of arts, and five to a bachelor of science. When does the student have to make this decision? Can he get a bachelor of arts and then after one more year get another degree?

S. T. Carpenter
Answer:

Yes, he gets a bachelor of arts in four and then he can go on and get a bachelor of science, or he can make the four terminal.

H. Benford
Question:

But he doesn't have to make the decision until then?

S. T. Carpenter
Answer:

No, he does not. That's the way I understand it.

G. P. Ransom
Question:

I have a question for Dean Attwood. What is the University's opinion of this basic college education at the Bachelors level, with specialization thereafter?

S. S. Attwood
Answer:

That's a tough one, although one that reminds me of the speaker who said "Gee that's an awfully good question, what is the next question?" One of the remarks that Mr. Carpenter made describes pretty well what many schools are doing. We are culling some of the dead wood in the curriculum, cutting down on the amount of actual skills that are required. Drawing is still retained but in a smaller amount than formerly. I think we give enough now to serve the purpose. We no longer expect everybody to take drawing and surveying, for example. And certainly at the other end of the scale we have crossed out steam engines and similar things in favor of the basic concepts of thermodynamics or across-the-board formal mathematical topics of one sort or another. Another remark that he made indicated that he favored retaining the departmental structure, Civil, Electrical, Mechanical, etc. There has been a trend in some places, such as U.C.L.A., where they have tried to build up simply an engineering curriculum without division into departments. Now I don't know too much about it at that particular institution but I have heard that there is an inevitable tendency to break into cliques, mainly for professional reasons. In other words Chemical Engineers like to associate with chemical groups, to belong to their particular professional society. So that if I have been correctly informed they are in a sense grouping themselves in effect even though not in name. So I would like to see the professional departments retained for professional engineering reasons. That does mean, however, that it leaves some fences between these departmental structures. I like to think that in the period that I have been here I have helped at least to revise these fences. Sometimes I like to feel that we have taken down the solid fences and put up picket fences instead, so that we can at least see through them. There is a considerable tendency toward the development of interdisciplinary activities. I can recall for instance that several of our professors have gone from one department to another and interchanged courses, just because they wanted to, with no pressure on them to do so. They were interested in seeing what the other side of the fence looked like and I like to encourage them.

In addition to the modernizations that I have talked about, we started the Science Engineering course some five or six years ago because we wanted to get more freedom into the curriculum than was available in the individual profession groups. In my opinion it has been very successful. It offers a student a wider variety of elective choice, but permits him to go back into one of the professional groups if he so wishes, or to take an elective major in any one of them and still stay in the Science engineering group. In general I think they do choose science and mathematics courses a little bit heavier. But instead of trying to throw the whole College over into that kind of operation, what we did was to set up something in parallel, study it and see how it worked. In my opinion it has paid off.

We also have other categories like Engineering Mathematics and Engineering Physics that have individual variances in elective programs, and we find that these different groupings appeal to different groups of students. One student might, for instance, go into Engineering Physics and would not go into Mechanical Engineering. I think we have perhaps saved him for Engineering by offering him a variety of choices. I don't know if I am getting at the question you had in mind. We are continually evolving, and changing, and building and continually trying to answer these problems. At the same time we are trying to retain a high degree of flexibility. I might go on to say that here we have a very considerable graduate program. We have 2900 undergraduate students and around 1150 graduate students. From my point of view the question of whether you want four or five years is an academic question so far as we are concerned. Then, furthermore, we have so much research work going on at this institution that both undergraduate and graduate students can be associated with, that they are getting a lot of training that might otherwise come to them in the early stages of industrial work. We are giving many of them a considerable amount of additional solid training that should pay off after they leave us.

R. H. Hoisington
Question:

I would like to ask Professor Carpenter a question in line with this move on the part of Yale and Case and other Colleges who consolidate their programs into one degree program, with the idea of specializing at the graduate level for a Master's degree. This is very fine for 25 percent of the students who are admitted to the graduate school. But in my position here I probably know more men who just get through the 2.0 or don't make it and this is the problem that will rise here in the future very shortly. What's going to happen to these men without a field of specialization? Where are they going?

