**SELECTION AND RETENTION OF
CIVIL ENGINEER EMPLOYEES**

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by
A. K. BRANHAM

**PURDUE UNIVERSITY
LAFAYETTE INDIANA**

Technical Paper

SELECTION AND RETENTION OF CIVIL ENGINEER EMPLOYEES

TO: K. B. Woods, Director
Joint Highway Research Project

July 24, 1957

FROM: H. L. Michael, Assistant Director

File 3-3-19
Project C-36-54

Attached is a technical paper entitled "Selection and Retention of Civil Engineer Employees" by A. K. Branham, research associate on our staff. This paper was presented at the 43rd Annual Purdue Road School in April and has been submitted for publication in the Proceedings.

The paper is a summary of a final report of the same title previously distributed to the Board. It includes a study of the shortage of civil engineers and suggested methods and procedures that might be utilized to relieve this shortage. A study of salaries in public agencies with those in private industry is included and a typical salary schedule is developed.

The paper is presented for the record.

Respectfully submitted,

Harold L. Michael, Assistant Director

HLM:bjk

Attachment

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Technical Paper

SELECTION AND RETENTION OF CIVIL ENGINEER EMPLOYEES

by

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Joint Highway Research Project
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Purdue University
Lafayette, Indiana

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SELECTION AND RETENTION OF CIVIL ENGINEER EMPLOYEES

GENERAL SUMMARY

Construction expenditures in the United States were about \$58.9 billion in 1955 and \$60.6 billion in 1956. Current estimates for 1957 indicate that total construction will be in excess of \$64 billion, and estimates of expenditures for the next decade show accelerated growth in construction and a corresponding increase in the demand for the economic resources of the nation. It is obvious that to plan, design, construct, operate, and to maintain these facilities will require economical and efficient use of manpower, money, materials, machinery and equipment, and the development and utilization of new methods and techniques in all phases of development and maintenance.

The most serious problem to be solved is the critical shortage of civil engineers, architects, technicians, craftsmen, and others engaged in the construction industry. The available data show that the number of engineers and technicians graduated in recent years is inadequate. Furthermore, the population and enrollment trends indicate the shortage will remain for the next decade.

Industry and governmental agencies may relieve the shortage of engineers by the development and use of more efficient equipment and through new techniques and procedures. In addition, the practice of using technicians and other supporting personnel will often relieve engineers for more important work assignments. In meeting the challenge of supplying and maintaining technical personnel, management must use

the most effective personnel techniques available to industry. In addition, the construction industry must develop new techniques if the manpower problem is to be solved.

The selection, employment, training, and maintenance of personnel are important phases of technical manpower administration. Job or position classification, employee recruitment, selection and placement, continuity of service, wage and salary schedules, training, promotion and transfers, working hours, holidays, annual leave or vacation, and other techniques must be fully developed as fundamental concepts of good personnel administration.

The study compares salaries in public agencies with those in private industry and indicates that salaries in public agencies must be increased if they are to compete favorably with private industry. Furthermore, a salary schedule for the various grades of engineers is developed. The mathematical expression includes allowance for experience, merit, and changes in economic trends.

SELECTION AND RETENTION OF CIVIL ENGINEER EMPLOYEES

by

A. K. Branham

INTRODUCTION

The U. S. Department of Commerce in cooperation with the U. S. Department of Labor early in 1957 reported total construction of the nation to be about \$58.9 billion in 1955 and \$60.6 billion in 1956. The latter program included \$44.1 billion in new construction and \$16.5 billion in maintenance and repairs. The expenditures for new construction included \$30.7 billion for private projects and \$13.4 billion for public projects. Estimates for 1957 indicate expenditures for all construction will be in excess of \$64 billion. Predictions for the next decade show an increasing rate of growth in construction and a corresponding demand for engineers, architects, technicians, craftsmen, and others engaged in the construction industry.

The Federal Aid Highway Act of 1956 gave impetus to a construction program of more than \$100 billion to be expended on a national basis during a 13-year highway improvement program, fiscal years 1957-69. The expanded highway program, as determined by the needs studies and outlined in the Federal Aid Act of 1956, will draw heavily upon the economic resources of the nation. The Bureau of Public Roads (News release, July 25, 1956) has estimated that 49 million tons of steel, 1,339 million barrels of cement, 128 million tons of bituminous material, 9,710 million tons of aggregate, and large quantities of other materials

will be needed in the highway construction program.

