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**Research Activities
in the School of Engineering
1962-1964**

DISCARD

J. G. KNUDSEN
Assistant Dean of Engineering
Oregon State University

THE Oregon State Engineering Experiment Station was established by act of the Board of Regents of Oregon State University on May 4, 1927. It is the purpose of the Station to serve the state in a manner broadly outlined by the following policy:

(1) To stimulate and elevate engineering education by developing the research spirit in faculty and students.

(2) To serve the industries, utilities, professional engineers, public departments, and engineering teachers by making investigations of interest to them.

(3) To publish and distribute by bulletins, circulars, and technical articles in periodicals the results of such studies, surveys, tests, investigations, and research as will be of greatest benefit to the people of Oregon, and particularly to the State's industries, utilities, and professional engineers.

To make available the results of the investigations conducted by the Station, three types of publications are issued. These are:

(1) BULLETINS covering original investigations.

(2) CIRCULARS giving compilations of useful data.

(3) REPRINTS giving more general distribution to scientific papers or reports previously published elsewhere, as for example, in the proceedings of professional societies.

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OREGON STATE ENGINEERING EXPERIMENT STATION,
CORVALLIS, OREGON

RESEARCH ACTIVITIES IN THE
SCHOOL OF ENGINEERING
OREGON STATE UNIVERSITY
1962-1964

By

JAMES G. KNUDSEN
Assistant Dean of Engineering

CIRCULAR NO. 31
SEPTEMBER 1964

Engineering Experiment Station
Oregon State University
Corvallis, Oregon

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RESEARCH ACTIVITIES IN THE
SCHOOL OF ENGINEERING
OREGON STATE UNIVERSITY
1962-1964

ENGINEERING EXPERIMENT STATION

G. W. Gleeson, Dean, School of Engineering
Director, Engineering Experiment Station

J. G. Knudsen, Assistant Dean, in Charge of
Engineering Experiment Station

INTRODUCTION

For many years Oregon has recognized the need for research to aid agriculture and forest and wood industries, and has actively supported research in these vital fields. It was not until comparatively recently, however, that the Engineering Experiment Station was established to further engineering research. In spite of the minor amount of support through State funds, the Station since 1927 has contributed a great deal of information and assistance to local industry through publication of more than 150 bulletins, circulars, and reprints of technical articles. These publications have resulted from research and investigations of the faculty and graduate students of the School of Engineering. Titles of the publications are listed on page 77 of this circular.

The Engineering Experiment Station, along with the entire School of Engineering, is a member of the Engineering College Research Council and the American Society for Testing Materials. Staff members of the Station and of the various departments of the school are members of important engineering societies such as the American Society of Civil Engineers, American Society of Mechanical Engineers, Institute of Electrical and Electronic Engineers, American Institute of Chemical Engineers, Society of Automotive Engineers, American Society of Heat and Air Conditioning Engineers, Society for Advancement of Management, and others. A majority of the faculty members are registered professional engineers of the State of Oregon.

ORGANIZATION

By act of the Board of Regents of Oregon State University on May 4, 1927, the Engineering Experiment Station was established at Corvallis to serve the State in a manner broadly outlined by the following policy:

1. To serve the industries, utilities, professional engineers, public departments, and engineering teachers by making investigations of significance and interest to them.
2. To stimulate and elevate engineering education by developing research spirit in faculty and students.
3. To publish and distribute through bulletins, circulars, and technical articles in periodicals the results of such studies, surveys, tests, investigations, and research as will be of greatest benefit to the people of Oregon, and particularly to the State's industries, utilities, and professional engineers.

The Engineering Experiment Station is an integral part of the School of Engineering. All staff members and laboratory facilities of the engineering school are available for the investigative work of the Station to the extent of funds allocated or contributed for this purpose.

The dean of engineering is director of the Engineering Experiment Station and guides its operation to conform with State and institutional policies. The assistant dean of engineering acts as the administrator in charge, technical editor of publications, and chairman of the Station executive council, which is composed of senior staff members representing the various departments of the School of Engineering.

The active staff is composed of members of the instructional staff who may be interested in various specific research projects, or of research fellows who are pursuing graduate study and are assigned to part-time work in the Station.

FACILITIES

A large portion of the physical facilities for carrying on research in the Engineering School is located in the various departments of engineering and, therefore, described separately in these sections. The Engineering Experiment Station, however, does have a limited amount of capital equipment, and it may be used by

anyone who has specific need for it in his research project. As a rule, equipment to be used mostly by one department will be purchased by that department.

Research space is provided mainly in the various engineering department buildings. The Engineering Experiment Station, however, has under its jurisdiction a laboratory having 10,000 square feet of floor space which is available for research projects having special area and height requirements. Research apparatus requiring as much as 20 feet of headroom may be installed in this building.

Considerable precision measuring and analytical equipment is located in the individual engineering departments. However, when necessary, the Engineering Experiment Station may receive technical assistance from other departments on the campus. A variety of up-to-date instruments are available, including an electron microscope, chromatographs, mass spectrometer, and various spectrophotometers. The Radiation Center has extensive facilities and equipment to service those research projects which involve the use of radioactive materials. A variety of computing facilities are available to researchers. The Statistics Computing Laboratory is equipped with an IBM 1410. In addition, it has an IBM 1013 Teleprocessor to the IBM 7094 of the Western Data Processing Center at UCLA. An IBM 1620 on the campus is used mainly for instructional purposes, but is available for research computing. This machine also is linked with an IBM 1627 plotter. In addition, the Mathematics Department has an ALWAC III-E digital computer and an analog computer is located in the Mechanical Engineering Department.

One of the most valuable of campus research facilities is the University library, which has an outstanding science and technology division. This division contains 200,000 volumes. In addition, library subscriptions to scientific and engineering periodical literature are exceptionally complete. A more detailed description of the University library is presented in Engineering Experiment Station Circular No. 32.

In carrying out research which involves fields outside of engineering, the Engineering Experiment Station may cooperate with the Agricultural Experiment Station, the Forest Research Laboratory, the Science Research Institute, the Marine Sciences Laboratory at Newport, the USPHS Pacific Northwest Water Pollution Laboratory, and various other state and federal agencies. As the list of various research projects described in

the following pages will show, such agencies as the Bureau of Public Roads, U. S. Public Health Service, Corps of Engineers, Bonneville Power Administration, Bureau of Mines, State Highway Department, and State Fish Commission are cooperators or supporters of research.

OPERATING POLICIES

Financial sponsorship of research is provided by the Engineering Experiment Station to the extent of the limited funds provided for that purpose. Research projects for Station sponsorship must be approved by the executive committee of the Station. In most cases, individual departments of the School of Engineering and the Station share responsibilities in financing research projects. The Station purchases expendable materials and provides research assistants when necessary.

The Station may contract for research sponsored by other state agencies, by federal agencies, or by industrial organizations if there is evident instructional and research value to the university.

There are several ways by which agencies and industrial organizations may sponsor research with the Engineering Experiment Station. These are outlined below with the distinguishing features of each method indicated.

Research Project

An organization may desire or need research on a specific problem in connection with its operations. The Engineering Experiment Station may undertake this research if there is apparent educational value in such work. The work will be directed by an engineering staff member competent in the particular field of research involved. The sponsoring organization provides funds to pay all costs, including salaries and wages of personnel involved, accident and retirement benefits for personnel, and special equipment, materials, supplies, and indirect costs. Indirect costs are a fixed percentage of salaries and wages, this percentage being determined by the University Business Office on the basis of federal audit of the sponsored research projects on the campus. Title to equipment purchased on a research project may or may not be vested with the Station, depending upon agreement made at the initiation of the work. Special areas of staff competence are listed elsewhere in this circular.

Cooperative Research Project

An organization may be interested in research in a field which is related to its activities but not directed toward a specific or an immediate problem. Such research may often be in a field that is part of the on-going research program of some engineering staff member. In such cases a cooperative research project is arranged whereby a sponsor and the University share the costs of the research. In these instances, the sponsoring organization pays salaries and wages of the personnel, accident and retirement benefits, materials and supplies, and a portion of the indirect costs. The University provides laboratory facilities and the capital equipment necessary for the carrying out of the research project. Indirect costs normally charged on cooperative research projects are one-half the indirect costs charged on research projects formerly described. In such cooperative research projects, the costs to the sponsor and to the University are approximately equal.

Research Assistantship

Industrial organizations may sponsor research in a field of their interest by granting a sum of money to the University to establish a research assistantship for a graduate student. Such research assistantships are normally accompanied by a cost of education allowance which is designed to cover the student's tuition, and materials and supplies for the research which he undertakes. Normally, under such arrangements, no money is available for the staff member who directs the graduate student. It must be realized, however, that the research conducted under such an arrangement will be of a nature that it adds to the state of knowledge in a field in which an organization is interested. It cannot be carried out to solve a particular applied problem that the company may have. Such problems are more appropriately handled under research projects.

In comparing the above means by which research may be sponsored by an industry with the Engineering Experiment Station, it will be noted that the degree to which the information obtained is directly applicable to the company's operation decreases from research projects to research assistantships. The research must have instructional value and be in line with the educational aims of the University. In all cases, however, the information obtained constitutes a definite contribution to knowledge.

According to Section C-10 of the Administrative Code of

the State System of Higher Education, the following provisions apply specifically to research sponsored by industrial organizations:

1. The study shall be made in the most modern, approved, and scientific manner and shall be prepared for publication in a scientific treatise, the same as any other, regardless of whether the results are favorable to or unfavorable to the product; and the result shall become available to the donor of the grant at the same time.

2. It shall be understood that the results of the findings shall in no manner be influenced by anything except the scientific conclusions.

3. The institution conducting the research shall not recommend individual products by commercial names, but shall give the results of its research with regard to the particular product and its opinion concerning the value of certain methods of preparing such a product.

4. The departments of the institution reserve the right to publish all or any portion of any investigation. The donor will, however, be supplied with the results before publication.

Policies and terms of a contract with agencies or industrial organizations are stipulated in a specific written agreement. Responsibilities of the sponsor and the University are included along with statements concerning records and reports, access of sponsor to facilities, records and accounts of the University, subcontracting, patent provisions, period of the contract, and any other pertinent general conditions that may be specified. (See pages 10 and 11.)

In some instances it may be advantageous to administer research contracts directly through departments of the School of Engineering. In such cases, policies and contract arrangements are the same as for research administered by the Engineering Experiment Station.

Patent Policy

The following text concerning patent policy is taken from a portion of Section C-10 of the Administrative Code of the State System of Higher Education:

- A. Objectives of patent policy.
 - 1. Assist personnel of higher educational institutions in developing and protecting inventions.
 - 2. Promote public welfare by patenting inventions and by controlling marketing of products or processes resulting therefrom to the end that there shall be the greatest possible benefit to the public.
 - 3. Determine equities and interests of all parties concerned with inventions.
 - 4. Promote further research.

- B. Agreement governing assignment of patent rights of inventor.
 - 1. An employee who develops what is considered to be a patentable invention must report findings to and confer with the institutional patent committee.
 - 2. Persons whose employment arrangements specifically provide for the performance of research duties, either full time or part time, must enter into a patent assignment agreement for all patentable inventions developed in the course of such research. For other employees, if the patent committee finds that institutional facilities or services were used to develop an invention, the inventor is expected to enter in a patent assignment agreement.

The institutional patent committee is appointed from the faculty to counsel with inventors, evaluate patent possibilities, appraise equities of the inventor, counsel with institution executives, and to negotiate contractual agreements with inventors. Such agreements are to be negotiated in collaboration with and approved by the Chancellor of the State System of Higher Education.

The comptroller and secretary of the board of the State System of Higher Education are authorized to enter into contracts in order to obtain patent assignments for the State from research staff members and to enter into necessary agreements or assign-

ments with the Research Corporation, a nonprofit organization for development of patents, or with others, to secure maximum benefit from inventions. Invention and patent rights may be released to inventor when it has been determined that ownership of such rights does not appear to be of benefit to the State.

Where funds for a research project are provided by an industrial organization, inventions and patent rights are to be handled in such a way that the industrial organization may be given the right to use the invention or patent license free within its plants, but all other invention and patent rights are to accrue to the benefit of the institution and the inventor.

In instances where an industrial concern requires exclusive patent rights, conditions of the research contract may be negotiated with the State Board of Higher Education.

Service Testing

In some instances, testing or routine investigations are desired by industrial firms, contractors, or governmental agencies. These investigations are not considered research because the University makes no decisions concerning conduct of the program. Engineering personnel merely conduct tests as specified by the firm or agency. Many times these follow standard testing procedures.

Testing services of the School of Engineering are not intended to compete with commercial laboratories. A considerable amount of testing is done, however, which requires unique equipment not available at commercial laboratories. Some testing service is performed at the insistence of contractors for their convenience when construction is being done in the vicinity of Corvallis.

Charges for testing services are made on the same basis as for research; i. e. , direct costs plus overhead charges. In most instances charges for testing by various engineering departments of the school will be higher than charges of commercial laboratories because of setup time. In addition, charges may vary because testing is done by any staff member, from instructor to full professor, who has time available to perform the task most expeditiously. In any event, there can be no guarantee that testing work not arranged for in advance can be done immediately. A testing staff is not maintained; faculty members must assign high-priority to the duties of teaching.

Industrial firms, individuals, and various agencies desiring testing services arrange for such activities directly with departments having the necessary equipment. If the testing program is of long duration or involves very great expense, contracts, letter agreements, or detailed purchase requests are employed to specify work desired and any other conditions. Individual tests and programs of short duration are usually arranged informally.

SAMPLE AGREEMENT FOR A

RESEARCH PROJECT

AGREEMENT

THIS AGREEMENT, dated _____, made and entered into by and between the _____ COMPANY, hereinafter called "Company", and the STATE OF OREGON, by and through the Oregon State Board of Higher Education on behalf of Oregon State University, hereinafter called "University".

WITNESSETH:

RECITALS:

1. Company desires to conduct research project to study _____.
2. University has at its disposal the personnel, facilities, and equipment to conduct the necessary study.

NOW, THEREFORE, the premises being in general as stated in the foregoing RECITALS, it is agreed by and between the parties hereto as follows:

THINGS TO BE DONE BY UNIVERSITY:

1. University shall assign personnel to perform the research.
2. University shall, in the first instance pay all the costs incurred by it in conducting the project and submit to the company not oftener than once a month the bills covering its current project costs. Upon completion of the project, or upon termination of the project, University shall submit to Company an itemized statement of all its project costs not previously reimbursed.
3. The work of the project is to be performed by the personnel of the Department of _____ at Oregon State University under the general direction of the Director of the Engineering Experiment Station. The work will be under the specific direction of Professor _____ of the Department of _____. For purposes of consultation and cooperation the University designates _____, Assistant Dean of Engineering, to represent it on behalf of the Engineering Experiment Station.
4. For the duration of this agreement University shall submit periodic reports (monthly, bimonthly, semiannually, annually, etc.). At the completion of the work a final report will be submitted within _____ months of the expiration date of the agreement.

THINGS TO BE DONE BY COMPANY:

1. Within _____ days of receipt from University of bills covering the current costs of the project, as referred to in paragraph 4 under THINGS TO BE DONE BY UNIVERSITY, Company shall audit and pay to University the amount of said bills, and upon completion of the project, or termination of the project, and receipt from University of an itemized bill for all costs for which University has not been previously reimbursed, as also referred to in paragraph 4 under THINGS TO BE DONE BY UNIVERSITY, Company shall pay to University all of the remaining and unpaid costs of University in conducting the work on the project.

S A M P L E

- 2 -

2. The actual total cost of the project for the period of this agreement, and the amount paid to University by Company for the period of this agreement, shall not exceed \$_____.

GENERAL PROVISIONS:

1. Exhibit A, The Proposal, gives the name of the study, a statement of reasons for undertaking it, its objectives, proposed procedure, and other information helpful in appraising the importance of the work and its scope.

2. Exhibit B, The Budget, lists items which are included in the term "costs" as used in paragraph 2 under THINGS TO BE DONE BY UNIVERSITY. Amounts opposite each item are estimates only. Items of cost shall include salaries and wages of personnel performing work of the project; old age and survivors insurance, state industrial accident insurance and retirement system payments for said personnel; equipment, materials, supplies, services, transportation, secretarial help, plus _____ percent (as established by the University business office on the basis of audit) of salaries and wages of personnel to cover any other indirect costs of the project.

3. Results of a general or fundamental nature which are a direct result of this work and which may be described without reference to information furnished by Company or pertinent to the business may be published in recognized technical journals or other publications but only by written consent from Company and subject to review by Company. The participation of Company will be acknowledged in such publications.

4. The Patent Policy of the University will be assumed to be applicable unless other arrangements have been agreed to between Company and University.

5. This agreement shall be in full force and effect from _____ to _____ and by mutual agreement of the parties may be extended _____ for periods of _____ year (s) or less.

6. This agreement may be terminated at any time by either party, upon such party's giving 30 days written notice to the other party.

IN WITNESS WHEREOF, the parties hereto have set their hands and affixed their seals as of the day and year hereinafter written.

OFFICIAL SIGNATURES OF
COMPANY

STATE OF OREGON, by and through
the Oregon State Board of Higher
Education on behalf of Oregon
State University

by _____
Secretary

by _____
Comptroller

Date _____

AREAS OF COMPETENCE OF THE SCHOOL OF ENGINEERING FACULTY

Each staff member of the School of Engineering has research and development capabilities in one or several areas of engineering. The composite of these areas of competence encompasses nearly every area in engineering.

The following list gives these special areas for each faculty member. The list is divided into two sections. The first section lists the various areas, and the numbers in parentheses refer to the staff members listed in the second section. Likewise, the numbers in parentheses in the faculty listing in the second section refer to the specialty areas in the first section.

SPECIALTY AREAS

1. Audio Visual Equipment, (13)
2. Chemical Kinetics
 - a) Reactor Design, (32)
3. Coastal Engineering, (5)
4. Communication, (72)
 - a) Telephone, (1)
 - b) Radio, (1), (19)
 - c) Television, (19)
 - d) Microwave, (1), (2)
 - e) Video Recording and Reproduction, (19)
 - f) Data Transmission, (19)
5. Computers - Digital and Analog
 - a) Systems, (68)
 - b) Design, (66)
 - c) Simulation, (68)
 - d) Application, (18), (30), (57)
6. Control
 - a) Systems, (68)
 - b) Competence and Reliability, (69)
 - c) Processes, (11)
 - d) Measurement, (11)
 - e) Dynamics, (65)
 - f) Special Areas, (69), (51)
7. Design
 - a) Timber, (27), (42)
 - b) Concrete, (27), (29), (53)

- c) Steel, (27), (53)
 - d) Rigid Frames, (27)
 - e) Plastic Analysis, (27), (29), (42)
 - f) Lightweight Concrete, (4)
 - g) Highway - Base and Pavement, (4), (12), (67)
 - h) Retaining Walls, (4)
 - i) Footings, (4)
 - j) Earth Dams, (6)
 - k) Powerplants, (28)
 - l) Structural, (29), (34), (53), (60)
 - m) Foundations, (34), (6)
 - n) Machine, (31), (56), (63)
 - o) Reactor (Chemical) and Vessels, (29), (77)
 - p) Mechanisms, (63)
 - q) Cooling Towers, (66)
 - r) Governors, (66)
 - s) Product, (62)
 - t) Jigs and Fixtures, (62)
 - u) Furniture, (26)
 - v) Light Construction, (35)
 - w) Dynamic, (29)
 - x) Automotive, (47), (54)
 - y) Shells, (65)
8. Economy, (41), (17), (19), (58)
9. Electrochemistry
- a) Electrochemical Cells, (43)
 - b) Batteries, (43)
 - c) Energy Conversion, (43)
 - d) Electro Deposition, (43)
 - e) Corrosion, (43)
10. Electronics
- a) Pulse Circuits, (3), (39)
 - b) Solid-State Devices, (3), (39)
 - c) Display Devices, (3)
 - d) Instrumentation, (46)
 - e) Switching, (72)
 - f) Circuit Reliability, (72)
 - g) Circuit Design, (72)
11. Energy Production and Use
- a) Solar, (28)
 - b) Electric Power, (18)
 - c) Automotive, (47), (54)
 - d) Electrochemical, (43)

12. Energy Transfer
 - a) Heat Transmission, (33), (36), (70), (73), (75)
 - b) Electrical Transmission Systems, (18), (40)
 - c) Vibrating Systems, (25), (36)
 - d) Colorimetry, (48), (73)
 - e) Power Systems, (18)
 - f) Super Conduction, (18)
13. Fluid Mechanics, (22), (33), (64)
 - a) Hydrodynamics, (64)
 - b) Groundwater Movement, (64)
 - c) Canals, (10)
 - d) River Systems, (5)
 - e) Hydrology, (10)
14. Graphics, (10), (13), (23), (67)
 - a) Descriptive Geometry, (21), (24)
15. Heating, Air Conditioning, and Refrigeration, (15)
 - a) Plant Design, (28)
 - b) Construction, (28)
 - c) Testing, (28)
16. High Voltage
 - a) Corona, (68)
 - b) Radio Noise, (68)
17. Hydraulic Machinery, (44)
 - a) Pumps, (56), (64)
 - b) Turbines, (44)
18. Mass Transfer
 - a) Diffusion, (74)
 - b) Vapor-Liquid, (71), (74)
 - c) Materials Handling, (29)
 - d) Transportation, (12), (41)
19. Materials
 - a) Structural, (37)
 - b) Nonmetallic, (25)
 - c) Nuclear, (25)
 - d) Testing, (25), (52)
 - e) Low Temperature, (50)
 - f) Metallic
 - g) Failures, (50), (52)
 - h) Measurement, (25), (50)
 - i) Examination, (50), (52)

- 20. Material Separation
 - a) Solvent Extraction, (45)
 - b) Adsorption, (45)
 - c) Crystallization, (45)
 - d) Ion Exchange, (45)
 - e) Ore Dressing, (77)
- 21. Mathematical and Numerical, (37), (40), (51), (33)
 - a) Models, (17)
 - b) Systems, (17)
 - c) Analysis, (2), (37), (51), (75)
- 22. Metallurgy
 - a) Physical, (8), (50)
 - b) Solid State, (8)
 - c) Rare Earth, (71)
- 23. Microbiological
 - a) Sanitary, (38)
 - b) Fermentation, (38)
 - c) Stream, (38)
 - d) Food, (38)
- 24. Nuclear
 - a) Instrumentation, (46)
 - b) Reactor Analysis, (15)
 - c) Materials, (25)
 - d) Systems, (31)
 - e) Separations, (45)
- 25. Oils
 - a) Essential Oil Distillation, (28)
 - b) Lubricants, (47)
- 26. Production Operations
 - a) Machining, (20), (57), (62)
 - b) Casting, (20)
 - c) Finishing, (26), (76)
 - d) Operational Analysis, (17)
 - e) Metal Forming, (57), (59), (76)
 - f) Millwork, (26)
 - g) Pattern Making, (76)
 - h) Cabinet Making, (76)
 - i) Quality Control, (58)
 - j) Scheduling, (35), (58)
 - k) Process Dynamics, (11)
- 27. Sanitation, (67)
 - a) Air, (7), (47), (54)
 - b) