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REPORT OF STUDY CONFERENCE  
ON THE  
GRADUATE EDUCATION OF SANITARY ENGINEERS

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CAMBRIDGE, MASSACHUSETTS  
JUNE 27-29, 1960

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REPORT OF  
AMERICAN SANITARY ENGINEERING INTERSOCIETY BOARD  
STUDY CONFERENCE ON GRADUATE EDUCATION  
OF SANITARY ENGINEERS  
CAMBRIDGE, MASS. JUNE 27-29, 1960

INTRODUCTION

Purpose of Conference

To bring together a group of about one hundred sanitary engineers and scientists from the fields of education, industry, consulting engineering, public health and public works agencies to discuss and study means for raising the educational standards of the sanitary engineering profession and of meeting the diverse requirements of the employers of sanitary engineers.

Sponsorship of Conference

A desire to hold a conference of this nature was expressed by many of the diplomates of the American Academy of Sanitary Engineers. The American Sanitary Engineering Intersociety Board, which is the certification board for the Academy, agreed to sponsor this conference and declared that it should be held at Cambridge, Mass., in June 1960. It was voted that the National Science Foundation, Harvard University and the Massachusetts Institute of Technology should be co-sponsors. A three-man Steering Committee was designated to run the conference. Thomas R. Camp, Chairman of the Board of Trustees of A.S.E.I.B., was appointed conference chairman, with Professor Gordon M. Fair of Harvard designated as Chairman of the Program Committee and Professor Rolf Eliassen of M.I.T. as Chairman of the Arrangements Committee.

Conference Arrangements

A grant from the National Science Foundation made it possible to pay the travel expenses of engineers and scientists from universities and public health agencies, as well as other expenses in running the study conference. Dunster House of Harvard University was selected as the meeting place and residential quarters for the conferees. Members of the Arrangements Committee were Professor James M. Symons and Mr. Irwin J. Kugelman of M.I.T. and Messrs. Robert S. Gemmel and Walter J. Weber of Harvard.

Conference Program

The Steering Committee was assisted by the A.S.E.I.B. Committee on Education, under the chairmanship of Professor Harold B. Gotaas, in

the selection of the program objectives. The wide scope of responsibilities of the sanitary engineering profession was divided into three areas of educational curricula: water resources engineering, air resources engineering, and environmental health. It was also agreed that committees should be established to lead discussion groups for Sanitary Science courses and for the accreditation of graduate curricula in sanitary engineering. Committee chairmen were selected for each of these areas of discussion. The Chairman of the Program Committee was directed to obtain working papers from each of the area chairmen and to have these papers available for distribution and study prior to the conference. These papers, which are appended to this report, served as the basis of discussion at the various conference sessions.

Prior to the conference copies of the Sanitary Engineering Education Directory were also distributed to all conferees. This report was published in January 1960 by the A.S.E.I.B. and was prepared under the direction of Professor Gilbert H. Dunstan, former Chairman of the A.S.E.I.B. Education Committee. It was also used as a working paper of the conference and is included in the Appendix of this report.

The program was as follows:

Monday, 27 June, 1960

- 10:00 a.m. Plenary Session - Purposes and Aims of the Conference
- 2:00 p.m. Committee Meetings
  - 1. Water Resources Engineering
  - 2. Air Resources Engineering
  - 3. Public Health Engineering

8:00 p.m. Committee on Accreditation

Tuesday, 28 June, 1960

- 9:00 a.m. Plenary Session - Discussion of Preliminary Reports
- 2:00 p.m. Committee Meetings
- 8:00 p.m. Committee on Basic Sciences

Wednesday, 29 June, 1960

- 9:00 a.m. Plenary Session - Discussion of Final Reports
- 2:00 p.m. Plenary Session - Resolutions

## FINAL REPORTS OF COMMITTEES

The committee meetings and plenary sessions led to a series of reports which are presented as conclusions of the conference. These reports are for the following committees:

Water Resources Engineering  
Air Resources Engineering  
Public Health Engineering  
Basic Science Courses

No report is presented for the Accreditation Committee inasmuch as the committee meeting developed material which was adopted as a series of resolutions. These follow in the following section of the report.

### Report of Committee on Water Resources Engineering

The scope of the sanitary engineer's interest in Water Resources Engineering was set forth by the Committee in terms of the diagrams presented by Chairman McGauhey in the working paper previously distributed to all participants in the Conference. By formal action the Committee endorsed Diagram 3, page 24, "as including the major present areas of water resources of concern to graduate programs in sanitary engineering." Some minor additions to the diagram were included for the purpose of classification. These, as indicated on the copy of the working paper appended to the official copy of this report include the following:

1. Add "Industrial Use" to the list of beneficial uses of water, in order to identify industrial water usage not associated with an "Urban Use" situation.
2. Add "Meteorology" and "Climatology" to the list of typical course offerings under the general heading "Sources of Water."
3. Add "Hydraulics" to the list of typical course offerings under the general heading of "Beneficial Uses of Water."
4. Change Title of Course No. 8 under the general heading of "Water Quality Control" from "Principles of Sanitary Engineering" to "Principles of Water Resources Engineering."

Assuming that Diagram 1, page 22, of the working paper effectively delineates the total scope of "Water Resources Engineering," a companion of the slightly revised Diagram 3 with Diagram 1 leads to the conclusion that sanitary engineering interest encompasses the entire field of Water Resources Engineering with the exception of some aspects of "Beneficial Uses of Water" in purely hydraulic engineering specialty areas. While this does not mean that Water Resources Engineering is a field pre-empted exclusively by sanitary engineers, it does indicate that the sanitary engineering concern with water resources is second to that of no other discipline, and hence, that in spite of the emergence of new fields of interest to the sanitary engineer, his future activity in the water resources field is destined to increase rather than to decline.

The Committee took full cognizance of the fact that a graduate program designed to develop competence in the field of water resources will inevitably be at the doctorate level. Furthermore, that even at the doctorate level a great variety of programs may be drawn from the subject matter outlined in Diagram 3. Thus the flexibility of program desired by both the educational institution and the graduate student is unhampered by the Committee's action.

Discussions centering around the basic preparation necessary for continuation study in sanitary engineering concerned particularly with water resources led to formal agreement by the Committee that prior to the granting of an advanced degree (M. S.) the student must have completed or must complete:

1. The program outlined in the 1957 N. R. C. Report, comprising  
Humanities and Social Studies -- 20%  
Mathematics and Basic Sciences; including Biology -- 30%  
Engineering Sciences -- 25%  
Engineering Analysis & Design, and elective subjects -- 25%
2. Physical and organic chemistry
3. Hydrology, including meteorology and climatology

In addition the Committee recommended:

A course in the principles of water resources engineering, embodying the scientific and engineering aspects of present courses in water supply and sewerage engineering.

1. Additional hydraulics beyond the first course in fluid mechanics
2. Courses in data and systems analysis, including statistics

A strong preference that the courses in physical and organic chemistry, and in hydrology be completed prior to the graduate years was expressed but for reasons of flexibility of program no such rigid requirement was recommended. The Committee also voiced a need for more attention to report writing and to both written and spoken English.

With specific reference to an M. S. degree program in sanitary engineering the Committee suggested the following minimum program as being appropriate:

1. The previously cited (1957 Report) program
2. Fluid Mechanics and Hydraulics      6 semester hours (approx.)
3. Fluid Mechanics Laboratory      2      "      "      "
4. Hydrology      3      "      "      "
5. Microbiology      3      "      "      "

6. Chemistry	6 semester hours (approx.)
7. Principles of Water Resources Eng.	9 " " "
8. Statistics	3 " " "

Inasmuch as several of the courses cited in items 2 to 7 inclusive may be expected to be a part of the undergraduate program and hence included in Item 1, the recommended minimum program would provide time for additional elective courses in pertinent water resources subjects or supporting areas.

For the M. S. Degree the Committee suggests that no thesis requirement be imposed.

P. H. McGauhey - Chairman  
Raymond Faust - Vice-Chairman  
Frank Butrico - Secretary

### Report of Committee on Air Resources Engineering

#### A. Scope

1. It was the consensus of the group that the term air resources engineering was not specific enough to designate the area of concern and the title Air Hygiene and Industrial Hygiene Engineering was adopted.

2. Because of its importance in relation to the above fields as well as other disciplines in environmental health engineering it was decided that radiological hygiene engineering should be ancillary to the above fields. It was hoped that this would also be considered as ancillary to the water resources and public health engineering curricula although our area perhaps has a broader interest in this subject.

#### B. Prerequisites

1. Prerequisites for entrance to the field were considered to be those recommended by the ECPD as minimum requirements for a Bachelor of Science degree in engineering (field unspecified). In general the time distribution should follow the distribution shown below.

### Areas of Concentration for Undergraduate Engineering Degrees

(a) Humanities and Social Studies-about	20%
(b) Mathematics and Basic Sciences-about	25%
(c) Biology such as general biology, physiology and microbiology-about	5%
(d) Engineering sciences-about	25%
(e) Sequence of engineering analyses, design ) and engineering systems ) - about	25%
(f) Electives )	

2. In addition the committee recommends that physical science majors would be eligible to enter these programs provided they complete ECPD minimum engineering course requirements concurrently or prior to their graduate work.

- C. The areas listed below are considered as a program for one academic year of graduate work.

Areas of Concentration for all Environmental Health Engineering

Basic to all environmental health engineering are the areas of needed competency listed below. (Detailed descriptions of courses covering these areas will be mentioned later.)

1. Biostatistics or Engineering Statistics related to environmental problems
2. Epidemiology
3. Radiological hygiene
4. Human and environmental physiology

- D. Areas of Concentration Common to Air Hygiene and Industrial Hygiene Engineering

1. Physiologic effects of environmental exposures (including radiobiology)
2. Analysis of air contaminants
3. Characteristics of air contaminants
4. Engineering control of air contaminants

- E. Areas of Concentration Specifically for the Air Hygiene Engineer

1. Required areas
  - a. Meteorology
  - b. Sources of contaminants (including fuels and combustion)
2. Optional
  - a. Conservation and utilization of air resources
  - b. Evaluation of air pollution

- F. Areas of Concentration Specifically for the Industrial Hygiene Engineer

1. Required
  - a. Measurement and control of industrial hazards (noise, vibration, heat, microwaves, illumination, pressure)
  - b. Air conditioning and industrial ventilation
  - c. Occupational health problems
  - d. Advanced radiological hygiene
2. Optional
  - a. Human factors engineering
  - b. Microbiology
  - c. Unit operations



G. Areas of Concentration for Radiological Hygiene Engineering

1. Required courses

- a. Over-all areas required for environmental health engineering
- b. From the required area for air hygiene and industrial hygiene engineering
  1. Physiologic effects of environment exposures
  2. Analysis of air contaminants
  3. Characteristics of air contaminants
- c. In the radiological hygiene area
  1. Radiological engineering
  2. Advanced radiologic hygiene
  3. Elements of atomic physics
  4. Chemistry of nuclear materials

2. Optional Courses

- a. Nuclear physics
- b. Nuclear engineering
- c. Quantum mechanics
- d. Meteorology
- e. Radiochemistry
- f. Water, food, and industrial waste courses

H. It was resolved that the primary field in the environmental health control area should be designated as environmental health engineering rather than sanitary engineering.

I. In general it was the consensus of the group that the essential features of many of the required and optional areas could be identified with courses as defined in the working paper.

Leslie Silverman - Chairman  
August T. Rossano, Jr. - Vice Chairman  
Harry F. Schulte - Secretary

Report of the Committee on the Engineer\* in Environmental Health

The objective of this report is to suggest programs of education that will equip the engineer to develop systems for management of the environment to promote the health and well-being of man. At the baccalaureate level the future engineer should have attained an operational understanding of basic engineering arts and sciences. Beyond the bachelor's degree, the educational program should provide a broad base for understanding the fundamentals of environmental control.

\*By this term is meant the Sanitary Engineer as defined by the Committee on Sanitary Engineering and Environment N.R.C. in 1943 and revised in 1954 and quoted in the 1957 Conference report.

The master's program, therefore, should be grounded in engineering and science. It should consist of graduate courses in engineering and specifically related courses in the natural and social sciences and mathematics with emphasis on engineering applications. This implies the need for a staff consisting of both engineers and scientists for teaching and research. With the attainment of the master's degree the engineer should possess the ability to carry on work of a professional nature including the design engineering facilities in one or more fields of special interest.

The engineering portion of the master's program should be sufficiently flexible to accommodate variations in need from one geographical area to another. It is suggested that a group of engineering courses be designated from which the master's curriculum may be programed according to regional need. Education in depth in a particular field will require study beyond the master's level - in some cases to the doctorate.

The educational institution and the engineering profession must share the responsibility for sound educational standards and the quality of engineering graduates. The employer and the individual should share the responsibility for job training and professional growth.

In presenting the following guide to studies at the Master's level, it has been necessary to give some indication of expected prerequisite preparation. Beyond this prerequisite area, a minimum of 48 semester hours of study should be divided approximately as follows:

Core content	26 semester-hours
Engineering area in depth	15      "      "
Elective	7
	<u>48 semester-hours</u>

Some of the courses required in the core may be taken in the undergraduate program, thereby permitting additional attention to depth courses or electives.

Areas in depth are intended primarily for development of engineering competence and discipline sufficient to permit professional performance or further study. These areas are intended to provide the education in principles and practices of engineering design. Typical areas for development in depth include:

Water Resources	Food
Air Hygiene	Vector Control
Industrial Hygiene	Operational Analysis
Radiation	

It is not expected that any institution will be able to provide teaching in all these areas.

#### The Core Program

Undergraduate      Graduate  
(Hours are illustrative only)

#### Social Economics:

Political Science, public administration  
and planning, legal and social aspects  
of engineering, economics

6

3

The Core Program (continued)

Undergraduate Graduate  
(Hours are illustrative only)

Mathematics:

Through calculus	(a)	
Advanced mathematics for engineers	3	
Mathematical & engineering statistics	3	3

Chemistry:

General chemistry	8	
Advanced chemistry	4	4

Biology:

Biology, bacteriology, parasitology		6
-------------------------------------	--	---

Physiology or Physiological Hygiene

3

Engineering Science, including hydrology,

fluid dynamics, thermo-dynamics

(a)

Physics, including modern physics

(a)

Engineering analyses, design, and engineering systems

(a) †

Radiation in Environment

2

Epidemiology

2

Environmental Health for Engineers

3

26

(a) As recommended by ECPD (in general, graduate courses are to be designed for the engineer in environmental health).

Areas in Depth

Illustrative of the "areas in depth" are the following:

Water Resources:

1. Required Courses

Stream analysis & Water Pollution Control	3 sem. -hrs.
Water & Waste Water Systems (Design)	6 " "
Total	9 " "

2. Electives (6 credit hours to be elected)

Advanced Hydraulics	3 sem. -hrs.
Advanced Fluid Mechanics	3 " "
Unit Operations and Processes	3 " "
Sanitary Chemistry	3 " "
Aquatic Biology	3 " "
Total	15 " "

Radiation:

1. Required Courses

Radiochemistry	3-4 sem. -hrs.
Radiobiology	3-4 " "
Design of Radiation Facilities	5 " "
Radiation Measurements	3-4 " "
Total	15 " "

## Systems Analysis:

1. Required Courses			
Numerical Analysis	3	sem.	-hrs.
Methods of Operations Research	3	"	"
Multivariate Analysis	3	"	"
2. Electives (6 credit hours to be elected)			
Applied Probability	3	"	"
Stochastic Processes	3	"	"
Automatic Computers	3	"	"
Engineering Economics (advanced)	3	"	"
Total	15	"	"

## Electives

The elective offerings will depend upon the strengths of the institution, but may be expected to include representative groupings of the following:

Environmental Health	Limnology
Human Ecology	Meteorology
Aquatic Biology	Ergonomics
Radiochemistry	Cellular Physiology
Advanced Hydraulics	Conservation
Oceanography	Community Planning
Shelter	Instrumental Analysis
Geology	Industrial Water Supply
Nuclear Physics	Industrial Waste Treatment
Nuclear Chemistry	Accident Prevention
and many others	

In addition, courses may be selected from areas in depth available at the institution. Core requirements not met in the undergraduate program may be replaced by suitable courses from among the electives.

Herbert M. Bosch - Chairman  
John A. Logan - Vice Chairman  
F. K. Erickson - Secretary

## Report of Committee on Biology and Chemistry Courses for M.S. Degrees in Sanitary Engineering

Following a general session devoted to a broad discussion of the subject of Basic Sciences in the Master of Science program for Sanitary Engineers, the Committee summarized the issues of concern in a preliminary report which was presented at the Plenary Session on Wednesday A. M., June 29. Further discussion ensued which served to define the points of variance and allowed the Session to reach agreement on courses and credit hours that were acceptable to the Committees concerned with the various aspects of Sanitary Engineering.

At the Plenary Session it was agreed that the name of this Committee be changed from the Committee on Basic Sciences to the Committee on Biology and Chemistry. Therefore, this report is rendered under that designation.

The major issue of concern relative to the suggested program of chemistry and biology courses, proposed for Public Health and Sanitary Engineers, involved the credit hours and subject matter to be taught in Sanitary Chemistry. After some debate, it was voted that the time allowed be increased from two to four semester hours without designation with respect to lecture and laboratory hours. Further it was voted that the term Sanitary Chemistry be changed to Chemistry.

The approved courses in Biology and Chemistry for Public Health and Sanitary Engineers are as follows:

Public Health and Sanitary Engineering

	<u>Hours/Week</u>		<u>Semester Hrs.</u>
	<u>Lecture</u>	<u>Laboratory</u>	
<u>Chemistry</u>			
Sanitary Analysis <sup>1</sup>	2	4	4
Chemistry <sup>2</sup>			4
Organic			
Physical			
Biochemistry			

Biology

Introductory			
Microbiology	2	4	4
Bacteria			
Algae			
Protozoa			
Higher forms			

- 1) Not required of those having had one or more semesters of quantitative analysis in an accredited institution. Recommend audit of lectures, however.
- 2) Not required of those having had one or more semesters of organic and one or more semesters of physical chemistry at accredited institution. Recommend audit of lectures pertaining to physical chemistry and biochemistry.

The program of chemistry courses for Air Resources Engineering was approved without modification.