S. T. Carpenter
Answer:

I would be glad to explain the Case program. It is an interdisciplinary type program based around the centers that I spoke of: materials, design, etc. They do permit each student to select from 8 to 9 courses, it depends, which would lead them to civil engineering, electrical engineering, mechanical engineering. What they have done is to put a restraint on the total number of such courses. The student would still be coming through in four years, basically able to work as a civil, electrical, or mechanical. He is also going to have this better idea of what the other man's problems are too. It represents quite a sensible program when you look at it. It will take some time in transition, I suspect. You have a great cross-section of staff to deal with. You move in engineering education not much faster than your staff will move. Otherwise, you move over a great number of deceased bodies, and this is not good. In other words, you've got to be a salesman, a politician, a convincer. If this is a good move to make you've got to show every man where he fits into the new scheme of things. I'm sure any educational administrator would say about the same thing.
Yale is a little different, they did away with the undergraduate school and now when the engineering student enters Yale College he's just a major like anyone else. He has an adviser

and this adviser is supposed to advise him on certain patterns of courses leading him to his engineering goals. This is the new scheme of things. At Swarthmore we decided we needed something to act as a catalyst so we simply said we wouldn't have any more departmental Honors programs. The Honors method of study is one of our strong points; we've had it at the College for 40 years. We agreed we would give up our own individual departmental Honors programs in favor of an Honors Program in Engineering Sciences. I think these plans are interesting, but having been a teacher for over 30 years I know that there is a learning aspect. Students, to learn, must have a problem and if you get them too far away from what they are interested in they are not interested in learning. And the main thing, I think, in education, is disciplined thinking. I think a man could be a disciplined thinker if he became an economics major. If he gets the right discipline in thinking, if he gets a chance to get up on top of the hill and at least take a little look down the other side of the mountain, then he's got an education. If he has learned the techniques and habits of disciplined thinking, a discipline in dealing with facts and synthesis, I think it will carry over.

Question:

There is one thing that we haven't mentioned today, maybe it's a little outside of the title. I'm surprised that someone hasn't brought up the question of obsolescence of the older engineer - what can be done about it?

S. S. Attwood
Answer:

You are hearing more and more about that as a big broad importan problem and we are making some efforts in that area, but it seems to me that that is one of the big problems and it certainly has just been touched on today peripherally. Does anyone have any comments on that? I'd be interested in hearing from our industrial friends -- whether they have any views on that question -- on what they and we can do about it.

S. T. Carpenter

That is a problem, it's a problem much more in engineering than in accounting. In our accounting department, an old accountant is still a good accountant because as a rule the laws have not changed very much. He is now a wiser accountant. An obsolescent engineer could be a wise engineer. His wisdom dwells in a narrow area, and we sometimes find it difficult to maintain a good match between his capabilities and the problems of today, but we wish that it weren't so. It's one of the tough problems to solve in the older people whose limited opportunity or ability to acquire more of the technology as they mature on their job has left them behind and we have obsolescence. Of course, there is such a thing as a corporate loyalty to an employee that pretty generally protects the old horses. You don't shoot them just because they don't win the race. That's the reason I was pleading for a more fundamental "Dr. Carpenter type" of education, to permit engineers to receive new knowledge more easily, because of their fundamental training has made it. When something new comes along he won't say, well, I won't ever understand this. But says, well, let's take a crack at it. It ought to be easy enough to understand, then you would have very much less of this obsolescence of our old engineers.

C. Schultheiss

Obsolescence rises when one has family obligations and so on and cannot avail himself of any formal education, and too often he is geographically located so he cannot attend a good school with any degree of efficiency - night school. And I think this area ought to put pressure on the University of Michigan for graduate work programmed to fit industry needs. Indeed, perhaps the working day could be dove-tailed to early classes or late afternoon classes, just so there would be some program available to engineers in the immediate communities. These people who have chosen suburban living find it difficult to spend most of their time traveling to campuses in town.

S. S. Attwood

We are doing a fair amount of it now, so far as circumstances seem to permit. We are willing to do more whenever the appropriate arrangements can be worked out.

S. T. Carpenter
Question:

I think there are a number of things we ought to do about that question that you speak of, and I think we can, but I think it's going to be expensive and I think industry is going to have to bear a great deal of the cost of this as they probably should. For example, we have so many new ways of imparting

instructions: programmed learning, tape instruction, closed circuit television. There are large cross-sections of industry that could really get together on a closed-circuit television and hire the best teachers in the country to do this sort of thing. It's awfully difficult for a man who has been out a good many years and if his calculus ended with, let us say, integral calculus. If he doesn't have a good understanding of differential equations he's going to have a very difficult time in many of these new areas to begin with, so where do you start? In other words you have to diagnose what I would call the jumping-off point in education. This is difficult. And you can start with something that is very fundamental, that a man can do at home, in which case this programmed learning is quite successful. I have seen several that were much better than the classroom instruction. I don't think it's ever going to take the place of a teacher.
I think there are a lot of things that we should do. I know we take our freshman engineers and our sophomores on inspection trips. We try to take our freshmen three times a year into various types of industry: electronic industry, mechanical industry, and inspection. Just take them a whole day and let them see for themselves what's going on and they are fascinated with this. But when I have a chance to take them over to the Westinghouse Steam Turbine Division, there is one place that I don't take them. I don't take them into the mechanical drawing room where they have 700 engineers with drawing boards back-to-back. I don't take them in there. I do take them to the computing center and they have a lot of fun there. But I don't take them into this room where there are 700 draftmen because we're trying to create at least a modern image to the engineer and this doesn't appeal. These people are obsolescent and are the ones that are perhaps keeping some of the boys away from engineering. They say, "Well, there is what I would be doing."

O. K. Kelley
Answer:

Maybe I can shed some light on that, that part of it which I consider one of the most important parts of our mechanical engineering. I don't know a single chief engineer in the General Motors Corporation who didn't start his career in the drafting room, because it is here where you can finally demonstrate that your thoughts and your ideas are realistically expressed in the design; and freehand sketches on the scratch pad are so often useless because you run out of space and the layout cannot be accurate. So a layout draftsman in his job is an honorable and necessary part of exercising engineering, so I would not personally hesitate to show these drafting men to these people if they intend to be design engineers. Now if they want to limit themselves and just become desk engineers; they are the ones that really understand and know the product and really know how to go about improving and changing and that takes place in the drafting room. So they don't spend too much time in drawing details, no, but they do enough of it to realize that every line and every dimension is exceedingly important and should be right. But they get, in 2 or 3 years time, to make so-called centerline layouts in which proposed designs are compared and checked in critical areas by accurately drawn penciled lines on the tape. Without that they would not be able to be in charge of a staff, a small engineering staff. The drafting boys are here to stay because I see no possibilities of a computer reading a man's mind and making a picture on paper and reproducing a form. The form is going to remain in pencil on a piece of paper with sharp lines including the dimensionally accurate concepts.

S. T. Carpenter

I certainly didn't want to speak disparagingly of the draftsmen, because I came up that way myself. What I was really trying to get over was that 700 draftsmen all jammed up in a room which should have about half as many people in it, is not a very encouraging scene; that's exactly why I don't show them that one.

J. L. York

This obsolescence comes home to me when I realize that I started in teaching 20 years ago as a part of a group of young Turks who were rebelling against the existing system. Ten years ago I was a victim of such a revolution, and I now see another on the horizon and I'm not sure I can survive that, in a technical sense. And this brings home the point that we do have essentially a generation of engineers every 10 years. Now either we are going to upgrade on a continuing basis the engineers who have left school, or we going to shoot the man who is one revolution behind, or two.

C. Schultheiss

Here is a light thought about this - we give up the steam and gas study, and the study of the steam engine, it's almost a cultural thing that we should be retaining. Even though the toy shelves have steam engines on them, they were gone for awhile and I missed having one as a boy, but it's evolving to that thing.

Comment:

But we still have one of these steam outfits left in our laboratory.

J. L. York

There is one comment that was made that I would like to try to answer, whether it was meant to be a question or an accusation or just a statement, and that was from the discussion this morning. The impression was made correctly that only about 25 or 30 percent of the graduates in the University in the Engineering College are admissable to our graduate school. Now whether this is good or bad is a question that would have to be decided, but perhaps the answer is that the transition from undergraduate college to graduate school is fully as severe in technical and psychological shock as the transition from high school to college. And we take about the same proportion over that hurdle each time. The distillation is becoming a little more severe and a little more concentrated. We could even carry this a step further and point out that perhaps one reason the technical institutes have been talked about but don't seem to have caught the imagination of everybody is that, by and large, the 4-year bachelor's man in engineering is being used as a technician today in a great many industrial organizations, and perhaps the technical institute is too late to fill the need. This comes back to what Dr. Trytten defined as an engineer this morning, and I don't think anybody asked him that question. He pointed out that 23 percent of the people who appear on that chart as an increase in the number of engineers did not get bachelor's degrees in engineering and that it was a mystery where they came from. I don't have an answer to the mystery but this is part of our problem. I'm not sure what constitutes an engineer today and it is something I think for all of us to think about. It's just part of the definition of where we're going in the two-year program, the four-year program, the five-year program, and the graduate degrees, etc.

O. K. Kelley

This amount of learning that the undergraduate engineer will accomplish on the job depends entirely upon these computers back of his eyebrows. I have seen many a man who went through college but college didn't go through him very well. And I have seen some less-than-graduate engineers become department heads and chief engineers, and managers in high positions, purely and surely because of their ability to engineer. They had a good enough base and hard enough personal drive. Maybe that's where the 25 percent comes from.

CLOSING REMARKS

J. L. York

Perhaps we can summarize this a little bit. It has been summarized once very well for us and we have been discussing the summaries to some extent. Could we say with some safety that it has been quite evident that we don't have enough engineers, and that our procedure for educating them is trending into more and more scientific approaches and that this revolution is under way, but that at the same time there is certainly a demand that we do not remove practice out of engineering and that we keep it tied to the theoretical and basic concepts. The proportions are our problem and yours and that's what we wanted to discuss, so we'll have to go home and think about these things. Thank you for coming.