In addition, more than 5 million man-years (1600 man-hours per-year per-worker) of on-the-site labor will be required to complete the task by 1969. In 1955, about 323 thousand workers were employed in the construction and maintenance of highways; a peak of 443 thousand workers will be needed in 1959; and about 302 thousand workers are expected to be employed when the program levels off in 1969.

Four task forces of the American Road Builders Association have reported that the road building industry- contractors and suppliers of materials, equipment, and technical know how - is able and willing to do the job. Some delay has been encountered in getting the program into expected production, but the industry reports that the job can be accomplished on schedule. The serious handicaps appear to be the finance program, especially at the state level, and the inadequate supply of technical personnel to plan, design, and construct the necessary highway improvements.

It is reasonable to assume that Indiana, like other states, will use its proportional share of the material and manpower resources in the orderly development of an adequate system of highways. Other public works programs in Indiana - water resources, public health, and conservation are expected to keep pace with the rapidly growing economy and they will also require an increasing quantity of the state's resources. These programs in Indiana can expect to encounter problems similar to those found in other states.

The basis of this study is not one of material or monetary resources, but one of manpower - especially the shortage of professional and technical manpower in several state agencies - the State Highway

Department of Indiana, the Department of Conservation, the State Board of Health, and the Flood Control and Water Resources Commission. Each agency has reported an inadequate number of engineers, that it is difficult to employ qualified engineers, and that their retention has become a problem. For example, the State Highway Department of Indiana reported 77 new additions in highway engineering personnel (including two returning from leaves of absence) were made in 1955. The total number of highway engineering personnel on the payroll on December 31, 1955 was 368; the need for an additional 172 engineers was reported at that time. The number of engineers employed by the same department one year later (December 31, 1956) was 350. This represents a net loss of 18 engineers in one year. Thus, one may assume that about 190 new engineers were needed on December 31, 1956. This portrays a critical condition within the State Highway Department - a department which currently has about 90 percent of all engineers employed in the several Indiana governmental agencies under study. This does not necessarily mean that the other engineering agencies of Indiana do not have engineering personnel problems. It is obvious that, in general, the employment or loss of an engineer will have a greater effect upon the productive capacity of these agencies, on a percentage basis, than would a similar condition within the State Highway Department of Indiana.

THE SUPPLY OF ENGINEERS IS LIMITED

Degrees in Civil Engineering

More than 120,000 civil engineers were gainfully employed in the United States in 1956. Approximately 32,000 engineers are employed by state, county, and city highway departments. About 17.5 percent, or

21,000 civil engineers are employed by state highway agencies. Industry and government are currently clamoring for more. But the source of supply is short - only 4450 bachelor degrees in civil engineering were awarded in June 1956 by schools accredited by the Engineering Council for Professional Development. An additional 600 civil engineers were graduated from schools not accredited by ECPD. Table I, Engineer Bachelor Degrees, shows that more than 5,000 graduates were available for initial employment as civil engineers in 1956. Their number may increase to 6,000 in 1957.

Population Growth

The population of the United States increased from about 150 million in 1950 to nearly 170 million by the end of 1956, representing an increase of about 2 percent per year. Estimates made in 1955 show that the population of the United States is expected to be in the range of 202-226 million in 1975; recent predictions indicate a population of 300 million by year 2000.

In late 1956, about 62 million persons in the United States were not over 19 years old, representing an increase of approximately 17 percent over 1950. The data also show the population in this age range is increasing at a rate of about 2.5 percent per year. When this rate of growth is compared with a gain of less than 2 percent per year for the total population, one may conclude that this group will soon fill the elementary and secondary schools, and may be expected to significantly increase the college enrollment within the next decade.

College Enrollment in Engineering

College enrollment is expected to swing upward in the years ahead.

TABLE I

ENGINEERING BACHELOR DEGREES^(a)
Estimates for 1955, 1956, 1957

Engineering Curriculum	Number of Bachelor Degrees By Year					
	1954-55 *	1954-55 Total	1955-56 *	1955-56 Total	1956-57 *	1956-57 Total
Aeronautical	650	700	800	900	1,000	1,100
Agricultural	250	300	300	350	400	400
Architectural	250	300	300	350	400	400
Ceramic	100	100	150	150	150	150
Chemical	1,950	2,200	2,450	2,800	2,950	3,300
Civil	3,550	4,400	4,450	5,050	5,350	6,000
Electrical	4,500	5,000	5,650	6,350	6,800	7,750
Engrg. Mechanics	**	**	**	**	**	**
Engrg. Physics	200	200	250	300	300	350
General	550	600	700	750	850	950
Geophysical	**	50	50	50	50	50
Geological	200	200	250	300	300	300
Industrial	1,150	1,300	1,450	1,600	1,700	2,000
Mechanical	5,250	5,850	6,600	7,500	7,800	8,900
Metallurgical	450	500	550	600	700	750
Mining	200	200	250	300	300	350
Naval Arch. and Marine	50	50	50	50	50	50
Petroleum	500	550	650	700	750	850
Sanitary	**	**	**	**	**	**
Textile	100	100	150	150	150	150
Other	350	400	450	500	500	600
TOTAL	20,250	22,600	25,500	28,750	30,500	34,500

* ECPD Accredited schools only.

** Less than 25 degrees.

(a) From EMC-SMC Newsletter No. 99, November 14, 1956. The above data are based on enrollment trends reported by the American Society for Engineering Education, and the Engineers Joint Council and the Scientific Manpower Commission have jointly estimated the number Engineering Bachelor Degrees. Figures are reported to the nearest 50.

Total enrollment in September 1956 was about 3 million and it may reach 4.6 million by 1970. Over one-half million students are expected to be enrolled in engineering in 1970; nearly double that of 1956. Population growth, an increase in the proportion of persons of college age who attend college, the increased interest in engineering, and the improvement of our economic status are important factors contributing to the upsurge of enrollment in engineering.

Engineering enrollments in colleges of the United States set a new high in September, 1956. They jumped 13.8 percent over September, 1955 while total college enrollment increased only 8.3 percent. The freshman engineering class in 1956 totaled 77,738, an increase of 6.7 percent over 1955. In comparison, total freshman enrollments were up only 4.9 percent.

The enrollments in engineering for academic years 1955-56 and 1956-57 are presented in Table II, Engineering Enrollment.

The U. S. Office of Education reported the number of earned degrees in 1955-56 to be about 10 percent short of the predicted figure. This is considerably below the estimate reported in Engineering and Scientific Manpower Newsletter, Number 99, November 14, 1956.

Attrition has been high as may be observed in the table presenting enrollments in 1955-56 and 1956-57 (See Table II). Only 55,767 of the freshman enrollment (72,825) of 1955-56 enrolled as sophomores. The U. S. Office of Education estimates that only 5⁷ percent of those who enter engineering courses as freshmen complete the bachelor's degree in engineering. Thus 57 percent of the 1956 freshman enrollment or 44,300 engineers will be graduated in 1960.

TABLE II

ENGINEERING ENROLLMENT

(1955-56 and 1956-57)*

	<u>1955-56</u>	<u>1956-57</u>
Freshmen	72,825	77,738
Sophomores	50,841	55,767
Juniors	39,377	44,610
Seniors	31,300	37,571
Fifth Year Regulars	1,358	1,387
Fifth Year Cooperative	1,450	1,838
Other	<u>24,297</u>	<u>32,210</u>
Total	221,448	251,121
MS Graduate Students	18,482	22,529
PhD. Graduate Students	<u>3,163</u>	<u>3,402</u>
Total	243,093	277,052

About 200,000 engineers are expected to graduate in the period of 1955-1960; this is 40,000 less than the number needed to meet the demand for engineers. Less than 15 percent will be civil engineers.

* Source: EMC-SMC Newsletter No. 102 - February 11, 1957.

Enrollment: Civil Engineering and All Engineering

A summary of a report giving a comparison of 1951 and 1955 enrollment by curriculum and degree on a national basis is presented in Table III, Comparison of Engineering Enrollment.

TABLE III
COMPARISON OF ENGINEERING ENROLLMENT

	UNDERGRADUATE			GRADUATE (MS and Ph.D.)		
	1951	1955	Percent Increase	1951	1955	Percent Increase
All Engineers	128,367	190,355	48%	19,327	21,568	12%
Civil Engrs.	19,744	23,784	20%	2,057	2,276	11%
Civil Engrs. as a percent of all engres.	15.4%	12.5%		10.6%	10.5%	

These data indicate that undergraduate enrollment in all fields of engineering increased 48 percent, 1951 to 1955; graduate enrollment increased 12 percent in the same period. Undergraduate enrollment in Civil Engineering increased 20 percent; graduate enrollment in Civil Engineering increased 11 percent. The data also show that civil engineers as a percent of all engineers decreased from 15.4 to 12.5 percent, 1951 to 1955. Graduate enrollment in Civil Engineering as a percent of all engineers remained nearly constant.

Placement of Civil Engineering Graduates

A recent survey conducted by the Highway Research Board shows that, on a national basis, less than 10 percent of the graduates in Civil Engineering (BSCE) accept initial employment with governmental agencies charged with the highway function. Manufacturing industries, consulting engineers, and the military services absorb nearly all of the civil engineering graduates, as shown in Table IV, Placement of Civil Engineering Graduates, National and Purdue University, 1956.

The seriousness of this problem may be observed when the percentage of the graduating civil engineers accepting initial employment with highway agencies (9.3 percent) is compared with the percentage of all civil engineers (17.5 percent, about 21,000 engineers) currently employed by highway agencies. This comparison appears to indicate that the number of civil engineers entering the highway construction field should be doubled. This assumption would be erroneous because productivity per man-hour in highway construction has increased about 40 percent within the past decade. In addition, the use of new equipment and techniques will further improve productive capacities.

THE SUPPLY OF SUPPORTING PERSONNEL

The Technical Institute

There has been a growing realization on the part of industry, government and educators that a man, when properly trained and oriented with a combination of limited engineering and scientific knowledge and manual skills can augment greatly the output of engineers and other professional personnel. It is also recognized that a sharp line of

TABLE IV

PLACEMENT OF CIVIL ENGINEERING GRADUATES,
NATIONAL AND PURDUE UNIVERSITY, 1956

Industry or Type of Employment Accepted	Purdue University		National*	
	BSCE(a) PERCENT	MSCE(b) PERCENT	BSCE(c) PERCENT	MSCE(d) PERCENT
1. Business, retail or wholesale	—	—	0.7	0.2
2. Contractors, general and highway	4.3	—	4.6	1.8
3. Contractors, building	2.6	—	4.3	1.4
4. Consulting engineering firms	12.1	25.6	12.4	14.3
5. Education, college, teaching, research, graduate study	6.9	0.0	7.7	17.4
6. Government, federal	3.8	2.3	6.8	2.4
7. Government, State Highway departments, toll, or other highway authorities	9.5	9.3	9.3	3.9
8. Government, county	4.3	—	1.0	0.8
9. Government, city	3.5	2.3	2.6	1.8
10. Government, other	0.9	—	1.8	1.6
11. Manufacturing, aircraft	4.3	2.3	6.3	2.9
12. Manufacturing, steel	3.5	—	4.9	2.9
13. Manufacturing, other	11.2	7.0	4.9	3.1
14. Petroleum pipe line companies	6.9	—	4.4	2.0
15. Railroad companies	2.6	—	1.5	1.2
16. Utilities electric, gas, water, telephone	0.9	—	3.3	0.6
17. Unknown and miscellaneous	18.9	16.3 ^(g)	10.0	24.6
18. Military service	— ^(g)	27.9 ^(f)	13.6	15.8
Total	100.0	100.0	100.0	100.0

* From Highway Research Board Study.

(a) 116 graduates

(b) 43 graduates

(c) 112 schools reporting, 2933 graduates

(d) 50 schools reporting, 489 graduates

(e) 4 graduates returned to foreign residence

(f) 9 graduates returned to military assignments

(g) Probably much higher

demarcation does not exist between the responsibility of the technician and the engineer. Some like to use the terms "how" and "why" to differentiate between the technician and the engineer.

What is a desirable ratio of the number of technicians to the number of engineers? The ratio appears to vary by source of information. Some suggest a ratio of 5 to 1; others suggest 1 to 1. A study conducted by the Highway Research Board shows that the ratio in 1956 was about 1.4 to 1 in state highway departments. The ratio will be higher in the highway field as more technicians are trained. This practice should relieve the engineer for more important duties. The growth of the technical institute program depends greatly upon the acceptance of the institutes as a significant source of manpower, acceptance of the program by secondary school counsellors, and acceptance by students who are interested in technical careers.

Many of the students enrolled in the various technical institute programs, at Purdue University and elsewhere, have either a full-time or part-time work assignment and pursue a part-time educational program. Such programs provide an excellent opportunity for the cooperative work-study approach in improving the manpower problem. The programs developed in California, Illinois, and Indiana are illustrative. The latter states are planning to train about 200 technicians in 1957.

The Cooperative Engineering Education Program

Purdue University and the State Highway Department of Indiana initiated a cooperative educational program in 1954. Other state agencies have shown a similar interest. This is also a proper step toward the recruitment and retention of engineers for upon completion

of their engineering education they can be effectively added to the professional group.

Temporary Employees as a Source of Personnel

College students may be employed on a temporary basis during the school year and during the summer session. If these students have some training in engineering or the sciences, they can, under adequate and proper guidance, fulfill certain positions and relieve the more skilled persons for higher type assignments. The employment of students during the summer serves a double function - help on necessary work is gained during the construction season, and the employer has an opportunity to introduce himself to a potential full-time employee.

A planned program of hiring high school students often leads to increased employment of either the high school graduate or the college graduate who has previous employment with a particular organization. The program conducted by the Michigan Highway Department is representative.

Non-engineering Graduates

Non-engineering graduates often possess certain skills of value to the civil engineering field. Those with training in mathematics, chemistry, physics, geology, cost accounting and others, when used as supporting personnel, can provide valuable assistance. Frequently, with only limited specialized training, they can perform assignments in their specialized areas or in related assignments as draftsmen, calculators, expeditors, cost analysts, traffic survey personnel.

High School and College Teachers

High school and college teachers with appropriate training may serve during the construction season. Here again public relations can be combined with the job.

After 50 as a Source

Older men, those of early retirement, and men who have been engaged in other fields form a source of supply for both professional and supporting personnel. There is a substantial number of engineers over the age of 50 who are having difficulty finding jobs. The Engineering Societies Employment Agency has reported it has a wealth of talent in older men it cannot place.

Certain industries and governmental agencies permit retirement on the basis of years served. Thus it is possible for an engineer in his early 50's to retire from a job and to accept employment elsewhere. This provides additional income.

ADMINISTRATION AND THE MANPOWER PROBLEM

It is recognized that the basic responsibility of the state highway administration is to plan, design, construct, and to maintain a system of roads and streets which will provide for the efficient, economical, reliable, safe, and comfortable interchange or distribution of people and products by highway transportation. Similar objectives and responsibilities are applicable in other state agencies employing engineering and scientific personnel. It is further recognized that these responsibilities must be preceded by legislative action which provides for adequate funds and authority and that this responsibility can be best

accomplished through efficient and wise use of machines and equipment, methods, materials, money, and manpower. Furthermore, adequate manpower is dependent upon objective policies, procedures, and methods for the recruitment and retention of competent personnel.

The major functions of the state engineering departments, as they pertain to the management of manpower, must include certain basic concepts of management. It must be recognized that top management in a state department - the commission and director or chief engineer - should determine policy, and that the administrative staff of the several divisions should formulate policy, be responsible for manpower program planning, for review and appraisal of manpower policies and practices, for consultation, and for service to the operating lines in the several divisions.

The administrators must face the fact that management of manpower is a continuous and full-time process, should be on the basis of competency and not subject to political desires and whims, and includes four major objective functions:

1. Discovery, procurement, selection, allocation, and placement of manpower on the basis of competence. This is especially true for registered engineers, graduate engineers in training, undergraduate engineers, scientists, and technicians who are in supporting assignments.
2. Control of such working conditions as will best utilize the services of personnel in their various assignments.
3. Provide various services to employees, seeking thereby to encourage continuing self improvement and increased efficiency.

4. Maintain personnel records and conduct effective personnel research.

At the outset management must recognize that job analysis is the initial step in the management of manpower and it serves as the basis for organizational planning and coordination, for recruitment, selection, placement, training, transfer, promotion, and compensation, for setting standards, preventing misunderstandings, improving working conditions, and others.

SUGGESTED SALARY SCHEDULES

Governmental agencies in competing with industry for civil engineers should give careful consideration to revising their salary schedules. Engineering News Record (June 21, 1956) reported that average salaries accepted by June 1956 graduates in civil engineering were slightly over \$421 per month, and the trend is upward. The graduates accepted jobs on the basis of opportunity, location, and salary, and in that order.

The average acceptance salary for June 1956 graduates in civil engineering from Purdue University was \$425 per month; in August, 1956, it was \$437 per month; and in February, 1957, it was \$455 per month. The average is expected to be \$500 for those graduating in June, 1957. A comparison of acceptance salaries for civil engineers and "all" engineers graduating from Purdue University in recent years is presented in Figure I, Number of Engineering Graduates (BS) of Purdue University With Average Starting Salary and Average Starting Salary of Civil Engineers.

FIGURE 1

NUMBER OF ENGINEERING GRADUATES (B.S.) OF PURDUE UNIVERSITY WITH AVERAGE STARTING SALARY AND AVERAGE STARTING SALARY OF CIVIL ENGINEERS

It may be observed in Figure I that initial salaries for civil engineers were ahead of salaries for "all" engineers during the period, 1950-53, but since 1953 they have been lagging behind salaries for "all" engineers. The trend in engineering enrollment, expressed in engineering degrees, is also presented in Figure I.

The recent Heller report, Final Report on State Government Organization (Exhibit No. 56) suggested an initial salary of \$350 per month for ASCE Grade I. It may be observed that suggested starting salaries for ASCE grades I and II shown in Table V, Suggested Salary Schedules, are below salaries accepted by recent graduates in civil engineering. The report also suggests a top salary of \$22,000. This also appears to be inadequate because a top salary of \$30,000 per year has become a reality in a neighboring state.

TABLE V
SUGGESTED SALARY SCHEDULE

ASCE Grade	Heller Report ^a	
	Minimum	Maximum
9	\$15,700	\$22,000
8	13,500	18,000
7	11,300	15,700
6	9,200	13,500
5	7,800	11,300
4	6,600	9,200
3	5,640	7,800
2	4,800	6,600
1	4,200	5,640

^a See Exhibit 56, Final Report on State Government Organization.

The trend in professional compensation was the subject of a paper presented by Professor E. B. Peck at the Engineers Joint Council General Assembly, January 17-18, 1957, in New York. The data used by Professor Peck in making a quantitative analysis of the trends in the earnings of engineers (1939-1956) was from the E.J.C. report "Professional Income of Engineers - 1956". A brief summary of the report is presented in Table VI, Annual Earnings of Engineers in All Activities.

Professor Peck's paper presents an analysis of salaries in relation to certain important economic factors; productivity, wages, and consumer costs. It proposes a framework of salary administration which includes experience, merit, and economic trends.

It was observed that the period of 1939-56 had been one of great economic expansion. In this period, the G.N.P. (Gross National Product) in constant dollars increased four-fold, while the cost of living doubled. Wage rates increased about three-fold while top management salaries increased less than the cost of living. Most of the middle class salaries were squeezed between rising wages from below and a relatively static top management salary.

This telescoping of salaries means that engineers' salaries have not grown with experience as rapidly as previously. Furthermore, telescoping appears in merit differentials. Productivity and wages have been rising rapidly, while top salaries have, until recently, remained static. This has produced a squeeze that has reduced experience and merit incentives.

The current rate of secular growth is about 3 percent per year and salaries should provide for this growth. This means that wages should about double in 23 years, and triple in 40 years. Furthermore, a secular increase should be granted without considering individual merit or productivity.

TABLE VI

ANNUAL EARNINGS OF ENGINEERS IN ALL ACTIVITIES BY YEAR OF ENTRY INTO THE PROFESSION*
(Report of 107,632 Engineers)

	YEAR OF BACCALAUREATE DEGREE														
	1955	1954	1953	1952	1951	1950	1949	1947 1948	1945	1944	1939	1934	1929	1920	1913
Highest	12,900	11,550	15,000 ^a	15,000 ^a	15,000 ^a	14,825	15,000 ^a	15,000 ^a	15,000 ^a	15,000 ^a	15,000 ^a	15,000 ^a	15,000 ^a	15,000 ^a	15,000 ^a
90th Percentile	6200	6675	7125	7475	7825	8500	9050	9825	10525	12000	14,150	14,700	15,000 ^a	15,000 ^a	15,000 ^a
75th Percentile	5725	6200	6475	6850	7225	7700	8100	8725	9125	10375	11850	12100	12600	13000	12675
Median	5300	5725	6050	6350	6625	7000	7300	7700	7875	8900	9875	9775	10125	10350	9750
25th Percentile	4875	5300	5550	5775	6075	6250	6550	6875	6900	7700	8175	8200	8400	8575	7725
10th Percentile	4550	5025	5100	5250	5525	5650	5875	6150	6075	6675	7025	6900	7100	7150	6400
Lowest	3000 ^b	3000 ^b	3000 ^b	3000 ^b	3000 ^b	3000 ^b	3000 ^b	3000 ^b	3000 ^b	3000 ^b	3175	3175	3000 ^b	3000 ^b	3000 ^b

* Source: Professional Income of Engineers - 19% - Engineers Joint Council.

a \$15,000 and over.

b Less than \$3,000.

The data of the E.J.C. report reveal that only 10 percent of the engineers earned \$15,000 within 20 years from their first engineering degree. Only 25 percent earned at least \$12,000 within 20 years; \$12,700 within 40 years. The median salary was about \$10,200 in 20 years; \$10,700 in 40 years. Other percentiles were lower and incentives for experience and merit approached zero. These data indicate that engineers in the upper 10 percent are those who profit by merit throughout their career.

Professor Peek, in order to provide annual merit and promotional increases as a function of experience developed the following equation:

$$dS/dt = kS(A-S)$$

Where "S" is the salary, "t" is the experience or years from degree, "k" is a constant computed for each curve from the end conditions, and "A" is the potential salary or asymptote of each curve.

The above equation implies that at any merit level, the annual rate of salary increase is proportional to the salary, multiplied by the amount of money left for salary increases for the rest of the career. The salary curves presented in Figure 2, Suggested Salary Schedule for Civil Engineers, June, 1957, suggest that each curve is aimed at a goal which is a potential for the employee. It does not mean that an employee is tagged with a potential early in his career and cannot change. Periodic merit rating and performance reviews can change these potentials.

The equation produced two curves, as shown in Figure 2, running from a determined initial salary to \$20,000 and \$30,000 respectively within 40 years. In practice the curves might run from initial salaries to maximum salaries of job classifications. This relates the curve to the job evaluation system. It also permits definition of potential in terms of job specifications.

FIGURE 2 SUGGESTED SALARY SCHEDULE
FOR CIVIL ENGINEERS JUNE 1957 *

* SALARIES ARE BASED ON CURRENT ECONOMIC CONDITIONS

As an example of how a set of curves obtained from the equation $\frac{dS}{dt} = kS(A-S)$ can be utilized to develop a salary schedule for a particular industry or organization, a possible salary schedule will be developed for a typical engineering organization.

Let us assume that the organization has 100 engineering positions, classified by job description and correlated with ASCE grades. These positions are illustrated in Table VII, Salary Schedule Information For Hypothetical Engineering Organization.

The determined salary conditions used may be any values which are representative. They should, however, be those that are realistic for the particular organization and they should be values which are competitive with those of comparable organizations. The values used in the example correspond to those used in Figure 2 and might be practicable for the engineering graduate of 1957.

Percentile curves required (99, 95, 85, 75, 50, 25, and 10 for the example) as shown in the Cumulative Percentile column Table ~~XIV~~^{VII} and as determined by the number of engineers in each grade are drawn using the determined salary conditions and computing a point on each curve for various years after graduation (as 10, 20, 30, and 40).

To develop salary ranges for each grade, it is necessary to select a reasonable time in grade for each grade prior to promotion to the next grade and a minimum time in grade for outstanding men. In the example these times are as shown in Table VIII, Example of Selection of Salary Ranges. The column entitled Top Percentile Each Grade of Table VIII is that determined from cumulative percentage of positions in each grade. Theoretically engineers filling positions of any grade need only be of the same relative

TABLE VII

SALARY SCHEDULE INFORMATION FOR
HYPOTHETICAL ENGINEERING ORGANIZATION

ASCE Grade	% Positions Each Grade	Cumulative Percentile	Determined Salary Conditions	
			Starting**	Maximum
9	1	100	7,200	30,000
8	4	99	7,200	29,500
7	10	95	7,000	29,000
6	10	85	6,800	28,000
5	25	75	6,500	25,000
4	25	50	6,000	20,000
3	15	25	5,700	16,000
2	10	10	5,400	12,000
1B (EIT)	*	-----		
1A (EIT)	*	-----		

* As many EIT's in Grade 1A and 1B to provide adequate engineering personnel in future years.

** The starting salary is that for Grade 1A, or in other words the first salary of the new engineering graduate. For example a new graduate who has the potential of being the best engineer in the organization (100 percentile) would be paid \$7,200 as initial salary while a new graduate of potential average ability (50 percentile) would start at a salary of \$6,000.

TABLE VIII

EXAMPLE OF SELECTION OF SALARY RANGES

ASCE Grade	Practical Time in Grade Prior to Promo- tion	Minimum Time in Grade	Top Percentile Each Grade	Salary Range		
				Minimum for Grade	Maximum for Grade	Max. in Grade including Longevity
9	—	—	100	23,600	—	30,000
8	4	3	99	21,600	27,400	29,500
7	4	3	95	19,400	25,000	29,000
6	4	3	85	16,800	22,400	28,000
5	4	3	75	13,200	18,200	25,000
4	4	2	50	9,800	14,200	20,000
3	3	2	25	7,600	12,400	16,000
2	3	1	10	6,600	11,000	12,000
1B	2	2	—	6,000	10,400	—
1A	2	2	—	5,400	8,600	—

quality percentile-wise as the position they fill. Engineers with an ability within the 10th percentile of all engineers in the organization could fill positions classified as Grade 2. They would not advance above Grade 2 and would stay in that grade for their full period of employment. Of course, better men would also be filling Grade 2 positions during their climb upward. All other grades would be similarly staffed.

For Grade 1A the minimum starting salary is equivalent to that starting salary to be paid to the 10th percentile engineers. In this example, it is \$5,400. The maximum salary for Grade 1A is that, as shown by the graph to be paid to the 99th percentile (the best one) engineer in training after two years with the organization. In the example it is \$8,600. The starting salary for Grade 1B is equivalent to that to be paid to the 10th percentile man after 2 years or \$6,000 and the maximum is the amount to be paid to the 99th percentile man after 2 years in Grade 1B or \$10,400.

The minimum and maximum salary for each grade thereafter are determined by finding on the percentile curves a series of three points (A, B and C)

Point A. The intersection of the lowest percentile curve that can furnish engineers to that grade and the vertical line corresponding to the cumulative practical time in grade prior to promotion to that grade.

Point B. The intersection of the highest percentile curve that will furnish engineers to that grade who will not be promoted to a higher grade and the vertical line corresponding to the cumulative practical time in grade prior to promotion to that grade.

Point C. The intersection of the highest percentile curve drawn (99th percentile one in the example) and the vertical line corresponding to the cumulative minimum time in grade prior to promotion to that grade.

The three points are then connected by straight lines, A to B and B to C. The same procedure is followed to determine a lower line for each grade. The area between two successive sets of lines represents the conditions for a grade and the minimum and maximum salary for each grade can then be read from the chart.

The maximum salary including longevity for each grade is the maximum salary used to develop the corresponding percentile curve. The areas of each salary range for the various grades for the example are shown in Figure 3, Selection of Salary Ranges. Data for ASCE Grade 9 was obtained, since it was the last grade, from the cumulative minimum in grade time to Grade 9 using the 99th percentile curve and the determined \$30,000 maximum. Data for Grade 2 assumes that all men staying in this grade for life are exactly of the 10th percentile type and hence points A and B for this grade are the same point. No longevity is shown for Grades 1A and 1B as these are engineers in training positions and it is assumed that all trainees would become registered and be promoted to a higher grade. In the event some man did not, he might be transferred to another salary schedule for technicians for other employees.

From Figure 3 one can obtain the proper salary and grade of any employee if years from graduation and percentile rank in terms of competency of the employee are known. For example a registered engineer with 15 years experience since graduation and with a 75th percentile rating should be in Grade 5 and earning about \$16,500 per year. Figure 3 also

FIGURE 3. SELECTION OF SALARY RANGES

shows that this engineer when 18 years removed from graduation should be earning about \$18,200. The unshaded area, delineated by vertical lines as far as 40 years from graduation and the appropriate curves, represents salary or allowance for longevity.

SUMMARY OF TECHNIQUES FOR RETENTION OF PERSONNEL

The techniques of recruitment and retention of engineering manpower presented in this report are not to be considered complete nor should they be expected to eliminate all inefficiency caused by the turnover of manpower. Among the various reasons for turnover found by several investigators are the following:

1. Inadequate salary schedules.
2. Failure to provide reasonably good tenure.
3. Work does not challenge the engineer.
4. Failure to provide adequate opportunity for professional development.
5. Inadequate recognition of service performed.
6. Inadequate fringe benefits - insurance, retirement, medical plans, hospitalization, vacation, sick leave.
7. Personality differences - management vs. the engineer.
8. Just plain politics.

Among the means suggested for combating turnover are the following:

1. Give policies for recruitment and retention appropriate stature.
An aggressive, realistic and imaginative recruitment program is essential to present to engineering students and other qualified personnel an accurate story of the challenge and opportunity to be found in Civil Engineering assignments.

2. Place engineers in assignments which will best utilize their abilities and interests. The work must be challenging to the engineer.
3. Make promotion on basis of merit, ability, and ingenuity.
4. Provide adequate incentives and opportunities for advancement.
5. Provide a wide variety of assignments.
6. Develop policy of upgrading from within industry or agency.
7. Develop adequate in-service training programs.
8. Encourage employees to continue their education and give recognition on this basis.
9. Promote and facilitate interest and activity in professional organizations.
10. Provide for stability of employment and an effective salary schedule. Establish as many fringe benefits as economically feasible. Sick leave and vacation should be accumulative. Health and life insurance benefits for state agencies should be comparable with those of industry and the federal government. Unemployment compensation and Social Security coverage should supplement and/or replace programs now in effect. The salaries must be commensurate with the responsibilities of the engineer and based upon professional competency, experience, and changing economic conditions.
11. Protect the engineer against arbitrary and unwarranted dismissal.
12. Improve communication. A vigorous and effective information service is necessary.

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