Clair N. Sawyer - Chairman  
 Marvin L. Granstrom - Vice Chairman  
 Perry L. McCarty - Secretary

## ACTIONS OF THE CONFERENCE

### Resolution on Conference Reports

A resolution was unanimously passed by the conferees recommending the acceptance of the reports of the individual panels, outside of their specific general recommendations, and the adoption of these reports in substance.

### Resolution on Accreditation

The following resolutions were approved unanimously by the conferees:

1. A. S. E. I. B. should endorse the accreditation by E. C. P. D. of graduate programs in sanitary engineering, including other engineering programs in sanitary engineering related to environmental health, beginning with Master's programs.
2. To be accredited in sanitary engineering, including other engineering programs related to environmental health at the graduate level, shall not have to offer instruction in more than one of the fields considered by the conference.
3. A resolution favoring these positions should be transmitted to E. C. P. D.
4. The resolutions and recommendations of this conference should be submitted to E. C. P. D. as guidelines or general criteria for the accreditation of suitable programs.

### Resolution on Terminology of the Sanitary Engineering Profession

Whereas: Throughout the three days of the Study Conference on Graduate Curricula for Sanitary Engineers the terms "sanitary engineer," "industrial hygiene engineer," "public health engineer" and "environmental health engineer" have been variously used to designate the engineer operating in the field of practice subject to the attention of the conference; and

Whereas: Such usage has been recognized as presenting difficulties in communication of ideas, in understanding of objectives, and in arriving at a full mutual acceptance of points of view of each of the several areas of engineering application represented; and

Whereas: Agreement on a term of common usage acceptable to all areas of engineering application party to this conference would be beneficial not only to fulfilling this conference's objectives but in promotion of the spirit of the profession and mutual esteem of the members thereof. Now, therefore, Be it Resolved: That the Study Conference on Graduate Curricula for Sanitary Engineers refer this issue to A. S. E. I. B. with a recommendation that it again be studied with appropriate representatives of the several areas of engineering application party to this field of practice; and Be it Further Resolved: That every possible effort be made to reconcile differences in the use and understanding of terminology designating the field so that a mutually acceptable engineering title of common usage be established.

### Resolution on Collaboration Among Schools

The conferees resolved to request the A. S. E. I. B. to refer to its Committee on Education to study the question of the desirability of collaboration among schools having programs in fields of engineering related to environmental health.

### Resolution on Length of Study for M. S. Degree

It was resolved that the time length of graduate instruction or continuation study for the first degree in sanitary engineering and environmental health be one calendar year rather than academic year.

### Resolution on Thesis Requirement for M. S. Degree

It was resolved that each institution shall be free to require the preparation of a thesis for the first degree in sanitary engineering and environmental health.

### Resolution on Common Core Courses

It was resolved that for the graduate programs in Water Resources Engineering, Air Resources Engineering and Environmental Health, the following courses would constitute a common core for each program: Chemistry, Microbiology, Radiological Hygiene, Statistics and Epidemiology.

### Motions of Appreciation and Gratitude

- To The National Science Foundation -  
For their generous contribution of funds to pay for travel of some of the conferees and for co-sponsoring the conference.
- To Harvard University and the Massachusetts Institute of Technology -  
For co-sponsoring the conference and providing the services, personnel and facilities which contributed to the success of the conference.
- To Thomas R. Camp -  
For his services as conference chairman.
- To Messrs. McGauhey, Silverman, Bosch, Sawyer and McKee  
For their preparation of working papers and services as committee chairmen.
- To Gilbert H. Dunstan -  
For his preparation of the Sanitary Engineering Education Directory.
- To the scientists who are supporting the program in teaching, research, and practice in the field of sanitary engineering.
- To Messrs. Symons, Kugelman, Gemmell and Weber for their invaluable assistance in the work of the Arrangements Committee.



## APPENDIX I.

### WATER RESOURCES ENGINEERING ASPECTS OF THE GRADUATE SANITARY ENGINEERING PROGRAM

By

P. H. McGauhey, Director  
Sanitary Engineering Research Laboratory  
University of California  
Berkeley

#### Introduction

Presumptuous indeed is the one who sets out unilaterally to define those areas of Water Resources Engineering which should properly fall within the purview of the sanitary engineer of the future; or to spell out in detail an appropriate qualifying program of graduate education. In accepting the invitation of Dr. Gordon Fair and his Program Committee to serve as chairman of a group concerned with this important aspect of our profession, I am, therefore, agreeing to be presumptuous in the extreme. For this I offer no apologies. If my ill-digested suggestions should provoke others to constructive and conclusive thinking in the matter, my mission will be accomplished.

The charge imposed by the Program Committee is that this shall be a "working paper that will provide a framework for the recommendations" of the committee on Water Resources Engineering, of which I am to serve as Chairman. Whether the recommendations will ultimately fit neatly within the framework, like the meat inside a lobster claw, or adhere to the outside of the skeleton, like the flesh of a dead duck, only time will tell. The charge, at least, is clear. It further requires that the paper look to the future rather than to the present and include "(1) A list of suggested courses and credit hours; (2) a detailed description of course content; (3) a listing of prerequisites for the specific courses and for graduate work in general."

To carry out the Program Committee's charge as best I may I have elected first to review some concepts of both sanitary and Water Resources engineering; then to consider "water resources", "water resources engineering", and "sanitary engineering" as a series of increasingly circumscribed fields as far as water resources are concerned; and finally, to isolate the area of primary concern to the sanitary engineer, adding to it certain other important aspects which are indigenous to sanitary engineering alone. Along the way I shall attempt to develop prerequisites for graduate work in general; and to suggest the nature and scope of courses appropriate to the graduate sanitary engineering program in particular.

#### Some Historical Considerations

The concern of the sanitary engineer to control the physical environment of man is historically deeply involved with the control and management of water. In fact, the provision of engineering works designed to deliver potable water to the human community and to usher it out of town when it has lost the respect of decent citizens was the very foundation of sanitary engineering. From such beginnings the interest of the profession went on with an ever broadening understanding and competence, to include the entire problem of protecting and altering the quality of water in the interest of public health,



aesthetics and human convenience. Why then, we may ask, in view of such a record, does it now seem necessary for us to consider what kind of a graduate program is needed to prepare the sanitary engineer for a task which he already seems to be doing well? Are his manifest interests and accomplishments not the result of appropriate educational programs in competent universities and colleges?

The answers are rooted in a variety of considerations, some of which require a more detailed examination of past and present history.

### A Matter of Concept

The first limitation of the sanitary engineer which justifies our deliberations concerning a graduate program for the future, lies in the somewhat narrow concept of water resources engineering he has inherited from his educational experience and from a lack of integrated thinking by the greater engineering profession of which he is a part. Again historical factors are involved. Examining them in some detail we see that man's innate desire to crowd together with his fellows in concentrations exceeding the biological limit of the soil early motivated a search for safe water and inspired the engineering works which brought it to the community. The spectacular achievements against water-borne disease occasioned by water supply engineering were alone sufficient to establish it as a respectable engineering field. In support of it, universities offered courses in Water Supply Engineering as an extension of basic hydraulics, newly sprung from the older "natural philosophy".

An equal concern for the fate of water after its use and abuse by man had to await further development. When this came about, the water supply engineer showed but little interest, leaving to the Street Department, and later to the Sewer Department the task of dealing with second-hand water.

As population concentrations increased and the mere conducting of sewage beyond the city limits could no longer pass for acceptable disposal, a new variety of engineer developed to deal with the problem. To prepare him, a course in sewerage engineering was added to civil engineering curricula. This new field was distinct from water supply engineering and the status of its practitioners was at best one grade below that of the "pure" water boys. And so by historic accident a community's problems of water use were relegated to two specialty areas.

Modern sanitary engineering had its beginnings in the concept that water supply and sewerage constitute a single field of engineering endeavor. But neither wide acceptance of this concept, nor the enlargement of the field to encompass many other aspects of environmental control, has yet erased the compartmentalization of the sanitary engineering mind or persuaded universities to integrate their courses dealing with water use. The result is that many university courses go on treating the engineering, biochemical, and design phases of "sewerage" as though they were quite unrelated to the same phases of water supply. At best we are only just beginning to grasp the concept that collection, transportation, treatment, and distribution of water followed by its re-collection, re-transportation, and re-treatment, and release after it has been given a burden of wastes, constitute but a single aspect of water use by a community. What we must now conceive is that in all of those phases we are dealing with water as a resource. Such is the first factor in our planning for the future.

The second limitation which justifies our deliberations is the fuzzy picture of Water Resources Engineering which pervades the entire engineering profession. This over-all lack of clarity is evidenced by the current magic of the terms "Water Resources" and by the groping of a wide spectrum of educational institutions and departments within these institutions, for a way to harness that magic to their own, often static, programs.

This new interest has been generated by a multiplicity of factors. Exploding populations, the earth's relatively fixed supply of water, disregard of water supply as a guide to location or a deterrent to community growth, interest in irrigation in non-arid areas, increasing water pollution, possibility of profit through public subsidy, over-pumping of ground waters, and recreational needs are among the numerous forces acting to excite various interests in Water Resources problems. Nowhere is this interest greater than in California where a proposal that the State itself embark on a program of water resources development unprecedented in all history has generated an interest which far transcends the State's boundaries.

While all these factors add to the glamour or excitement of "Water Resources Engineering" they serve also to add to the confusion. At the root of this confusion is the fact that the term "water resources" ranks with "home" and "mother" as something all right-minded citizens favor. In different individuals therefore it evolves different images. To some it suggests "conservation", a sacred concept suggesting preservation of our natural waters as museum pieces withdrawn from human use. To others it means the beauty of a wilderness which ought to be rendered inaccessible to human beings. To one it may signify great reaches of trout streams unknown to all people other than himself; to another it is unlimited space for boating, camping, and throwing beer cans. To some it represents a source of saleable power or a place to develop commercial resort facilities; to others it means a free sewer for their wastes. In general it refers to "unused" or "virgin" waters, but the sanitary engineer must in the future come to look upon water in all its conditions of quality from virgin snow to sewage to sea water as a resource worthy of engineering concern.

A third limitation, of importance to those interested in the graduate program of future sanitary engineers is the minor role engineers have played in public planning. As an example we might consider the expert designer of hydraulic structures whose contribution is often that of providing technical design of a dam only after others, generally not engineers, have made the decision that any water resource development at all shall be undertaken, that it shall involve a dam, and, perhaps, that the dam shall be of such a height or at this or that location. In such a circumstance the sanitary engineer concerned with but one of the aspects of a development program might conceivably be even less effective in public decision making than the structural designer.

The same lack of clarity evident in the engineering profession is to be found in the universities. Fired by the current glamour of "water resources development" and "water resources engineering", (often considered by engineers to be synonymous) various institutions have been endeavoring to set up programs tied to such fields. In some, the Department of Economics views the matter of water resources as one for its principal concern. At the same time the departments of Political Science and Public Administration view it as coming within their purview. The engineering school looks upon it as the province

of hydraulic engineers and so multiplies its courses dealing with technical unknowns, and intensifies its research to find answers, which may become scientifically significant should somebody decide to undertake a program involving the building of hydraulic structures. Meanwhile in another section of the university the Department of Agricultural Economics is surprised at all the excitement in an area it thought to have pre-empted years ago.

Occasionally an institution finds itself lacking in strong departments which deem themselves individually and separately capable of inheriting the field of Water Resources. Yet it shares the current urge to find some device by which to launch a graduate program in the field. Water Resources seems made to order. The university therefore enters into a discipline-wide treaty between several departments, gets out a brochure, and is ready for the wave of students eager to be about water resources engineering as a career. Disappointment often comes in that students from the Middle East are about the only ones to show an interest. Meanwhile the local water resources development agencies continue to hire B.S. graduates in civil or hydraulic engineering, specialized, if at all, in old-line techniques. What is more important to this committee, sanitary engineers show no interest at all. They seem not to recognize Water Resources Engineering as one of their fields, being generally content to deal with water in a quite narrow sense--as a material to be shoved around the environment as necessary to meet the "standards" set by Public Health or Water Pollution Control agencies.

#### A Concept for a Program

Where a program to be entitled "Water Resources Engineering" is to be established it is evident that it must transcend any single engineering specialty. By the very nature of water resources problems they include vast considerations of economics, law, public policy, and government planning, as well as engineering and science. Where we may look for such an all-inclusive program is not yet determined. It may well be that those institutions which can offer inter-disciplinary programs will come to predominate the field. Obviously the sanitary engineer cannot pre-empt the field while at the same time developing proficiency in the several other areas of his interest. Nevertheless much of his concern is within the field of water resources engineering. The suggested graduate programs set forth herein is therefore based upon certain concepts:

1. That the sanitary engineer's concern with water can and should be recast within a broader framework, and
2. That his program should provide for at least a minor directly in Water Resources Engineering at the Ph.D. level.

It is within the first of these concepts that I suggest that water be considered as a resource regardless of whether it is to be found in the headwaters of streams, in the ground, in the sewers, or in the ocean. Furthermore engineering considerations at any time should include those of quality, both present and future, in relation to both water needs and water uses.

## General Prerequisites for Graduate Work

Prerequisites for graduate work in sanitary engineering in general should continue to include graduation from an accredited and recognized undergraduate curriculum preferably civil or chemical engineering; or in some other branch of engineering or in engineering science. Graduation in chemistry, biology, biochemistry, or soil science, should also be qualifying subject to the possession or the acquiring of a knowledge of the basic mathematics, applied mechanics, hydraulics, and water resources engineering required of engineers seeking to enter the field. This is not simply to say that in the future the basis for graduate work in sanitary engineering should remain exactly as it is today, but rather that it should continue to be founded in engineering instead of losing its way by sharing in the current failure of engineering to recognize its relationship to science. The undergraduate program, however, should undergo drastic revision with three major objectives, which do not include that of becoming indistinguishable from science.

1. Challenging the developing mind to its full capacity.
2. Streamlining and coordinating subject matter so that a single basic principle need not be repeated in course after course, where clad in varied trappings it appears each time as something new and different to both student and instructor.
3. Divesting the so-called "humanistic" studies of courses which are pure drivel, as well as those which are in fact as highly specialized as are the increasingly "abhorrent" courses in engineering.

Since I state these objectives both strongly and bluntly, some explanation or elaboration may be in order.

The first objective involves non-uniform production goals for students of different capacities. Just how this is to be achieved is not easily stated. I have seen it demonstrated in the laboratories of technical institutes where, for example each student working in an electronics laboratory completes as great a range of experiments as time will permit, whether it be one or five. The development of the good mind is thus not dulled by boredom while the stupid grope in twilight, nor are the stupid relieved of the duty of groping at all while the bright mind races on to complete a brief experiment for an entire group.

Concerning the second objective, it is well shown that the horizons of learning are now so far flung that he who is to push them back within his allotted threescores and ten has no time to linger at the post, be he delayed by inadequate challenge or by repetition of fundamental principles with which he is already familiar.

A few rough examples of repetition of principles may serve to illustrate my point. The child, for instance, who learns by the age of 6 how to balance a stick on his forefinger, or to enjoy a teeter-totter in the playground, struggles at 20 in his statistics class to understand how the median of a set of data may be found by the arbitrary origin method. Then having grasped the procedure involved he proceeds with equal difficulty to learn how to find where the shear is zero in a simple beam carrying concentrated loads. Or having learned the

theory of the pendulum, he fails to recognize it in trial and error solution of mathematical problems, or to see the relationship between the Hardy Cross method of rigid frame analysis, and the same author's method of evaluating the flow of water in a distribution system. While refinement of principle and understanding of application is a part of advancing learning, failure to recognize the principle at all must in the future be deplored.

If we are to survive as a civilization, some short cut must be found from the constant level of ignorance, at which we are all born, to the ever widening horizon of human knowledge. Such a path can best be achieved by weeding out the wasteful overlapping of undergraduate courses. Our earliest efforts to bridge this ever-lengthening span from fixed center to receding horizon took the form of increased specialization at the undergraduate level. Soon we were confronted with two serious developments (1) the loss of ability of one specialist to communicate with another for lack of an adequate common pool of learning or human experience, and (2) the theorem (sic) that the engineer is a uniquely narrow specialist.

To overcome the first of these deficiencies our decision was to broaden the educational basis of our curricula, thus providing a pool of "humanities" common to a broad spectrum of educated men. The inescapable secondary, however, was a further delaying of the students progress from congenital ignorance to front line intellectual contribution, making more urgent than before the need for a streamlining of course material.

Now none of us are of a mind to abandon the broadened educational base as a qualifying requirement for graduate work. But too few have questioned the usefulness of what now passes for "humanistic" studies in our undergraduate curricula. So intent have we been in getting engineering students off their technical diet, that no one seems to have noticed the sawdust in its substitute. My thesis, therefore, is that a drastic revision of the non-technical portion of the undergraduate program should be pre-requisite to graduate work in general.

To be quite specific; the "humanities" have been variously and classically defined as "literature, philosophy, and the fine arts". For engineers, however, the term has been watered down to "humanistic" (i. e., tend toward the humanities) or "socio-humanistic" studies and interpreted as meaning essentially anything whatsoever that is non-technical, non-engineering, nonsensical, or useless. It may be strictly specialized as long as it is not one of the unholy engineering specialities. Or it may indeed be a respectful offering in the humanities. In the gamut of acceptable trivia are such courses as "Family Relations", or six semester hours of "Social Science", devoted to what able students describe as "one man's opinion of how the U. S. A. should be rebuilt". Courses in the general area known loosely as "Business Administration" are essentially countless. Economics comes in as a time-honored specialty. Here and there geology is likewise accepted as socio-humanistic if it be taught at a superficial level such that the engineer does not become involved in problems of the ability of the earth to support his structures. When mingled with courses in English, and other subjects which we might all agree are humanizing in their influence, we have the hodge-podge that makes graduate work in technical fields imperative without at the same time serving its intended purpose.

Now I am willing to concede that to some degree the failure results from segregating engineering sections and assigning them to graduate assistants lest

the learned professor "waste his fragrance on the desert air". Nevertheless, the inherent weakness in the program itself is over-riding. My proposal, therefore, is that the interpretation of what constitutes the humanities be brought more in line with the classic concept of the term. The goals of this area of undergraduate effort should be upgraded and the range of mediocre offerings drastically curtailed. Instead of being exposed to the context of a variety of offerings in the realm of commerce the student should through literature be introduced to the world of ideas, learning to read, to observe, and to understanding the meaning and use of words. Through philosophy he might come to appreciate the lessons of history, and to understand the systems by which man has cloaked himself in dignity, arranged to tolerate others, justified his actions and relationships, and risen above his own squalid nature. Some knowledge of the fine arts might well lead him to enrich his life through creative activity, liberating him perhaps from the status of the mass spectator at the mercy of the stupid.

With an interest in ideas, and with the ability to read, a man so educated might confidently be expected to learn for himself the principles of real estate selling, the elements of commercial relationships, and the rudiments of economics. With so sharp a sickle he could hardly fail quickly to deal with the underbrush so often seemingly mistaken for the cutting tool itself.

I have taken overlong to say that preparation for graduate work in general should look to a co-ordinating and streamlining of technical principles, and to a drastic revision and upgrading of the non-technical requirements.

#### Water Resources Engineering at the Undergraduate Level

While a detailed consideration of the ways in which the technical context of an undergraduate engineering program may be more efficiently presented is beyond the scope of this paper, some attention should be directed to the water resources phases of such a program. It seems evident that the civil engineering or other undergraduate student anticipating the study of sanitary engineering at the graduate level should continue to take a basic course in fluid mechanics concerned with the statics and dynamics of incompressible and compressible fluids. This should be followed by a sound course in hydraulics laboratory designed to bridge the considerable gap between the theory of fluids and its engineering applications. The third course in this water resources engineering series should derive from and replace the traditional courses in water supply and sewerage engineering. While retaining much of the technical context of the two it should present it in a broader conceptual framework and comprise a single unified course on a 3-hour per week basis throughout the student's senior year. To bring it in line with other core courses, and to differentiate it from a subsequent graduate course in the same general field, it might be titled "Principles of Sanitary Engineering (Water and Wastes)", or "Principles of Water Resources Engineering". Under this or a more appropriate name it should deal with the engineering and management of water in the interests of the citizens and the industries of a modern municipality. Through it the student should come to consider water in all its conditions of quality as a resource to be controlled and managed for a variety of beneficial uses, although he might study it in detail with reference to but one major use, i. e., urban use. After setting the role of water in man's activities in its proper historical and economic perspective, the course would develop, in a logical sequence, the basis for water needs in

domestic and industrial activity through population and water use forecasting; consider sources of water from the standpoint of surface and ground water hydrology; explore the subject of engineering for water development; examine the matter of water quality changes through the hydrological cycle and through all stages of municipal use, in both its scientific and engineering aspects; familiarize the student with engineering for the collection, transportation, and distribution of a water supply, and for its re-collection, re-transportation, and reclamation for further beneficial use; and finally, consider the legal and financial arrangements for water developments.

Most undergraduate curricula presently permit some elective courses which the student may devote to his field of special interest. In this category three 3-unit courses in the broad field of water resources engineering might well be taken by the prospective sanitary engineer, assuming for the sake of this discussion that our current rush to "science" does not obliterate the residue of engineering left by our previous embracing of the "humanities". These are Ground and Surface Water Hydrology, Sanitary Chemistry, and Micro-biology of Water. Such courses would probably not be markedly different in the future than at present, however, a suggestion as to their context is presented in a subsequent section.

#### Water Resources Engineering at the Graduate Level

At the graduate level it is to be expected that an appreciable divergence will appear in the programs of students seeking to major in Water Resources Engineering, Hydraulic Engineering, and Sanitary Engineering. In order to isolate the area of special interest to sanitary engineers, therefore, three diagrams have been prepared. In Diagram 1 an attempt is made to list the major areas of water resources engineering, together with the scientific and engineering courses commonly provided to satisfy the interest of students in each of these areas. Both undergraduate and graduate courses are included, even though the aggregate represents far more numerous specialized subjects than could be included in the program of any individual student.

Diagram 2 represents that portion of the Water Resources Engineering field presently of immediate concern to the sanitary engineer. While no claim is made that the diagram is exhaustive in its treatment of the subject it serves to indicate that the sanitary engineer's interest in water is confined to a limited range of "beneficial use of water" and "water quality control". Concern with the sources of water and with broad planning for water resources development is incidental to the use and quality concepts.

Diagram 3 indicates that in the future sanitary engineering should be concerned with water quality control in all its aspects, with a greater range of beneficial uses, with the sources of water, and to a very great degree with the over-all planning and management of water.

Further analysis of Diagram 1 could be made to show that Water Resources Engineering as such is essentially non-existent at present, and that Hydraulic Engineering is principally concerned with beneficial use of water. In the future a broad coverage of the planning and management of water could be combined with appropriate aspects of the other three major areas to form the engineering backbone of a doctorate program in Water Resources Engineering.

DIAGRAM 1

SCOPE OF WATER RESOURCES ENGINEERING

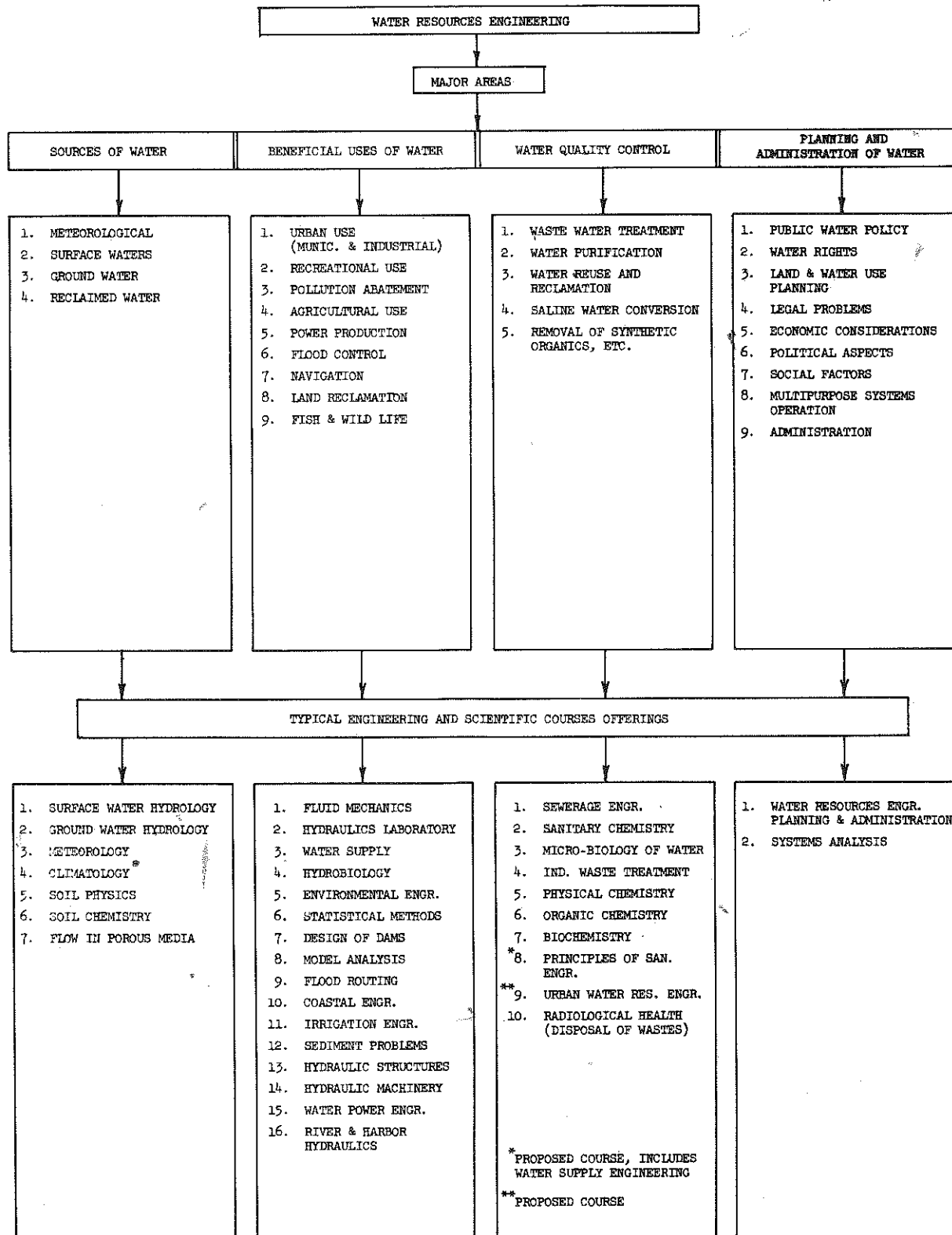




DIAGRAM 2

NORMAL CONTEXT OF WATER RESOURCES ENGINEERING IN SANITARY ENGINEERING

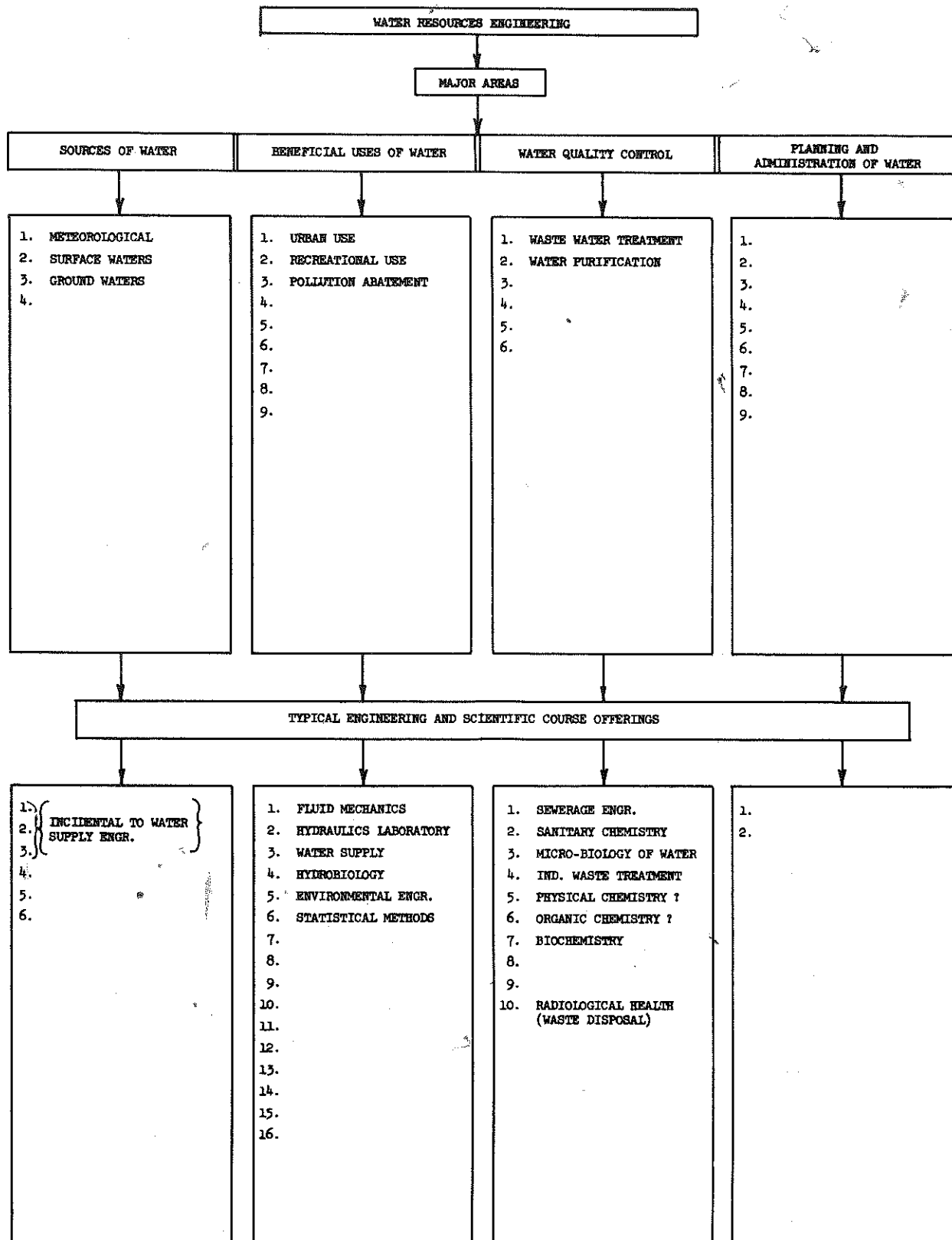
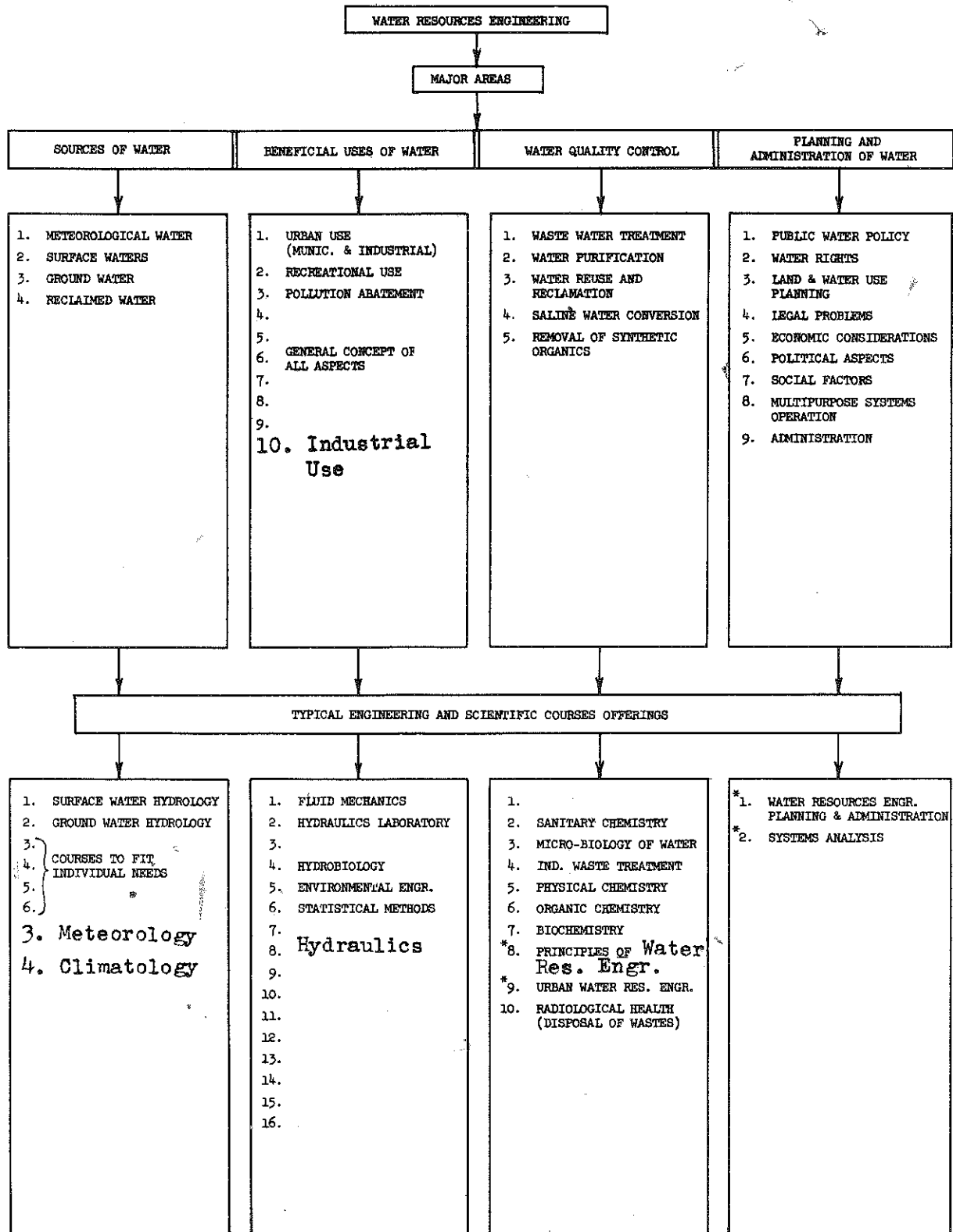


DIAGRAM 3

FUTURE CONTEXT OF WATER RESOURCES ENGINEERING IN SANITARY ENGINEERING



\* NEW COURSE

Diagram 3 might be utilized also to lay out a Ph. D. program in sanitary engineering which emphasizes the water resources aspect of the profession. A program having the maximum of impact could result from developing graduate minors in water resources engineering and in chemistry in parallel with a sanitary engineering major based on environmental engineering, radiological waste problems, air sanitation, industrial wastes, and statistics. Presupposing some undergraduate elective courses will continue to be offered, the program might be somewhat as follows in Table 1.

Table 1

<u>Undergraduate Courses</u>			
1. <u>Required</u>		2. <u>Elective</u>	
Fluid Mechanics	3 units	Ground and Surface Water Hydrology	3 units
Hydraulics Lab.	2 units	Sanitary Chemistry and Biochemistry	3 units
Principles of Sanitary Engineering (Water and Wastes)	6 units	Sanitary Microbiology	3 units
<u>Graduate Courses</u>			
<u>Sanitary Engineering Major</u>			
Environmental Engineering	3 units		
Air Sanitation	3 units		
Radiological Health Problems	3 units		
Industrial Wastes	3 units		
<u>Water Resources Minor</u>		<u>Chemistry Minor</u>	
Urban Water Res. Engr.	4 units	Adv. Sanitary Chemistry (organic)	3 units
Water Res. Planning and Management	4 units	Biochemistry	3 units
Systems analysis	3 units	Physical Chemistry	3 units
Hydrobiology	3 units	Soil Science	3 units

For a student entering the graduate program without the undergraduate electives, the foregoing outline would be considerably altered. Also in cases where the needs of an individual student could best be served by pursuing minor work in public health, biology, or some other specialty outside the water resources engineering field, the water resources aspect of the doctorate program would become minimal. The hard core of the graduate sanitary engineering program might then become:

Sanitary Engineering

Urban Water Resources Engineering	6 units
Environmental Engineering	3 units
Air Sanitation	3 units
Radiological Health	3 units
Industrial Wastes Problems	3 units

The necessary chemistry and biology, statistics, and other subject matter would then be built around this core. Environmental engineering, however, could become a part of a public health minor. Statistics might become a part of a revised course in Systems Analysis and included in an appropriate minor field.

When the proposed maximum program suggested in the table is compared with the areas of sanitary engineering interest and the supporting courses shown in Diagram 3, it is obvious that some compromise must be made between eliminating subject matter altogether and presenting a shallow survey course covering a variety of subjects. It is therefore necessary to consider the context of the courses proposed in Table 1. The nature of many of these is suggested by the course titles. However, the scope of several of them merits greater consideration than I have given in the preparation of this paper, if a wide range of important concepts are to be given substance without multiplying courses and hence unduly prolonging the period of graduate education.

The nature of the single undergraduate course (Principles of Sanitary Engineering) designed to replace traditional courses in water supply and sewerage engineering has already been suggested. Four revised graduate courses are likewise worthy of consideration.

1. Environmental Engineering. Three units. This course, designed to supplement the undergraduate course in Principles of Sanitary Engineering, which deals primarily with urban water supply and waste water problems, would be open to advanced undergraduates or graduate students. It is of the nature of public health engineering and treats with a wide range of environmental control problems, the solution of which involves engineering works. Disposal and reclamation of solid municipal wastes and animal manures; the control of insects, rodents, and other vectors of disease; the problems of housing; the many facets of urban and rural environmental control; and the principles of epidemiology are typical of the subjects treated.
2. Urban Water Resources Engineering. Four to six units. This represents the major core course in the graduate sanitary engineering program dealing with the theoretical and technical aspects of water quality control. Prerequisite is the undergraduate course in Principles of Water Resources Engineering, and courses in the chemistry and biology of water and sewage should precede or be taken concurrently. It is designed to replace traditional graduate

courses in sanitary engineering principles, and in theory and design of water and sewage works. It is intended to familiarize the student with the latest theories underlying all unit processes used in water and waste treatment, as well as with their application to process design and to plant operation and management. Typical processes are aeration, flocculation, sedimentation, flotation, coagulation, filtration, aerobic and anaerobic biodegradation, fermentation, ion exchange, sterilization, etc. The inter-relationships between water quality and various consumptive and non-consumptive uses are discussed, as are the engineering, scientific, and regulatory aspects of water pollution control. Detailed concern with the beneficial use of water for municipal and industrial purposes and in recreation and pollution control is related in the perspective of multiple beneficial uses of water by mankind.

3. Water Resources Engineering Planning and Management. Four to six units. This course, designed primarily for the engineer, deals broadly yet specifically with the origins and basic concepts of water rights and water law; with the social, economic, and political considerations underlying public water policy; with the nature and scope of agencies involved in water use and control at the local, state and national levels; with the underlying philosophy and role of regional developments such as TVA, and of river basin commissions and compacts, in the economic development of America; and with the history, philosophy, and role of subsidized irrigation water, multi-purpose projects, and power and other national policies on water resources development and associated economic activity.
4. Systems Analysis. Three units. This course deals with both the analysis and synthesis of complex systems, with special reference to the operation, management, and administration of river basin and other water resources developments. The application of digital computers, electric analogs, and statistical methods to the optimization of benefits, the routing of floods, and a variety of other technical and economic factors is studied in detail.

The more traditional courses suggested in Table 1 might be less drastically altered but should be expected to be changed in emphasis to keep pace with developing technology and expanding knowledge in the field. Briefly, the coverage which might be anticipated is somewhat as follows.

1. Ground and Surface Water Hydrology. Three units. In this course would be presented the fundamentals of climatology and meteorology, as well as certain aspects of geophysics. Detailed concern, however, is for that portion of the water which becomes available to man as surface or ground waters. Rainfall-runoff characteristics, nature and control of floods, river hydraulics, evaporation control, management of ponded water, seepage, percolation, and natural phenomena are studied from a theoretical and engineering viewpoint. Natural and artificial ground water recharge, sea water intrusion, and well development are likewise given careful study.

2. Soil Science. Three units. The nature of porous media, and the physical and chemical phenomena associated with the flow of water and other liquids through such media, is the principal concern of this course. It is closely related to ground water hydrology in many aspects but deals to a greater degree with the nature of the medium and the way in which characteristics of colloids and other earth particles bring about the phenomena familiar to the ground water hydrologist.
3. Hydrobiology. Three units. This course is designed to give the engineer a fundamental understanding of the ecology of waters in a natural biological balance and of the effects of wastes on receiving waters. Basic considerations of water pollution control in the interest of human and aquatic societies are developed. Bioassays of domestic and industrial wastes are conducted, and studies made of the methods of evaluating benthic and planktonic life and of interpreting the responses of such life to stream pollutants.
4. Industrial Wastes. Three units. The nature of numerous fundamental industrial processes is presented, together with the specific environmental problems created by the waste products. Alleviation of these problems through "in plant" process changes as well as by waste treatment is explored. The theory as well as basic scientific and engineering nature of the unit processes suited to industrial waste treatment are presented. Metals processing, food processing, fermentation, pulp and paper, textiles, synthetic fiber, chemicals, pharmaceutical, and petroleum are among the specific waste producing industries studied in relation to environmental control. Waste problems are considered from the standpoint of the public, the industry itself, and regulatory agencies, as well as in relation to their effect on water as a resource for beneficial use.
5. Radiological Health. Three units. While the scope of this course transcends its concern with water, it is nevertheless deeply concerned with the effect of radiation on water resources and biologic life. Radioactive dust in meteorological waters, fallout in water supplies, isotopes in sewage resulting from industrial and medical use of such materials, and the disposal of wastes from the atomic industry all present problems of importance to the engineer concerned with the environment. The nature, detection, and effects of radioactivity in these many circumstances are presented, as are the applications of radioisotopes to the tracing of ground water, the movement of sediments, the behavior of settling tanks, the functioning of biological systems, and other systems of immediate concern to the sanitary engineer.

For the purpose of this preliminary paper it is assumed that the context of courses in Air Sanitation and in Sanitary Chemistry and Micro-biology are well understood or are to be presented by other committees of the Conference. Refinements of the water resources engineering program may confidently be expected to result from the conference. For this reason I have not worried too greatly over the shortcomings of my program, nor exercised particular restraint in the presentation. It is my hope that in finding me "all wet" the reader will be concerned to produce supporting evidence from which the Conference may distill the intelligent graduate program which the sanitary engineering profession seeks to define.

## APPENDIX II

### AIR RESOURCES ENGINEERING

by

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### INTRODUCTION

I would like to preface my discussion with the comment that this title was selected by the Program Committee. Consequently, it is necessary to define what, in my opinion, is included in the concept of air resources engineering. The atmosphere in which we live, in terms of man's survival, is our most vital resource. Those of us in the fields of industrial hygiene and air pollution control will always claim this as a technical priority. Man can survive for hours, perhaps even days, without water and food yet he can only exist but a few minutes in the absence of air or in the presence of a seriously contaminated atmosphere. In spite of this fact there are far fewer environmental health engineers working in this area than in the water and sewage fields.

The situation is rapidly changing as you well know since the atmosphere conveys all kinds of gaseous liquid and solid pollutants to man including radioactive gases and particulates from weapons testing and many other sources. There has been a growing awareness in recent years of the limited number of people adequately trained to handle these problems on a thorough and rational basis.

The 1957 Conference report\* does not define Air Resources Engineering, therefore I will attempt to indicate in this discussion what should be included. Because clean air is so vitally necessary to man's comfort, welfare, and livelihood, it is only natural that we define this commodity in as definite physical terms as possible. The air we breathe in terms of the tolerance to changes can vary significantly in barometric pressure and even in percentage of its essential component, oxygen, without seriously influencing maintenance of life or comfort. Thus man can adapt readily to

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\* Report of the Conference on Education, Training and Utilization of Sanitary Engineers. Conference Report-1957, National Academy of Sciences, National Research Council, Washington, D.C.

altitudes up to 10,000 feet and also to variations in oxygen composition from 21 per cent to 17 per cent without seriously affecting the maintenance of biological equilibrium. On the other hand, except for pure asphyxiants such as carbon dioxide, nitrogen, and similar gases, he will have difficulty adapting to more than a few hundreds of a per cent of most other toxic gases. Similarly he cannot adapt well even to inert dust concentrations greatly in excess of several milligrams per cubic meter of air.

Air Resources Engineering may therefore be defined as the field in which the environmental health engineer works to provide for man in his total environment, a continuous supply of air free from significant amounts of toxic or irritating agents. Since air is used for industrial processes in many ways, as well as by man and animals, manifold sources of contamination are created. This contamination may exist within the factory, mine, or mill in amounts higher than in the general atmosphere surrounding the plant yet it is essential that concentrations be controlled in each instance.

The kinds of engineers and specialists in the environmental health control field who are engaged in practice at the present time are included under the following categories:

- a. Industrial hygiene or occupational health engineer.
- b. Air pollution control engineer.
- c. Radiological hygiene engineer.

These three categories all have areas of common educational training and operational interest. In many instances it is difficult to make a clear-cut separation of spheres of interest. This is particularly true in the first two categories since the existing differences are essentially those of concentration of pollutants and their effects. In the third case it is essential that the radiological health engineer be informed on the effect of radioactive particulates regardless of their source. Some waste treatment operations may create airborne particulates and gases from the concentration or reduction of solid or liquid wastes. Storage tanks or handling of liquid, solid or gaseous wastes may also produce an external dose problem from the source radiation. It is because of these complexities that clear-cut distinctions in the environmental health field are difficult and perhaps foolhardy to make.

Our teaching at Harvard in these three areas for the last quarter of a century has not necessarily utilized sanitary or civil engineering as a basic background. In fact, the majority of our students have not been sanitary or civil engineers but rather from chemical or mechanical backgrounds.



SUGGESTED COURSES OF STUDY  
(With Assigned Credit Hours)

In establishing a list of suggested courses it is desirable, in my opinion, to indicate courses which are common to the whole field of air resources engineering and then those which are specific for industrial hygiene, air pollution control, and for radiological health. The distribution of credit hours or units is based on one academic year (9 months) Master's degree program or its equivalent for each of the three indicated fields.

Since credit unit systems vary in institutions the course credit values will be presented on a basis of semester hours with the latter defined as one class hour per week per semester or half year. Laboratory and seminar sessions are usually given a weighting of one-half this value. On this basis it is assumed that a Master's degree program will require 30 semester hours with a possibility of variations of  $\pm 10$  per cent or more depending upon institutional requirements and limitations.

For a basic program in the field of air resources engineering there are certain courses which are essential to all of the three categories mentioned above. These are as shown in Table 1.

TABLE 1  
Courses for all Candidates in Air Resources Engineering

No.		Semester Hours
1	Biostatistics or Engineering Statistics (related to Environmental problems)(Includes computation laboratory exercises)	4
2	Epidemiology	2
3	Human Physiology	2
4	Air Analysis	3
5	Toxicology (including radiobiology and effect of air contaminants)	3
6	Radiological Hygiene	3
Total required for all candidates		17

Courses for the three categories which are recommended for those concentrating in separate areas are given in Table 2, in two groups, required and optional. Available to all groups but not listed are courses in reading or research up to 10 per cent of the program.

In addition to the courses listed in Table 2, general courses in public health administration or practice, history of public health, advanced statistics and advanced mathematics should be available for optional registration.

It will be apparent from the listing in Table 2 that there are many courses required and optional courses which apply to all three categories and may be taken by candidates in all three groups. Obviously, any student desiring to receive enough education to be competent in more than one of the groups will require an additional year.

#### A. Courses for All Categories

##### 1. Biostatistics or Engineering Statistics

A basic course in techniques and the use of statistical methods. It introduces the student to demographic concepts, the structure of the population in relation to environmental problems and the use of the life table. It includes discussions on the nature and composition of rates and their use from administrative and epidemiological points of view. Such a course would provide an introduction to the theory of measurements and distributions, testing of significance of differences and the interaction of variables. Basic concepts of probability and association of sampling techniques and construction of controlled experiments. Random sampling numbers, non-parametric methods and statistical estimation, likelihood and confidence limits would be covered including analysis of variance of simple and multiple correlation. Time should be allocated to consideration of environmental problems such as accident frequency rates and radiation injury studies. Provision of an assigned computation laboratory and extensive illustrative problem considerations are necessary adjuncts to such a course.

##### 2. Epidemiology

This course includes lectures on the principles, purposes, and methods of epidemiology. Illustrations are by reference to classical and current epidemiological studies. A small number of diseases are to be covered in detail to show the methods by which our present level of knowledge has been reached and to illustrate principles. The course includes a brief discussion of the influence of genetics and environment on the etiology of disease and examples drawn from current epidemiological studies on occupational disease, air pollution and radiation exposures and their effects on the general public.

TABLE 2

Courses for Industrial Hygiene, Air Pollution Control, and Radiological Hygiene Engineers

I. Industrial Hygiene Engineering				II. Air Pollution Control Engineering				III. Radiological Hygiene Engineering			
<u>REQUIRED COURSES</u>				<u>REQUIRED COURSES</u>				<u>REQUIRED COURSES</u>			
<u>Course</u>		<u>Sem. Hours</u>		<u>Course</u>		<u>Sem. Hours</u>		<u>Course</u>		<u>Sem. Hours</u>	
Industrial Hygiene Engineering		3		Meteorology (micro)		2-3		Advanced Radiological Hygiene		3	
Aerosol Technology		3		Advanced Air Analysis		3		Elements of Atomic Physics		3	
Advanced Air Analysis		3		Environmental Physiology		2		Chemistry of Nuclear Materials		3	
Environmental Physiology		2		Aerosol Technology		3		Radiological Engineering		3	
				Industrial Hygiene Engineering		3					
<u>OPTIONAL COURSES</u>				<u>OPTIONAL COURSES</u>				<u>OPTIONAL COURSES</u>			
Advanced Radiological Hygiene		3		Advanced Radiological Hygiene		3		Spec. Environmental Problems		2	
Sanitary Chemistry		3		Special Environmental Problems		2		Advanced Air Analysis		3	
Special Environmental Problems		2		Elements of Atomic Physics		3		Environmental Physiology		2	
Sanitary Microbiology		3		Industrial Psychology		2		Quantum Mechanics		3	
Industrial Psychology		2		Unit Operations (Chem. Eng'g)		6		Nuclear Physics		3	
Industrial Chemistry		3		Sanitary Chemistry		3		Meteorology (micro)		2-3	
Unit Operations (Chem. Eng'g)		6		Sanitary Microbiology		3		Radiochemistry		3	
								Nuclear Engineering		3	

### 3. Human Physiology

Intended for students who lack background in physiology. Because of its importance in toxicology and radio-biology the time is divided equally between cellular physiology and organ and organ system physiology. Discussion of the function of the total organism is very necessary. Emphasis ordinarily will be placed upon the respiratory and circulatory systems because of their concern with transport of contaminants to the various organs of the body. Some laboratory work or demonstration is to be provided to acquaint the students with observation of living systems. If more extensive coverage is desired this course can be increased to 3 semester hours with more laboratory demonstrations provided.

### 4. Air Analysis

This course includes the determination and interpretation of adverse conditions found in work places of all types such as mines, mills, or factories. Methods covered include the determination of the physical properties of the air such as temperature, pressure, humidity, and air motion, sampling and determination of atmospheric impurities and normal constituents of the air such as gases, particulates, bacteria, and pollen.

### 5. Toxicology (Including Radio-biology and Effects of Air Contaminants)

Principles of toxicology are the primary subject in this course. It includes discussion of the acute and chronic effects of toxic agents on biological systems, criteria of damage, effects of the route of administration and the design of toxicological experiments as well as toxic responses in disease states. Radiation biology is to be discussed as a special case of toxicology wherein the specific properties of radiation with regard to biological systems are covered. The subject matter will include the physiological effects on cells and whole organisms, dose-response relationships, protective measures and determination of tolerance estimates for external and internal radiation hazards. A limited number of demonstrations and specific experiments can be included in relation to the course in advanced radiological hygiene on absorption and elimination of radionuclides.

### 6. Radiological Hygiene

The first course in this subject should present the essentials of atomic physics and radiation biology as an introduction to the evaluation of health hazards from ionizing radiation. This course includes a number of experiments on measurement of radio-activity such as counting methods, neutron flux measurement, dosimetry, calibration and decontamination.

B. Courses in Designated Categories in Industrial Hygiene, Air Pollution Control, and Radiological Hygiene Engineering

I. Industrial Hygiene Engineering

a. Required courses

(1) Industrial Hygiene Engineering. A series of lectures, demonstrations, and field trips showing the relation of working conditions to health with special reference to control of health hazards and of adverse conditions of temperature and humidity, the prevention of industrial disability and diseases and workmens compensation. The last half of the course should cover control procedures and methods including wet methods, general industrial ventilation, industrial exhaust system design, air and gas cleaning, and protective respiratory equipment.

(2) Aerosol Technology. A technical course which deals with the properties of aerosols and their behavior from a mathematical and physical standpoint. It includes generation of aerosols, optical characteristics, coagulation, deposition, filtration, diffusion, electrostatic properties and electron microscopy. A limited number of laboratory demonstrations and experiments should be included concerning measurements and behavior.

(3) Advanced Air Analysis. A secondary course following the basic course in air analysis in which further study and laboratory work is devoted to chemical and physical analysis of particulate matter of primary concern in occupational health studies such as silicosis. The measurement of particle size and other parameters, performance of filters, protective respiratory devices and other air cleaners is included.

(4) Environmental Physiology. The subject matter of this course includes physical fitness, exercise, and work under various environmental conditions, and the effects of the state of health and age upon physical performance and fatigue. Energy cost and efficiency are related to different kinds of industrial activities.

b. Optional courses

(1) Advanced Radiological Hygiene. This item is discussed under required courses (see III, a (I)).

(2) Sanitary Chemistry. Chemical principles applicable to sanitary engineering operations. Equilibria and reaction rates in aqueous media and the theoretical chemistry of coagulation, disinfection, adsorption, corrosion, sludge digestion and similar problems.

(3) Special Environmental Problems. An advanced lecture and seminar course covering such environmental problems as noise and noise measurement, aero-allergens, community air pollution and its control, microwave hazards, solid waste disposal by incineration, nuclear reactor safeguards, handling of rocket propellants and similar unique exposures.

(4) Sanitary Microbiology. Bacterial cytology and physiology, quantitative bacteriology, destruction of bacteria and other micro-organisms, immunity and antibiotics, application of bacteriology to air, water, foods, swimming pools, soils and sewage. Viruses.

(5) Industrial Psychology. A basic course concerned with the techniques of experimental psychology and anthropology as applied to problems of occupational health and safety. Matching of mental and physical abilities to job requirements and the design of equipment in relation to human capability and limitation is discussed. Effects of fatigue, environmental stresses, aging and psycho-social environment in the control of accidents is included.

(6) Industrial Chemistry. A basic course which deals with the chemistry of industrial processes for the production of mineral acids, alkalis, fertilizer, polymers, paper, detergents and miscellaneous industrial processes.

(7) Unit Operations of Chemical Engineering. A basic course which discusses in detail the unit processes such as industrial stoichiometry, crushing, grinding, distillation, absorption and extraction, fluid flow, heat transfer, and drying. Usually considered as a two semester course.

## II. Air Pollution Control Engineering

### a. Required courses

(1) Meteorology (Micro). A course which deals principally with the physics and behavior of the lower atmosphere. It will cover the structure, physics and dynamics of the atmosphere and its relation to the local climatology. The subject matter indicates the mathematics and physical relationships pertaining to the diffusion of gases from stacks and other sources.

(2) Advanced Air Analysis. See Item I, a (3).

(3) Environmental Physiology. See Item I, a (4).

(4) Industrial Hygiene Engineering. See Item I, a (1).

### b. Optional courses

(1) Advanced Radiological Hygiene. See Item III, a (1).

(2) Special Environmental Problems. See Item I, b (3).

(3) Elements of Atomic Physics. Atomic nature of matter and electricity, wave and particle aspects of electrons and light, quantum theory of the hydrogen atom, spectra, periodic table, x-rays and nuclear physics.

(4) Industrial Psychology. See Item I, b (5).

(5) Sanitary Chemistry. See Item I, b (2).

(6) Sanitary Microbiology. See Item I, b (4).

### III. Radiological Hygiene Engineering

#### a. Required courses

(1) Advanced Radiological Hygiene. The second term of radiological hygiene deals with more advanced radioactivity instrumentation and measurement, the biophysics of radiation and hazards from interval emitters. Typical examples of bio-assays by radioassay and radiation dosage measurement is included. The course will involve some laboratory sessions dealing with biological materials and small animals.

(2) Elements of Atomic Physics. See Item II, b (3).

(3) Chemistry of Nuclear Materials. Chemistry and chemical processing of materials of importance in nuclear engineering including uranium, thorium, and plutonium, zirconium, beryllium, graphite, heavy water and others. The course also includes some discussion of problems of isotope separation; solid, liquid and gaseous waste chemical treatments.

(4) Radiological Engineering. A discussion of advanced and applied radiation, protection problems, development of radiological design criteria for operations in radiation laboratories, establishment and application of reactor safeguards emergency planning and control of radioactive wastes.

#### b. Optional courses

(1) Special Environmental Problems. See I, b (3).

(2) Advanced Air Analysis. See I, a (3).

(3) Environmental Physiology. See I, a (4).

(4) Quantum Mechanics. An introduction to quantum theory.

(5) Nuclear Physics. Topics included are properties of nuclei, nuclear transformations and reactions, stability of nuclei, interaction of radiation and matter, the discovery of elementary particles, nuclear instruments and accelerators.

(6) Meteorology. See II, a (1).

(7) Radiochemistry. A course in the handling and analysis of radionuclides and isotopes. Tracer techniques and applications.

(8) Nuclear Engineering. Nuclear reactions, neutron physics of neutron diffusion and reactor theory, introduction to reactor design.

### PREREQUISITES FOR COURSES

The above grouping of courses implies that certain prerequisites are necessary for certain categories of courses. Because of the fact that the most desirable educational background for air resources engineering is primarily chemical engineering it is apparent that the candidates should, if possible, have a fundamental grounding in chemistry including physical and organic. However, these may be taken concurrently or as prerequisites for certain courses.

All candidates should have mathematics through calculus and differential equations; basic courses in physics; thermodynamics and mechanics. One limitation most engineering or physical science majors have is a deficiency in biological sciences. For this reason the conference report\* specified at least an elementary course in biology (general, physiology or microbiology) at the undergraduate level. In addition to or even in the absence of this course it is believed that a graduate course in human physiology is essential in the training of individuals whose primary pursuits will be in the provision of safe living or working conditions for man.

For graduate work in general it should be recognized that the undergraduate program most adaptable to air resources engineering would be honor graduates in engineering or the physical sciences, particularly physics or chemistry and some mathematics concentrators with minors in physics or chemistry. In our experience the best candidates are those who qualify on this basis, however, a student who finishes in the upper quartile in the Graduate Records Examination in Engineering or a physical science is a good prospect.

A basic engineering background is most desirable as it enables the candidate not only to evaluate and measure but to interpret and design and provide controls as well.

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\* See footnote, page 29.



For courses specified above the above background is suitable for the courses for all three areas in air resources engineering. In the special groups of courses the necessary prerequisites in some cases are that the courses specified be taken in sequence. This is obvious for courses in advanced radiological hygiene and air analysis. It also follows that human physiology is a prerequisite for toxicology and radiation biology.

Chemistry of Nuclear Materials requires sanitary chemistry or its equivalent and Quantum Mechanics requires Elements of Atomic Physics and some advanced mathematics as does Nuclear Engineering. No special prerequisites are necessary for the other courses specified beyond the general engineering and physical sciences background specified earlier.

#### PROBLEMS OF ACCREDITATION OF GRADUATE PROGRAMS IN SANITARY ENGINEERING

It is apparent from the curricula outlined above that in the field of Air Resources Engineering approximately one-third or more of the courses are in the public health and biological areas and therefore a sound program should have available contact or instruction offered by Schools of Public Health or similar groups in Preventive Medicine in order to get competent instruction in epidemiology, biostatistics, physiology, and toxicology. The usual graduate school courses in biology and physiology are geared to mammalian rather than human physiology and toxicology. It is also apparent from experience in this field that contact with industry and industrial developments in all three categories is necessary to be able to present to the student the changing nature and development of new approaches in the field. This involves field trips and possibly field assignments for short periods.

In regard to possible accrediting agencies a problem exists because most of the orthodox engineering professional groups are reluctant to provide such accreditation in a field where biological effects and environmental influences are so essential. Organizations such as the American Industrial Hygiene Association or the Health Physics Society are not composed primarily of environmental health engineers, in fact, the AIHA has less than 25 per cent engineers in its membership and the newly formed AIHA-ACGIH Certification Board plans on certifying many types of specialists. In the Health Physics Society a similar situation exists and their primary interest is in certifying health physicists although their newly formed Certification Board will cover certain areas in radiological engineering related to waste disposal.

On a similar basis the composition of the membership of the American Public Health Association is such that they would not be interested in certifying engineering programs. They have, however, established some guide-lines for accreditation of programs in Schools of Public Health for MPH and Dr. P. H. degrees.

In order to accredit graduate programs and evaluate course content in the area of this paper it is apparent that a group composed of senior engineers and scientists teaching and working in the environmental health field which includes air resources engineering should take steps to provide such accreditations.

It is the writer's opinion that the group most qualified to do this is the American Sanitary Engineering Intersociety Board. Because of the opposition of many air resources engineers, particularly in state agencies, to being included and defined as sanitary engineers it is to be hoped that the broader title of Environmental Health Engineering Intersociety Board would be adopted.

It is the hope that the ECPD will consider using the ASEIB to provide assistance in accrediting graduate programs in air resources engineering. In the event that ECPD declines to take this initiative it is necessary, in my opinion, for ASEIB to provide such accreditation or recommend a procedure whereby such accreditation can be provided.

Along these lines a recent Ad Hoc Committee was established by the Atomic Energy Commission Industrial Hygiene Fellowship Board of the Oak Ridge Institute of Nuclear Studies (for AEC fellowship reviews) to recommend an educational program for graduate instruction in industrial hygiene. This recommended practice for programs of instruction has not yet been released by the Committee but should provide a useful guide-line for industrial hygiene training. Essentially the same report was made to the American Industrial Hygiene Association by its Education Committee in April. At its April, 1960 meeting, the American Industrial Hygiene Association also discussed the trends and needs in industrial hygiene education. Along these lines it is useful to refer to the definition, scope, function and organization of industrial hygiene\*. There has also been discussion by the Ad Hoc Committee of the Atomic Energy Commission Fellowship Board as to possible accreditation and review of institutions offering graduate work in this field by the American Industrial Association Education Committee or by the AIHA-ACGIH Certification Board. This approach has already been discussed above and has the limitations defined above.

While this activity has been progressing in this direction for industrial hygiene education programming, little has been done in the air pollution control engineering or radiological health engineering fields. The Health Physics Fellowship Committee of ORINS has assembled the teaching program at the several schools approved for offering training in health physics but has not yet defined an ideal or accredited program.

The fact that these groups are already interested in such programs makes it important that engineers define their own needs rather than have such programs incorporate engineering training into splinter or limited scope groups.

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\* Industrial Hygiene Definition, Scope, Function and Organization. American Industrial Hygiene Association Journal 20:428 (1959).

APPENDIX III.

EDUCATION, TRAINING AND UTILIZATION OF SANITARY ENGINEERS  
IN THE FIELD OF PUBLIC HEALTH

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Introduction

The utilization of sanitary engineers in public health, particularly at the state level, is a practice of long standing. Some state health departments have engaged the services of engineers since well before the turn of the century, and the contribution made by these engineers to the promotion and preservation of the public health has long been recognized as vital to the welfare of their community. Confining this paper to a consideration of the engineer in governmental and non-governmental public health agencies does not indicate a lack of awareness of the value of similar contributions made by engineers in private practice or industry.

Prior to World War II, the work of the sanitary engineer in a public health department was so highly esteemed that, often in practice, he was the health officer's principal deputy. At that time, the public health effort was focused, to a considerable extent, on the control of communicable and infectious diseases. In the United States, we can be justly proud of the almost complete eradication of communicable waterborne diseases such as typhoid fever. There is no doubt, and this is recognized by most public health physicians, that the major share of the credit for this belongs to the sanitary engineer. The role of engineers in the complete eradication of malaria in the United States is also well appreciated.

To guide deliberations on curricula designed for present and future needs of engineers in public health, it may be well to identify briefly the factors that contributed to attainment by engineers of a very high status in public health departments during the "communicable disease" period. Among these factors I

suggest were the following:

1. The pioneer sanitary engineers in health departments were primarily trained as engineers and most of these pioneers had very sound and broad engineering knowledge. On this sound engineering knowledge they superimposed in-service training in epidemiology, statistics, chemistry, biology and administration.
2. In most states the engineer in the health department was a professional engineer who was accepted fully by his fellow engineers in private practice, not because of laws or regulations but because of his sanitary engineering competence. It is accurate to state that in many instances the state sanitary engineer acted as an unpaid and unbiased consultant to designing engineers and as a result of this consultation, municipalities were provided with safer and better water supplies and sewerage systems than they might have received otherwise.
3. The sanitary engineer was accepted by the medical group in the health department as a professional colleague. His engineering competence made it possible for him to give important assistance in solving the pressing problems of the environment particularly those of water and waste water as they related to communicable diseases.

#### The Changing Pattern in Environmental Health

As has been suggested, in the United States, many of the older problems of environmental disease have been solved and the needs for environmental control have changed, but the needs for environmental control by engineering means have nevertheless not diminished. However, the new problems call for a change in emphasis in the preparation of engineers for duty in the field of Public Health. It is often said that it is essential for generals to prepare to fight the next war and not the last one. It is equally important to prepare engineers not to cope with the typhoid fever of the previous generations but to deal with the problems of a new era. We are now witnessing the coming of age of industrial chemistry,

and we have had a preview of the potentials of nuclear energy. New processes and products, new materials and new energy uses provide the exploding population with new and higher standards of living. This has brought with it a whole series of new problems in the control of the environment. We are faced today with these new problems, in very much the same way as we were faced, at the turn of the century, with the need for the environmental control of communicable diseases. Fair<sup>1</sup> has described the evolution of micro-chemical hazards as follows:

"The micro-chemical agents of disease are the products of technological break-throughs, more particularly of break-throughs associated with the Second World War and the uneasy peace that has succeeded it. The impact of these products on man's condition and his environment has been profound. The changes that have been effected are quick-moving and complex. Let me pass some of them in review.

"DDT and related insecticides have been dispersed on a world-wide scale for the protection of man and his domestic animals and for the conservation of food and forage crops. Other synthetics have found use as rodenticides, weedicides, and piscicides. They, too, have helped to conserve food and increase its production. Today, furthermore, some 400 chemicals, including antibiotics, are estimated to be added to foods as preservatives, anti-oxidants, thickeners, thinners, moisteners, emulsifiers, and colouring agents. Aided by heat, cold or irradiation, the spoilage of food has been reduced to a low figure. Altogether, the drive for more and better food and for its conservation and preservation has been stupendous. Within the term of reference of this lecture, however, disturbing side effects have accompanied these developments. These relate, in particular, to the exposure of man to an environment that contains mounting concentrations of physiologically active chemicals that may build up to toxic strength unless adequate control measures are instituted.

"Developments parallel to these essentially agricultural changes in man's environment are taking place in his industrial and communal environment as well. Existing industries are expanding and new ones are being founded to meet the needs and wants of a growing and 'affluent' society. New metals and alloys and new organic synthetics have come into production. Power requirements have multiplied, and nuclear fuels are about to compete with fossil fuels as sources of energy. The automobile has become the preferred means of transport over short distances, the aeroplane over long ones. New and increased industrial activity, new methods of transportation, and a greater consumption of fuels, in general, have carried pollutants in increasing amounts into our environment in hygienically significant quantities. They too, await our control in larger measure.

"The post-war changes in our environment, it will be observed, have one element in common: vastly increased amounts of often new chemical substances that reach the food we eat, the water we drink, the air we breathe, and the soil we cultivate or build upon. Although their concentrations in the environment are generally minute, some of them, we now know, are so active biologically

that they are held responsible for important disease processes as well as general malaise. It is to the prevention and control of these that public health officials will have to direct their efforts with increasing vigour in the foreseeable future. Newly suspect among micro-chemical pollutants of the common environment are many of the synthetics that are washed into water from industrial, agricultural, and related operations; organics and other substances that are released to or created in the air by the combustion of fuels and waste materials; and, most dramatic perhaps, radioactive substances that enter water supplies, the atmosphere, and the soil from varied atomic-energy sources. So great, indeed, have become the demands on air, water, and soil for the dispersal and stabilization of pollutants that it has looked at times as if the conquest of outer space might eventually become a necessity for survival rather than a pawn for prestige."

#### Present Activities and Functions of the Engineers in Public Health

In 1955 a subcommittee of the Committee on Professional Education of the American Public Health Association prepared a report<sup>2</sup> on the qualifications of engineers in public health. That report listed the following sanitary engineering activities as being carried on in the public health field:

1. Water supply, treatment and distribution.
2. Sewerage systems, sewage and industrial waste treatment and control.
3. Water pollution control.
4. Municipal and rural refuse disposal.
5. Control of rodents and insects and noxious weeds.
6. Food sanitation involving the production, pasteurization, and processing of fluid milk and other manufactured dairy products; control of processing, storage, handling, and distribution of meat and meat products, poultry, bakery goods, fish, shellfish, canned and frozen foods; and the sanitation of public eating and drinking establishments.
7. Sanitation of schools, places of public assembly, camps and summer resorts, swimming pools, other bathing places and recreational areas.
8. Promotion of healthful housing.
9. Home accident prevention.
10. Control of atmospheric pollution including fumes, dusts, gases, odors, and pollen.
11. Industrial hygiene and sanitation, involving special engineering problems relating to industrial and manufacturing processes, and including varied elements of environmental sanitation.
12. City planning and redevelopment involving housing standards, heating, lighting, ventilation and plumbing.

13. Noise abatement.

Some Special Considerations in the Training of Engineers for Public Health

In this discussion, I make no plea for the use of the terms "Public Health Engineer" and "Public Health Engineering". These may have certain advantages but, in my opinion, terminology is of minor importance; the important consideration is the education and training of engineers for work in public health. It is immediately apparent that it is inaccurate to speak of public health engineering education and training in the same sense as one speaks of education and training for air resources engineering or water resources engineering. If, in the future, an engineer in the public health department is to be successful, he must possess primary competence in engineering and in an engineering specialty. His training must contribute to producing a truly professional engineer in every sense of the word including eligibility for licensing or registration as a professional engineer. The functions of a sanitary engineer in public health are indeed so varied that additional education beyond the baccalaureate is a necessity. The APHA report on educational qualifications previously referred to very properly states that "The varied functions of a sanitary engineer in public health work necessitate additional education beyond that ordinarily acquired by basic training in engineering. Successful performance in his profession requires: a) an intimate and working knowledge of the physical, chemical, biological and engineering sciences upon which the sanitary control of the environment is made; and b) the ability to identify, evaluate and explain in terms of a public health implication those environmental factors that will promote and protect health, or those that are capable of injuring health."

Academic Preparation for Entrance into Specialized Public Health Training

Specialized training in public health must be at the graduate level. The student, as he comes to graduate training, should have had preparation similar to that recommended in the 1957 Conference Report on Education, Training and

Utilization of Sanitary Engineers<sup>3</sup>. It is essential that the engineer be soundly prepared in mathematics prior to his academic work in the specialized field of Public Health; he should have a good working knowledge of differential equations. He will, undoubtedly, need an adequate background in chemistry (including organic, physical, and biological chemistry) and he must have had a satisfactory introduction into the biological sciences including bacteriology, virology, and parasitology. If necessary, his training period should be extended in order to correct deficiencies in his background.

#### Length of Course

At the Master's level, the length of the instruction will depend, necessarily, to a great extent on the student's previous education and training. If he has had specialized training in one of the sanitary engineering specialties, required additional training might well be completed in a normal academic year of 9 months. For such a man, a period of 15 to 18 months of training might well lead to degrees in both a specialized technical field and in the general field of Public Health. If large numbers of young men directly out of a suitably undergraduate engineering program are to be attracted into graduate training, ordinarily not more than one calendar year (approximately 48 weeks of instruction) will be feasible.

#### Course Content

The program suggested herein is designed to be covered in three terms each of 16 weeks. During this 48 week period, it is assumed that a student could earn from 45 to 48 semester hours of credit. Suggested required courses, together with credits are listed below.

<u>Subjects</u>	<u>Semester Hours</u>
Epidemiology	4
Elements of Statistical Analysis	3
Principles of Environmental Health	4
Public Health Practice	5
Biology for Sanitary Engineers	6
Radiological Health and Nuclear Physics	6



	<u>Semester Hours</u>
Electives	17-20
Total	45-48

The electives would allow the student, in consultation with his advisor, to arrange a program that would provide greater training in depth in one field of engineering. As an example, most of these electives might lie in water resources engineering. Air resources engineering and nuclear reactor design are examples of other appropriate fields. It is to be hoped that these electives would not be thinly spread over a variety of fields.

#### The Use of Engineering Schools and Schools of Public Health for Training

Education of sanitary engineers who wish to work in Public Health must be accomplished in an environment that is in full sympathy with the aims of Public Health. If he is to provide the proper guidance for his advisees, the instructor must, himself, feel that engineers have a worthwhile role in Public Health and that the field of Public Health is professionally attractive to the young engineer. This is not intended to imply that it is mandatory that the training of engineers for public health be accomplished in Schools of Public Health. However, it is the author's belief that this education can only be accomplished at a university that is able to furnish adequate training both in the engineering sciences and in the field of public health and preventive medicine. In my opinion, Schools of Public Health should not undertake the first graduate training of engineers for public health unless they have available to them facilities that can be used to strengthen the technical engineering knowledge of the trainee. This carries with it, not only the implication of close physical proximity of the facilities but even more so a spirit of genuine cooperation between the faculties of engineering and public health. An important role of the professor of "public health engineering" is advising in the proper selection of course work outside of the School of Public Health.

### Training at the Doctoral Level

In the field of Public Health there will be needed a certain number of persons who have been trained to the doctoral level. They will be needed for teaching, for research, and for occasional positions of leadership in administration. In some cases it would be more appropriate that this training to the doctoral level be in one of the major fields of engineering with the minor field being public health. There will, naturally, be many cases where it would be preferable that the major field be public health and the minor field be one of the engineering specialities. Other minor fields such as political science or one of the natural sciences might also be appropriate for some candidates.

### Course Descriptions

Descriptions for the suggested required courses follow.

Epidemiology: Occurrence and prevention of communicable, degenerative and industrial diseases; factors in the spread of infectious diseases with detailed discussion of selected diseases; epidemiological and statistical methods of investigation of both infectious and non-infectious diseases.

Environmental Sanitation: Methods for promoting man's health and comfort by controlling the environment; organization of sanitation activities; food sanitation, including food infection and poisoning; water sanitation; sewage treatment and stream sanitation; disposal of solid wastes; housing; control of air pollution; noise control; and safety.

Statistics: Variation; frequency distributions; probability; tests of significance; power; regression; other methods of association; standard distributions including normal,  $t$ ,  $X^2$ , binomial, Poisson; special distributions arising from non-parametric procedures; vital statistics including official sources, population changes, and rates.

Public Health Practice: Structure, basic functions, activities and staffing of public health agencies; special qualifications of personnel; methods of public

health education; budgeting; program planning and appraisal of public health procedures.

Biology for Sanitary Engineers: Plant and animal forms important in environmental sanitation.

Radiological Health: No specific course description has been attempted in this paper inasmuch as the question of radiological health is a problem common to all discussion groups.

Appendix 1 contains an outline of the work in sanitary biology now available in the School of Public Health, University of Minnesota for engineers and non-medical graduate students. I am indebted to Dr. Theodore A. Olson, Professor of Public Health Biology in the School of Public Health for preparation of this outline.

In Appendix 2, listed by title only, are courses in various departments of the University of Minnesota that, at one time or another, have been taken either as required or elective courses by engineers receiving training at the graduate level in the School of Public Health.

#### References

1. Fair, G. M., (1959), New Factors in Man's Management of His Environment, The Chadwick Trust, London.
2. Committee on Professional Education, APHA, (1955), Educational Qualifications of Engineers Engaged in the Field of Public Health, AJ PH 45:84.
3. Education, Training and Utilization of Sanitary Engineers, (1957), NAS-NRC, Washington, D. C.

Appendix 1

School of Public Health  
University of Minnesota

CONTENT OF COURSES IN PUBLIC HEALTH BIOLOGY

Biology for Non-medical Public Health Personnel

Course #1

ORIENTATION IN SANITARY BIOLOGY

A. Lectures, seminars and conferences

- I. Biology and its relation to public health problems.
- II. The language of biology
  - a. An introduction to Greek and Latin stems and roots
  - b. The technique of scientific word building
  - c. The recognition of meanings of new words by an analysis of their basic parts
- III. Classification and nomenclature of living things
  - a. The principal phyla of the plant kingdom and their recognition. A brief resume of the ten phyla of the subkingdom Thallophyta including the phyla Cyanophyta to Schizomycophyta (Blue-green algae to bacteria). Also included are the phyla Bryophyta and Spermatophyta of the subkingdom Embryophyta.
  - b. The principal phyla of the animal kingdom and their recognition. A brief resume of the 22 principal phyla of this group including organisms from the Protozoa to Chordata.
  - c. The Binomial System of nomenclature.

IV. Microbiology

a. The history of Microbiology

Leeuwenhoek	Robert Hooke	John Needham
Walter Reed	Aristotle	Spallanzani
Paul Ehrlich	Galileo	Franze Schulze
Roger Bacon	Louis Pasteur	Theodor Schwann
Robert Koch	Klebs	William Welch
Edward Jenner	Loeffler	Theobald Smith
Elie Metchnikoff	Joseph Lister	Alexander Flemming
Oliver Wendell Holmes	Phillip Semmelweiss	Francesco Redi

- b. Bacterial morphology
- c. Reproduction and growth of bacteria
- d. Cultivation of bacteria
- e. The molds
- f. The yeasts
- g. The viruses
- h. The rickettsiae
- i. The control of microbial populations
  - (1) By physical means
  - (2) By chemical means
  - (3) By antibiotics and antibiosis
- j. Microorganisms and disease
  - (1) Infections and virulence
  - (2) Resistance and immunity
  - (3) Serological methods
- k. Practical microbiology
  - (1) Microbiology of foods
  - (2) Microbiology of air
  - (3) Microbiology of milk
  - (4) Microbiology of water
  - (5) Microbiology of sewage

V. The blood and its components

- a. The blood as a tissue
- b. The blood as an oxygen carrier
- c. The blood as a clotting agent
- d. The blood as a carrier of food
- e. The blood as a carrier of wastes
- f. The blood as a part of the defense system against disease

VI. Blood types, an introduction to serology

VII. The Morphology of typical insects

- a. Anatomy of the grasshopper
- b. Anatomy of the cockroach
- d. Anatomy of the mosquito
  - (1) Adult mosquitoes
  - (2) Larval mosquitoes

VIII. A synopsis of the common Arthropoda with special reference to the Insecta (Hexapoda)

IX. Orders of insects

- a. A discussion and demonstration of the recognition characters of 28 orders of insects.
- b. Instruction in the use of entomological keys for the identification of insects to orders, families, and species.

X. Insect control methods - general

- a. Chemical
- b. Physical

- c. Biological
- d. Dangers associated with the use of certain insecticides

XI. Morphology and anatomy of a representative mammal

- a. The external and internal anatomy of the rat, Rattus norvegicus.

XII. Animal ecology and distribution

B. Practical applications of Sanitary Biology (field and laboratory exercises or lectures relating to practical problems).

I. Demonstrations and practical first-hand experience with the following items of equipment:

Bathythermograph	Wisconsin plankton net
Nansen water-bottle	Juday Plankton trap
Kemmerer water-bottle	Foerst Centrifuge
Pettersen dredge	Aquatic plant grappler
Ekman dredge	Reversing thermometer
Secchi disk	Thermistors
Surber sampler	Aquatic winches
Phleger corer	Booms and Metering Wheels

II. Identification and study of 25 representative aquatic flowering plants.

III. Instruction and practice in conventional techniques for collection, preservation and mounting of insect and other arthropod specimens.

IV. Instruction and practice in the rearing of insects that may be useful in experimental work and in the demonstration of life cycles. The following insects are reared:

- a. The Aedes aegypti mosquito
- b. The house fly Musca domestica

V. Instruction in the use and care of various types of microscopes.

VI. Special exercises and demonstrations in the field of microbiology.

- a. The use of stains including the gram stain
- b. Isolation of an organism, in pure culture (from a mixed culture)
- c. The hanging drop technique
- d. The coliform test (presumptive, confirmed and completed)
- e. Tissue culture technique; showing virus plaques
- f. Bacterial morphology
- g. Demonstrations and culture of representative yeasts, fungi, and chromogenic bacteria
- h. Plate counting techniques
- i. "Millipore" filter techniques

- j. Agglutination tests
    - (1) Brucella
    - (2) Salmonella
  - k. The complement - fixation test; a demonstration
  - l. Bacteriological examination of utensils based on the method described in the U.S.P.H.S. restaurant code. Each student goes through the entire procedure and gives a report on his findings. The samples are collected under practical conditions.
- VII. Introduction to the morphology and identification of plant pollens.
- VIII. Introduction to the morphology and identification of plankton
- a. Zooplankton
  - b. Phytoplankton
- IX. Introduction to the technique of mosquito identification
- a. Mosquito larvae
  - b. Mosquito adults

School of Public Health  
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CONTENT OF COURSES IN PUBLIC HEALTH BIOLOGY

Biology for Non-medical Public Health Personnel

Course #2 INSECTS VERSUS MAN: PARASITOLOGY: MEDICAL ENTOMOLOGY

A. Lectures, seminars and conferences

I. Introduction

The interaction of Arthropods, Animal parasites and Man in relation to parasitism and disease.

II. Animal Parasites of Man

- a. Animal parasites and parasitism
- b. The characteristics and detailed life cycles of representative human parasites; with special reference to environmental control measures. The following species are studied:

<u>Plasmodium vivax</u>	<u>Fasciolopsis buski</u>
<u>Plasmodium flaciparum</u>	<u>Dracunculus medinensis</u>
<u>Plasmodium malariae</u>	<u>Trichinella spiralis</u>
<u>Endameba histolytica</u>	<u>Trichiurus trichiura</u>
<u>Trypanosoma cruzi</u>	<u>Chlonorchis sinensis</u>
<u>Trypanosoma gambiense</u>	<u>Paragonimus westermanni</u>
<u>Leishmania donovani</u>	<u>Schistosoma haematobium</u>
<u>Leishmania braziliensis</u>	<u>Schistosoma mansoni</u>
<u>Leishmania tropica</u>	<u>Schistosoma japonicum</u>
<u>Ascaris lumbricoides</u>	<u>Hymenolepis nana</u>
<u>Wucheraria bancroft</u>	<u>Hymenolopis diminuta</u>
<u>Onthocera volvulos</u>	<u>Taenia saginata</u>
<u>Enterobius vermicularis</u>	<u>Taenia solium</u>
<u>Necator americanus</u>	<u>Diphyllbothrium latum</u>
<u>Strongyloides stercoralis</u>	<u>Dipylidium caninum</u>
<u>Ancylostoma braziliense</u>	<u>Echinococcus granulosus</u>
<u>Ancylostoma duodenale</u>	

III. Arthropods and Medical Entomology

- a. Insects versus man
  - (1) Beneficial relationships
  - (2) Damage caused by insects
    - (a) Economic
    - (b) To health of man
- b. Arthropods and disease

A discussion of the morphology, habits, life cycles and general ecology of the following vectors and of the etiological agents of diseases they may carry.



- (1) Mosquitoes
- (2) Ticks and mites
- (3) Fleas
- (4) Lice
  - (a) sucking
  - (b) biting
- (5) Bed bugs
- (6) Triatomidae
- (7) Phlebotominae
- (8) Simuliidae

B. Laboratory exercises and special studies

I. Trichinosis

An exercise in which the life cycle of a living parasite is followed through two hosts.

- a. Recovery of living trichinae from infected mice or rats
- b. Feeding of a known number of live cysts to experimental mice
- c. Observation of symptom in mice
- d. Recovery of mature living adults from the intestines of the experimental mice. Both male and females must be found.
- e. Recovery of larvae as they first make their way into muscle
- f. Demonstration of fully infective, coiled and encysted trichinae in mouse muscle

II. Instruction and practice in the technique of micro-slide preparation. The following mounts are prepared:

- a. An adult female mosquito
- b. An adult male mosquito
- c. Two other specimen selected by students

III. Instruction and practice in the recognition of arthropods and parasites. This includes "sight identification" or the use of keys in recognizing the following:

- a. Any of the common species of mosquitoes, excluding only the rare or bizarre forms
  - (1) Adult males and females
  - (2) Larval specimens
- b. Fleas, Lice, Blood-Sucking Bugs, Sand Flies, Ticks and Mites and other invertebrate intermediate hosts
- c. All common Helminth eggs
- d. The adults of the common Helminths

IV. Identifications of fresh-water molluscs

- a. Gastropods (snails)
- b. Pelecypoda (clams)

- V. Identification of fresh-water fishes.
- VI. Calibration of microscopes to be used in plankton counting and for measurements necessary to taxonomic work with various types of microorganisms.

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CONTENT OF COURSES IN PUBLIC HEALTH BIOLOGY

Biology for Non-medical Public Health Personnel

Course #3      FIELD PRACTICE IN SANITARY BIOLOGY

A. Lectures, conferences, readings and laboratory exercises

- I. Identification of Phytoplankton.
- II. Identification of Zooplankton.
- III. Stream pollution biology - indicator organisms.
- IV. Aquatic insects - mature and immature.
- V. Survey techniques.
- VI. Dissolved oxygen, BOD, and other technical methods needed in limnological surveys.
- VII. The calculation of an oxygen sag curve.
- VIII. Plankton counting and techniques for the measurement of microorganisms.
- IX. The logistics of field survey.

B. Assigned field problems

Each student is assigned, either alone or with one or two associates, a problem in Environmental Health which has biological aspects. He must plan his study in its entirety. The initial design is approved by the instructor who also watches the progress of the work and is available for consultation. In other respects the student is "on his own" as he would be in a practical situation. Drawing on the preceding training in courses 1 and 2 he should be able to carry out the necessary work by himself. A formal report on the project is submitted at the end of the term. The latter constitutes the primary basis for judging the students' performance and has a large weight in estimating the final grade.

A wide range of topics is acceptable. The following represents a partial listing:

- a. A general limnological study of a small pond
- b. Study of the oxygen resources and the heat budget of two or more lakes as evidenced by observations from the spring break-up to the middle of May
- c. A pollution survey of a small stream
- d. A survey of the phytoplankton in the storage reservoirs and in the original raw-water source of large water supply

- e. The life of a rapid stream
- f. The life of a spring-fed brook
- g. The survey of the typical insect population in a circumscribed terrestrial or aquatic environment.
- h. A study of the spring ecology of a temporary or permanent pond
- i. The plankton and its variation in time and space within a lake
- j. Biological activity as evidenced by the oxygen balance and photosynthesis in a lake

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CONTENT OF COURSES IN PUBLIC HEALTH BIOLOGY

Biology for Non-medical Public Health Personnel

Course #4

BASIC PHYSIOLOGY

A. Lectures, conferences and readings

I. Introduction

Scope of physiology and its relation to problems in public health.

II. Atoms, molecules and life.

III. Protoplasm and its basic properties.

IV. The cell as a unit of structure and function.

- a. plant cells
- b. animal cells

V. Cells and the organism.

VI. The organization of plants.

VII. The organization of animals.

VIII. The activities of protoplasm.

- a. Metabolism
- b. Reproduction

IX. Metabolism.

- a. Autotrophic nutrition
- b. Heterotrophic nutrition
- c. Gas exchange
- d. Respiration - cellular
- e. Energy requirements and functions - cellular

X. Machinery of the human body.

- a. Blood and the internal environment
- b. The heart, its associated vessels, and their work
- c. Blood flow and pressures
- d. The mechanism of breathing
- e. Alimentation
- f. Muscle activity
- g. Mechanisms for body correlation
  - (1) Nervous system
  - (2) Chemical control - endocrine glands

- h. Sensory mechanisms and the external environment
- i. Physiological aspects of the body defenses against diseases

XI. The unity of all living things in terms of comparative physiology.

B. Laboratory exercises and demonstrations

Special projects and displays to illustrate and support lectures.

Appendix 2

School of Public Health  
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(Required or elective courses taken by engineers receiving training at the graduate level)

PH 100A-B-C Elements of Public Health (5)  
PH 102 Environmental Sanitation (3)  
PH 104 Epidemiology I (3)  
PH 105 Epidemiology (3)  
PH 106 Public Health Administration (3)  
PH 108 Introduction to Biostatistics (2) (may be substituted for 140)  
PH 110-111 Biometric Principles and Laboratory (5) (may be substituted for 140)  
PH 112A-B-C Public Health Engineering: Plan Examinations (3)  
PH 113A-B-C Public Health Engineering: Field Investigations (6)  
PH 115 Food Sanitation (3)  
PH 116 Public Health Engineering Administration (2)  
PH 117-118-119 Sanitary Biology (9)  
PH 120-121, 130-131 Biostatistics II and III (10)  
PH 123 Topics in Public Health (ar)  
PH 125 Public Health Education (2)  
PH 126 Occupational Health Programs (3)  
PH 140 Vital Statistics I (3) (may be substituted by 108 or 110 and 111)  
PH 152 Industrial Hygiene Engineering (3)  
PH 154 Control of Radiation Hazards (3)  
PH 155 Introduction to Air Pollution Problems (3)  
PH 156 Air Pollution Surveys and Controls (3)  
PH 191 Science of Human Nutrition (3)  
PH 194 Human Factors in Industry (3)  
PH 200 Research (ar)  
PH 210 Seminar in Public Health (1)  
PH 212 Seminar in Public Health Engineering and Sanitation (ar)  
PH 230 Field Practice: Environmental Sanitation (2)  
Aero 173 Introductory Meteorology (3)  
Aero 174 Applied Meteorology (4)  
AgBi 106 Animal Biochemistry (3)  
AnCh 140 Water Analysis (3)  
Arch 104 City Planning (3)  
Bact 116 Immunology (4)  
Bot 112 Aquatic Flowering Plants (4)  
Bot 150 Phycology I - Algae (5)  
Bot 155 Fresh Water Algae (4)  
Bot 177 Photosynthesis (3)  
CE 161 Hydrology (3)  
CE 170 Water Supply (3)  
CE 171 Sewerage and Sewage Treatment (3)  
CE 172 Sanitary Laboratory (3)  
CE 173 Sanitary Engineering Problems: Water (3)  
CE 174 Sanitary Engineering Problems: Sewage and Industrial Wastes (3)  
CE 175 Industrial Waste Disposal (3)  
CE 261 Water Plant Design (3-5)  
CE 262 Sewage Plant Design (3-5)  
ChEn 131-132 Chemical Reactor Analysis (6)

ChEn 161-162-163 Nuclear Reactor Design (9)  
DyHu 109 Market Milk (3)  
DyHu 150 Dairy Bacteriology (3)  
D Ind 102 Condensed Milk Products (3)  
Ent 117-118 Animal Ecology (6)  
Ent 124 Biology of Immature Insects - Aquatic Forms (4)  
Ent 242-243 Insect Physiology (8)  
Ent 254-255-256 Advanced General Entomology (9)  
Ent 257 Insecticides and Their Action (3)  
F Tec 101 Food Technology (3)  
F Tec 102 Food Technology (3)  
F Tec 105 Frozen Food Problems (3)  
Geog 133 Climatology (3)  
Geog 134 Advanced Climatology (3)  
Geol 101 Sedimentary Geology (3)  
Geol 154 Geological Oceanography and Limnology (2)  
Ind E 182 Industrial Safety (3)  
ME 146 Fuels and Combustion (3)  
ME 160 Psychrometrics and Air Conditioning (3)  
ME 161 Heating, Air Conditioning Design (3)  
ME 163 Principles of Particle Technology (3)  
ME 166 Industrial Ventilation (3)  
ME 169 Air Conditioning and Refrigeration Laboratory (2)  
Phys 121 Experimental Nuclear Physics (3)  
PoHu 154 Poultry Products (5)  
Pol 120-121 Municipal Functions and Administration (6)  
Soc 115 Social Aspects of Housing and Standards of Living (3)  
Soil 128 Soil Chemistry (3)  
Zool 144 Medical Entomology (3)  
Zool 145 Parasitic Protozoa (3)  
Zool 146 Helminthology (3)

(Quarter credits ( ) are equivalent to 2/3 semester hours.)



APPENDIX IV.

BIOLOGY AND CHEMISTRY COURSES  
FOR M.S. DEGREES IN SANITARY ENGINEERING

By

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Metcalf & Eddy, Boston, Massachusetts

The purpose of any accreditation plan is to ensure that accepted levels of education are maintained. This requires the establishment of a standard curriculum, qualified teaching staff, and adequate facilities in terms of space and equipment. Because of the broad aspects of sanitary engineering endeavor which covers the areas of water resources, public health and air resources, some considerable degree of freedom must be maintained in order that potential candidates for the sanitary engineering profession will not lose interest and become discouraged casualties. With the modern trend toward de-emphasis of engineering training at the undergraduate level and greater attention being given to training in the sciences, it is likely that our concepts of additional training in the basic sciences at the graduate level will have to be revised from time to time. At present, we must assume that the basic sciences will be taught in the classical manner and that winners of the baccalaureate degree will have no special orientation toward or appreciation of the special problems in sanitary engineering or environmental health.

Although there is a strong trend at the present time for abandonment of specialized engineering education at the undergraduate level, there is no assurance that there will be a mass movement in such a direction. It is likely that if such a change occurs it will be gradual, and there are some who contend that the pendulum will return toward its present position, following adjustments of a less radical nature. In any event it is to be expected that the background and training of those who volunteer for education in sanitary engineering during the next decade will be extremely varied. It seems important that we be careful not to close the doors to graduates from schools that are slow to make the

transition. In addition, many of our potential students will be coming from foreign countries where no control can be exercised over undergraduate training. In view of good international relations, it seems important that the door be kept open for these people as many of them have more pressing problems than we have.

Finally, the basic education required by those specializing in the field of air resources appears to be sufficiently different from that needed for water and public health engineers to merit special treatment.

On the basis of the considerations mentioned above, the following curricula are proposed in the basic sciences:

Public Health and Sanitary Engineering

<u>Chemistry</u>	<u>Hours/week</u>		<u>Semester hours</u>
	<u>Lecture</u>	<u>Laboratory</u>	
Sanitary analysis <sup>1</sup>	2	4	4
Sanitary chemistry <sup>2</sup>	2	0	2
Organic chemistry			
Physical chemistry			
Biochemistry			
<u>Biology</u>			
Introductory microbiology	2	4	4
Bacteria			
Algae			
Protozoa			
Higher forms			

1. Not required of those having had one or more semesters of quantitative analysis in an accredited institution, Recommend audit of lectures, however.
2. Not required of those having had one or more semesters of organic and one or more semesters of physical chemistry at accredited institution. Recommend audit of lectures pertaining to physical chemistry and biochemistry.

Air Resources Engineering

<u>Chemistry</u>	<u>Hours/week</u>		<u>Semester hours</u>
	<u>Lecture</u>	<u>Laboratory</u>	
Analytical chemistry	3	4	5
Organic chemistry	3	0	3
Physical chemistry	3	0	3

Description of Basic Science Courses

Chemistry

Sanitary Analysis - A specialized course in analytical chemistry designed to teach the theory, chemistry, and application of the common determinations and techniques encountered in the analysis of natural waters, domestic sewage, and industrial wastes. The laboratory work should include, physical, volumetric, gravimetric, colorimetric, electrometric, and spectrophotometric method of analysis. The B. O. D. test serves as an example of a bio-assay technique.

Minimum requirements should include: 1. Instruction in use and care of analytical balances, preparation of standard solutions, and laboratory techniques; 2. Experience in determining color, turbidity, pH, acidity, carbon dioxide, alkalinity, hardness, residual chlorine, chlorides, dissolved oxygen, B. O. D., C. O. D., ammonia nitrogen, organic nitrogen, nitrites, nitrates, solids, iron, manganese, sulfates, and fluorides.

If more than four hours per week can be devoted to the laboratory work, the following additional determinations are desirable: phosphates, grease, volatile acids, and gas analysis.

Sanitary Chemistry - A certain knowledge of organic, physical, and biochemistry is essential in sanitary engineering particularly as a basis for understanding physical and biological phenomena of natural or induced character. This course should be designed to teach the fundamentals of organic, physical, and biochemistry and their application in sanitary engineering practice.

Organic Chemistry - Aliphatic and aromatic hydrocarbons, their oxidation products, other derivatives, reactions, nomenclature, structure, carbohydrates, fats, proteins, soaps, synthetic detergents, etc. A minimum of attention should be given to preparation of organic compounds except where industrial wastes are involved. Emphasis should be on how the compounds can be destroyed biologically.

Physical Chemistry - The gas laws, particularly applications of Henry's law; properties of solutions, vapor pressure, Raoult's law, surface tension, Poiseuille's law, binary mixtures; osmosis; dialysis; electrolytic dissociation; solvent extraction; chemical kinetics; electromotive force; oxidation and reduction potentials; adsorption; and colloidal phenomena.

Biochemistry - Enzymes, coenzymes, and significance of physical factors such as temperature and pH; buffers; biochemistry of carbohydrates, fats and proteins.

### Biology

Introductory Microbiology - A survey course designed to acquaint sanitary engineers with harmful or nuisance microorganisms that he must conquer, and beneficial organisms that he must harness and control in biological treatment processes.

Bacteria - General considerations related to morphology, physiology, nutrition, reproduction, and growth rates. Pathogens, coliforms, and beneficial soil forms.

Plankton - Algae, protozoa, rotifera, crustacea, pathogenic forms. Nutrition, nuisance aspects, role in water supplies, and waste treatment.

Helminths - Flat worms, round worms, parasitic forms.

Fungi -

APPENDIX V.

SOME THOUGHTS ON THE ACCREDITATION OF  
GRADUATE PROGRAMS IN SANITARY ENGINEERING

By

J. E. McKee  
Professor of Sanitary Engineering  
California Institute of Technology

Meritorious though it may be for professors and practicing engineers to discuss curricula and course content for any professional discipline, such discussions are likely to bear little fruit if they are not supplemented by action. One form of action that comes immediately to mind is the establishment of a system of certification or accreditation. While voluntary self-improvement of academic programs may occur as the result of frank discussions, betterment is likely to be accelerated by an organized program of inspection based on criteria or standards of performance.

It is the purpose of this paper to investigate many facets of the accreditation problem and to suggest several questions that deserve thorough and thoughtful debate. It is the further purpose of this presentation to suggest to the American Sanitary Engineering Intersociety Board a course of action relative to accreditation.

A thorough discussion of all ramifications of the accreditation mechanism is not within the purview of this document; yet a brief resume of the background of accreditation should help to bring all members of this Study Conference into rapport with several phases of the problem that often escape recognition. Following a presentation of background information, the question of professional schools versus graduate schools is raised, and the merits of accreditation are compared with those of academic freedom. If accreditation appears to be desirable, it may be wise for this assembled group to consider the criteria for accreditation and the mechanism for its accomplishment. This paper reviews the question of what agency should handle accreditation and what cooperation it should receive.

## The Background of Accreditation

The history of higher education in the United States and indeed throughout the world is characterized by a struggle between forces of control and those of academic freedom. Control has been exercised in various degrees and at intermittent periods by ecclesiastical groups, by state agencies in the United States, by national governments elsewhere, by regional associations, for a short time by the Association of American Universities, and more recently by professional societies. Opposition to such control has been led by strong independent faculties in the larger universities, where there is an inherent pride in academic freedom and in the guiding of local destinies.

In his recent book, Selden (1) submits the definition: "Accrediting is the process whereby an organization or agency recognizes a college or university or a program of study as having met certain predetermined qualifications or standards." He also reviews the history of accreditation as it relates generally to all fields of education, tracing the development, reformation, and counter-reformation of the philosophy of this subject.

As Selden points out, there is a difference of opinion as to which organization first employed accrediting as a means of external control of educational standards. Church, state, medical, and alumni groups contest this distinction. It is significant to note, however, that the creation in 1885 of the New England Association of Colleges and Secondary Schools was the first attempt to bring together, for the common good, institutions in the same geographical area. It led subsequently to the formation and development of regional accrediting agencies, of which there are now six. Today, these regional associations are the major accrediting agencies for entire colleges and universities. Despite marked diversities among the six regions, they all share four common goals: (1) Improvement of admission standards. (2) Maintenance of minimum academic standards. (3) Stimulation of institutional self-improvement. (4) Counter-balancing of adverse pressures from many

external and some internal sources.

A working principle of the regional associations is that accrediting is done not so much on absolute or minimum standards as by evaluating the school against its stated objectives. This is necessary because of the wide variety of types of schools.

Accreditation by a professional discipline was initiated by the medical fraternity in 1904. It was followed by the famous report of Abraham Flexner in 1910, which set a precedent that many other professions have attempted to emulate. The legal brethren inaugurated accreditation in 1921, subsequent to an eight-year study financed by the Carnegie Foundation. During the late 1920's, landscape architecture, music, nursing, optometry, and several other disciplines began accrediting and in the 1930's chemistry, dentistry, engineering, pharmacy, theology, social work, and many others followed suit. Today, approximately 30 professions are actively accrediting.

The proliferation of accrediting groups led, in the late 1930's, to an organized clamor of opposition. This reaction was epitomized by Tigert (2) who criticized the accrediting agencies for being too numerous, for encouraging uniformity and restricting experimentation, for assessing excessive costs, for demanding too much duplication of effort, for invading the rights of institutions and destroying institutional freedom, for sometimes considering matters irrelevant to accrediting, for developing a guild system or trade-unionist attitude, and for employing outmoded standards.

Partly as a result of this reaction, a Joint Committee on Accrediting was formed "to pass on new agencies trying to start accrediting, to prepare an approved list of accrediting agencies, to work eventually toward the elimination of some, to foster simplification in procedures and a reduction in duplication, to end any dictation by groups outside the educational field, and to restore a proper responsibility to the states and the institutions" (1). In 1949, this Joint Committee was enlarged and transformed into the National

Commission on Accrediting which is recognized today as the central coordinating agency in the entire field of accreditation in the U. S.

In addition, the Office of Education in the Department of Health, Education, and Welfare was charged in 1952 with the responsibility of publishing a list of schools and programs accredited by state, regional, and recognized professional agencies. In addition, the Commissioner of Education must publish a list of nationally recognized accrediting agencies which he determines to be reliable authorities. It has become important for institutions to be accredited and listed in the publications of the Office of Education so that their graduates will not be excluded from government departments and positions, and so that they will not be jeopardized in any distribution of governmental funds. In effect, then, inclusion on the list of "Accredited Higher Institutions" is more than a matter of prestige. It is almost an economic necessity.

Where does engineering fit into this historical pattern, you may ask? Without taking time to trace the history and development of accreditation of engineering programs, it is significant to note that the Engineer's Council for Professional Development (ECPD) is recognized today by the National Commission on Accrediting as the sole agency to coordinate and handle accreditation of engineering curricula. Indeed, the organization of ECPD on 3 October 1932 was an outgrowth of a Conference on Certification, attended by representatives of seven engineering societies. While ECPD now engages in several areas of professional development, accreditation remains its major "raison d'être." The original criteria for accreditation, approved by ECPD on 10 October 1933, have continued to be the basic guide for the Education and Accreditation Committee. In 1955, however, a set of "Additional Criteria" was adopted for guidance in the accrediting of engineering curricula.



## Objectives and Procedures of Accreditation by ECPD

Recent annual reports by ECPD describe the organization and objectives of the accrediting program, list the basic policies, and present the accrediting procedure. All of the material in that statement is germane to this discussion, but for sake of brevity only the basic policies are quoted below:

"1. The accrediting of curricula rather than institutions, for it is well recognized that curricula of quite different standards may sometimes be found at the same institution.

"2. Accreditation of an institution by its respective regional accrediting agency or association is prerequisite to inspection and accreditation of an engineering curriculum.

"3. The consideration for accrediting of only those curricula leading to first degrees in engineering at an institution - generally undergraduate curricula. Accreditation of graduate programs is not included at the present time pending further stabilization of the objectives and operation of graduate engineering education among the institutions and the profession.

"4. The invitation to institutions to submit curricula without persuasion or pressure brought to bear by the committee.

"5. The avoidance of rigid standards as a basis for accrediting, in order to prevent standardization and ossification of engineering education and to encourage well-planned experimentation.

"6. As a safeguard to the public and without setting any rigid standards, the nonaccrediting of curricula which omit a significant portion of a subject in which the public may reasonably expect engineers of that field to have competence.

"7. The careful consideration of qualitative as well as quantitative factors through a visit of inspection by a competent committee of engineers and engineering educators.

"8. The review of the findings and recommendations of the inspection committee by the appropriate regional chairman, by the Education and Accreditation Committee, and finally by ECPD.

"9. The publication of a list of accredited curricula only, with no information available to any person (other than proper officials of an institution concerned) as to whether any curriculum or institution not on the accredited list had been under consideration by ECPD." (3)

Attention is invited especially to the third basic policy, i. e. that only those curricula leading to first degrees in engineering at an institution - generally undergraduate curricula - shall be considered for accrediting. On the basis of this statement, however, master's programs in aeronautical engineering and chemical engineering have been accredited for many years at Caltech. These programs draw many of their students from undergraduate programs in the basic sciences and consequently the students have had no previous opportunity to participate in an accredited engineering program. In a similar manner, the first degrees in engineering physics and in civil, electrical, mechanical, and sanitary engineering at Harvard University have been accredited inasmuch as there are no undergraduate degrees in engineering at that institution. These curricula extend over five years and terminate with either a bachelor's or master's degree. In 1959, the University of California at Berkeley requested that some of its first degrees in specialty phases of engineering, including sanitary engineering, be accredited on the master's level. At the same school, the undergraduate curricula in civil, mechanical, chemical, and other branches of engineering had been accredited for many years. Indeed, sanitary engineering had previously been accredited as an undergraduate option in civil engineering.

The Berkeley request, for accreditation of master's degrees in certain specialized disciplines following bachelor's degrees in more general fields of engineering, led to considerable discussion by the Education and Accreditation

Committee of ECPD. Although four of the graduate curricula at Berkeley were recommended for accreditation, and the chemical engineering and aeronautical engineering curricula at Caltech were recommended for continuation of accreditation, the E. & A. Committee recognized that this action marked a major turning point in the basic policies. Consequently, a subcommittee was appointed to consider this problem and to report back to the plenary session in October 1960. The subcommittee consists of Dr. Newman A. Hall of Yale, Chairman, Dr. Harold L. Hazen of M.I.T., Dr. Elmer C. Easton of Rutgers University, and Dr. Robert R. White of the University of Michigan.

It would be a great help in the deliberations of this Sanitary Engineering Conference to have the recommendations of the E. & A. subcommittee. In fact, the writer has communicated with the Chairman of the subcommittee to try to get a preview of that group's opinion; but apparently the question is not yet resolved. The subcommittee, in turn, will be looking with extreme interest to the recommendations of this present Conference, for it is generally recognized that sanitary engineers are taking the lead in promoting accreditation of graduate curricula.

At the present time, the Education and Accreditation Committee of ECPD is composed of seventeen representatives of the constituent societies of ECPD. Of the present seventeen members, two represent ASCE, three ASME, two AIChE, for a total of seven members from constituent societies of the American Sanitary Engineering Intersociety Board. In addition, two other ASCE members are on the E. & A. Committee representing ASEE and NCSBEE. In effect, then, over half of the E. & A. Committee consists of members of constituent societies of ASEIB.

In 1959, the Education and Accreditation Committee of ECPD initiated a policy of inviting to its meetings observers from the constituent societies. These observers are generally chairmen of the education committees of the several societies. They attend the full period of the committee meetings and

observe the same responsibility for the confidential nature of the discussions and recommendations as do the regular members of the committee. This writer attended the 1959 meetings as the Chairman of the ASCE Committee on Engineering Education.

This new procedure provides a liaison for assuring that the interests of the constituent societies are properly safeguarded. While such vigil is not necessary at present, the procedure provides assurance to the constituent societies and fosters education, goodwill, and cooperation. Only one of the societies, the American Institute of Chemical Engineers, exercises any special review power over the recommendations on chemical engineering curricula. As the pioneer group in engineering accreditation, the chemical engineers maintain the right to study each chemical engineering inspection report and to recommend appropriate action if necessary. By and large, however, the chemical engineers go along wholeheartedly with the ECPD inspections and recommendations.

It is recognized that the foregoing review of the objectives and procedures of accreditation by ECPD is cursory. The reader can get a more comprehensive understanding from the annual reports of ECPD, and the conferees are invited to ask questions during the discussion that will follow presentation of this paper.

#### Should Graduate Curricula in Sanitary Engineering be Accredited?

This question has received the attention of sanitary engineers in recent years. Indeed, it is a major question of this Conference. On 18 June 1959, an ad hoc group of sanitary engineering professors met at the ASEE convention in Pittsburgh and adopted the following motion:

"That the group approves in principle the accrediting of master's degree programs in the field of sanitary engineering by an appropriate professional agency to be determined by the American Sanitary Engineering Inter-society Board."

Undergraduate engineering education in the United States is undergoing at the present time a tremendous metamorphosis. Advanced mathematics, basic sciences, engineering sciences, and humanistic-social studies are taking so much time in the undergraduate program that specialized courses in the practice of engineering are being postponed to the graduate level. As a result, the former sanitary engineering options of civil engineering programs on the undergraduate level are rapidly disappearing, and sanitary engineering is being recognized as a specialty field for graduate study. Indeed, undergraduate programs in engineering are rapidly approaching the status of "pre-engineering," much the same as pre-law or pre-medicine. One does not have to use a crystal ball to foresee the day when undergraduate programs in the conventional fields of civil, electrical, mechanical, and chemical engineering will be replaced by pre-engineering, degree-eligible programs that will prepare the embryonic engineer for graduate study or for on-the-job training in almost any field of the broad engineering profession. The philosophy of this inevitable progress will be the subject of the ASCE-ASEE-NSF Conference on Undergraduate Curricula in Civil Engineering to be held at the University of Michigan on 6-8 July 1960. Many of the participants of this Sanitary Engineering Conference will probably attend the later Civil Engineering Conference.

One of the major problems facing the entire engineering profession today is not what will happen to the undergraduate curricula (for they will most certainly tend to become pre-engineering in character) but rather whether the advanced work should be carried out in a graduate school or in a professional school. Medicine, law, and theology have developed largely through professional schools. It is possible that engineering may follow in the same pattern within the next decade or two. In contrast, basic sciences have remained within the fold of the graduate academic programs leading generally to the Ph.D. degree. Within the graduate schools, the tradition of academic freedom has been strong enough to forestall any serious attempts at dictation or

regimentation by any program of certification or accreditation.

It appears, therefore, that the question of professional school versus graduate school is paramount to any decision relative to the merits of accreditation. If this Conference decides that graduate programs in sanitary engineering are to develop in the pattern of the professional school, accreditation appears to be inevitable. As a prelude to a debate on this question, let us consider some of the arguments in favor of each position.

#### The Case for Professional Schools and Accreditation

In the event that graduate programs of sanitary engineering develop within the administrative structure of professional schools of engineering (or in some universities within schools of public health), the following advantages of accreditation will probably accrue:

1. Sanitary engineering will be recognized truly as a professional field, possibly on a par with medicine, law, theology, and public health.
2. The technical content of curricula, the qualifications of staff members, and the physical facilities will be upgraded by frequent inspections, with the result that sanitary engineering education should improve tremendously.
3. Students will be better able to select schools that will provide superior education and will be assured of proper scope and intensity of training.
4. Fringe programs of a non-professional or mediocre level will be discouraged.
5. The staff and administration of each school will have approved criteria to serve as guidelines for improvement, and as a corollary advantage, administrations will be better able to judge their sanitary engineering staffs.
6. Graduates of accredited programs will be recognized as being competent in prescribed disciplines, whereas graduates of non-accredited programs will have to prove their competence by professional service and achievement.

7. State, federal, and professional agencies that utilize procedures for registration or certification will be assisted in the screening of candidates.

8. Employers of graduates of accredited programs will have a degree of assurance relative to the competency of the graduates.

9. Philanthropic groups, trade associations, and governmental agencies will have a better yardstick to measure the merit of schools to which they contribute or with which they contract. The USPHS, in particular, will be better able to select schools for traineeship awards, training grants, or block program support.

Without doubt, other advantages will become apparent to the reader and the conferees.

#### The Case for Graduate Schools and Non-Accreditation

At present, graduate programs of sanitary engineering are administered in most universities by the faculty of arts and sciences, through a Dean of Graduate Studies. There are many exceptions, to be sure, and in some schools parallel doctoral programs are offered, e. g. a student may aspire to the Ph. D. degree under the faculty of arts and sciences or he may settle for a Doctor of Engineering or a Doctor of Science degree under the engineering administration. The following advantages are suggested for affiliation of sanitary engineering programs with the graduate schools of arts and sciences, without accreditation;

1. Sanitary engineering will be recognized as an academic discipline, possibly on a par with physics, chemistry, biology, and other sciences, or with history, sociology, economics and related arts.

2. Doctoral candidates in sanitary engineering will be subjected to the same high academic requirements as those in any other scientific discipline.

3. Cross-fertilization with the basic sciences will be enhanced.

4. Individual professors of outstanding ability can have a great influence on small classes of one or two graduate students without having to build up

departments with broad coverage to meet requirements for accreditation. It is a tradition of graduate schools that a strong rapport exist between professors and a few advanced students.

5. Institutional freedom will be safeguarded.

6. Experimentation in curricula will be encouraged and uniformity will not be imposed by outside control.

Again, it is recognized that the reader and conferees may wish to expand this list, especially if they favor this position.

#### If It Is Advisable, How Should Accreditation Be Accomplished?

As described hereinbefore, the National Commission on Accrediting recognizes ECPD as the sole accrediting agency in engineering. With this restriction, it would be difficult to get permission for ASEIB to enter the accreditation field, without the concurrence or tacit approval of ECPD. One must consider, moreover, that three of the six constituent societies of ASEIB are also among the eight constituent societies of ECPD. It would be unrealistic for ASEIB to work at cross-purposes with ECPD. Consequently, there remains only one course of action for ASEIB, namely, to cooperate wholeheartedly with ECPD in accreditation.

Collaboration with ECPD might well take the following course. Guidelines for the use of ECPD inspectors could be drafted, approved, and proposed by ASEIB. Whenever a school requests that its professional or perhaps even its graduate curriculum in sanitary engineering be accredited by ECPD, the chairman of the inspecting committee could select (from a list approved by ASEIB) a sanitary engineer to accompany the inspecting team. The work of this sanitary engineer would be blended with the activities of the entire inspection team and the report and recommendation would be that of the team, to be cleared through the entire Education and Accreditation Committee of ECPD. This procedure was followed to a large extent in the accreditation of the graduate program in sanitary engineering at Berkeley in 1959, except that the sanitary



engineering member of the inspection team did not have any guidelines from a group such as ASEIB. Instead, he had to use his own judgment, augmented by the deliberations of the entire inspecting team.

The foregoing suggestion of collaboration is contingent upon a decision by ECPD that graduate curricula in sanitary engineering will be considered for accreditation. A favorable decision will open the way for continued accreditation of first degrees in sanitary engineering on the master's level and undoubtedly the number of requests for such accreditation will increase, in graduate schools as well as in professional schools.

If the subcommittee of the E. & A. Committee recommends against accreditation of any graduate curricula, if the whole committee sustains that recommendation, and if the recommendation is adopted by the Council members of ECPD, the sanitary engineering profession will be faced with a difficult decision. Indeed, all of the specialties of engineering that rely upon graduate education, will be confronted with the same problem. Three courses of action would then be open: (1) each specialty of engineering might inaugurate its own accreditation program, upon approval by the National Commission on Accrediting, with a resulting proliferation of visits to each campus, (2) the engineering disciplines might band together to form a new council for accrediting on the graduate level, to consolidate criteria and inspections much as ECPD does for undergraduate programs, or (3) further pursuit of graduate accreditation could be abandoned.

In considering the pros and cons of accreditation of graduate curricula in sanitary engineering, a distinction should be made between master's programs and those leading to higher degrees such as the Ph.D. One school may have a strong well-balanced program on the master's level, oriented primarily toward training in the practice of the profession with little emphasis on research. Another school may have a single brilliant research-minded sanitary engineer

who inspires one or two doctoral candidates each year but fails to develop a strong master's program. Should the first school gain the distinction of accreditation while the second one is scorned for failing to meet standardized requirements? In the epilogue of his book, Selden (1) asks several questions of this nature, which deserve serious consideration by any group interested in accreditation. (These questions will be read at the Conference.)

### Summary, Conclusions, and Recommendations

This "working paper" has attempted to present some historical and background information relevant to accreditation, to describe the objectives and procedures by which ECPD now handles accreditation of engineering programs, to discuss the question of graduate schools versus professional schools, to list the merits of accreditation and non-accreditation, and to suggest a program of collaboration with ECPD. It was the primary purpose of the paper to stimulate thoughtful discussion.

Four conclusions appear to be indisputable.

1. ASEIB should not engage directly in accreditation without the approval of the National Commission on Accrediting, which now recognizes ECPD as the sole agency in engineering, nor without the concurrence of the Office of Education, which publishes a list of nationally recognized accrediting agencies.

2. Undergraduate engineering education is undergoing a tremendous metamorphosis that will probably result in the adoption of pre-engineering curricula with specialized programs such as sanitary engineering being relegated to the graduate level.

3. A few master's programs in engineering have already been accredited by ECPD where they lead to the first degrees in engineering.

4. The critical decision relative to continued and expanded accreditation of graduate curricula for first degrees in engineering now rests with ECPD. It should be resolved within the next year. Until then, ASEIB should not take definitive action, although it can make its wishes known to ECPD.

Tentatively, the following recommendations are submitted:

1. ASEIB should take a strong position favoring the accreditation of master's programs in sanitary engineering, public health engineering, environmental health engineering, and related disciplines.
2. A resolution favoring this position should be transmitted to ECPD.
3. ASEIB should pledge full support of ECPD in the accreditation of master's programs and should provide guidelines or criteria for ECPD inspection teams.
4. In the event that ECPD elects not to continue accreditation of master's programs as first degrees in engineering, ASEIB should request permission to conduct its own accreditation program on the level of the graduate or professional school.

#### References Cited

1. Selden, William K., "Accreditation: The Struggle Over Standards in Higher Education" Harper and Brothers, New York (1960), 138 pp.
2. Tigert, John J., "Objectionable Practices of Accrediting Agencies" School Society, 50, 407 (1939).
3. Engineers' Council for Professional Development, 27th Annual Report, p. 28, for the year ending 30 September 1959.

APPENDIX VI.

INTRODUCTORY REMARKS AT OPENING OF CONFERENCE

By

Thomas R. Camp  
Chairman, A.S.E.I.B.

On behalf of the American Sanitary Engineering Intersociety Board, the Massachusetts Institute of Technology, Harvard University, and the National Science Foundation I wish to extend to you a cordial welcome to this Study Conference. We are grateful that so many have found it possible to give freely of your time and efforts to this important project. I wish you every success in your endeavors.

The objectives of this conference are twofold: first, to study the present and future educational needs of sanitary engineers in order to develop graduate curricula and general course contents and objectives to meet these needs; and second, to explore the advisability, the feasibility, and methods of accrediting master's degree programs in sanitary engineering. In order to assist you in your deliberations I will endeavor to paint a general picture of the present status of recruitment and education of sanitary engineers and of what I believe will be required for the future.

During the decade from 1947 through 1956 baccalaureate degrees with specialties or options in sanitary engineering numbered 1995, or about 200 per year; master's degrees numbered 1327, or about 133 per year; and doctor's degrees numbered 63, or about 6 per year. Taking due account of graduates who went on to obtain master's degrees and went further to obtain doctor's degrees, the total production per year was about 300. The total number of sanitary engineers in the United States is about 6000 which requires annual recruiting at the rate of about 200 per year, assuming an average tenure in practice of 30 years. These figures tend to indicate that we are losing about one third of our trainees to other fields.

In a recent survey of Sanitary Engineering Manpower by Frank A. Butrico and Israel Light of the Public Health Service it was found that almost two thirds of the practicing sanitary engineers are concentrated in the water-related fields of water supply, waste treatment, and water pollution control. Most of the remainder are occupied in general sanitary engineering work, with the largest number in any single specialty, industrial hygiene and occupational health, amounting to only 4.5% of the total. As you well know, we have never had enough properly trained sanitary engineers in the water-related fields; and with the present population explosion, the shortage is becoming acute. The demand for properly trained engineers in the fields of air pollution control and radiological health is also growing very fast. In my judgment, we could use from 10,000 to 12,000 properly trained sanitary engineers at the present time, and more will be needed in the future. The Public Health Service has estimated a need of about 22,000 by 1970.

For the past three years the number of engineering students enrolled in colleges and universities has decreased progressively. This is very unfortunate in that it occurs at a time when the need for engineers of all types

is on the increase. In our recruitment of sanitary engineers we must, therefore, compete not only with other branches of engineering, but also with other disciplines, particularly science which seems to have considerable glamour to young people today.

In my opinion the best way for engineering schools to meet the competition with science is to modify undergraduate engineering curricula so as to devote more time to science and engineering science with professional and practice courses deferred in large measure to graduate years. This is in line with the objectives of A. S. E. E.'s Grinter Report. In this way the undergraduate scientific preparation will be broad enough for any type of engineering practice or for a scientific career. This method of attack should be especially fruitful for sanitary engineering because it will produce a very much larger reservoir of potential candidates for graduate training in sanitary engineering.

A major objective of this conference is to improve graduate curricula in sanitary engineering. This objective necessitates an improvement in undergraduate preparation for the graduate courses. The upgrading in the education of sanitary engineers may make recruitment more difficult in the immediate future. It is absolutely essential, however, to an improvement in the competence of sanitary engineering personnel and in the long run it should make the field more attractive to bright young men who are seeking a challenging career.

In your deliberations, you will consider the essential undergraduate prerequisites for graduate study in sanitary engineering. You have a vital interest therefore in the improvement of undergraduate curricula. As many of you know, there will be a conference on civil engineering education at the University of Michigan July 6-8. The conference on civil engineering education is sponsored by the Cooper Union, the A. S. C. E., the A. S. E. E., and the National Science Foundation. Its objective is to improve undergraduate civil engineering curricula. Doubtless many of you will attend the Ann Arbor conference. I hope you will press for adequate undergraduate preparation for advanced training in sanitary engineering.

In our recruitment of new personnel into sanitary engineering practice, we must compete with private industry or we will not get the best men or the numbers we require. We can offer interesting and challenging work; but so can many other fields of endeavor, some of which are highly remunerative. Although most of the vocational guidance literature on sanitary engineering is slanted in favor of careers in government, the best opportunities for creative endeavor and for advancement in the sanitary engineering field are in private engineering practice. The aforementioned report by Butrico and Light on Sanitary Engineering Manpower indicates a median income for self-employed sanitary engineers which is 60% higher than the median income for any other category. A review of the 1959 Roster of the American Academy of Sanitary Engineers shows that 22.6% of all the diplomates are principals engaged in the private practice of engineering, and 6.9% are employees of engineering firms. It is probable that there are many more young sanitary engineers employed by private engineering firms who have not yet qualified for certification by the A. S. E. I. B. According to the aforementioned survey of Sanitary Engineering Manpower, about 50% of the engineers who responded to the questionnaire are employed by government. The

April 1960 "Scientific Manpower Bulletin" shows that about 45% of the sanitary engineers in the National Register of Scientific and Technical Personnel, 1956-1958, were listed as in industry, business or self-employed. In my judgment about 40% of all sanitary engineers are in private engineering practice, either self-employed or employed by engineering firms. This field of opportunity for future sanitary engineers is bound to expand not only in the water-related fields but even more rapidly in the air-related and radiological health fields. These facts should be fully exploited in vocational guidance of high school and undergraduate engineering students.

The latest figures indicate that the number of candidates for the master's degree in sanitary engineering has dropped to 120 or less. The Sanitary Engineering Education Directory, published in January 1960 by the A.S.E.I.B., reveals that there are 65 colleges and universities offering master's degrees in sanitary engineering or in civil engineering with specialties in sanitary engineering. This indicates an average of less than two candidates for the master's degree per institution. In my opinion this is academic freedom gone wild. At least four to six staff members should be required at any institution for adequate instruction in all of the disciplines required for any specialty in the field of sanitary engineering. With such a staff and the necessary laboratory equipment, it is hardly economical to have less than 20 to 30 students per year. If graduate curricula in sanitary engineering are to be accredited, perhaps one objective of such accreditation would be to correct the above described situation.

Further review of the Sanitary Engineering Education Directory reveals that approximately 290 professors and instructors in this country are engaged in teaching or research in some aspect of sanitary engineering. Since the total production of sanitary engineers from our colleges and universities in one year is about 300, including both baccalaureate and graduate degrees, there is an equivalent of about one professor or teacher working part time or full time for each recruit produced. This seems to me to be highly uneconomical. In view of the fact that substantially all of our colleges and universities are hard put to it these days to secure enough funds, and all of them are dependent in part upon the taxpayer or endowments, a general reorganization should be considered to reduce the number of persons teaching sanitary engineering.

The American Sanitary Engineering Intersociety Board is dedicated to the advancement of sanitary engineering. The Board is therefore interested in improvement in the training of sanitary engineers and improvement in the quality and number of recruits to the field. We ask your help in these endeavors.

## APPENDIX VII.

### REGISTERED CONFERENCE PARTICIPANTS

<u>Name</u>	<u>Affiliation</u>
Baird, C. O., Jr.	Northeastern University
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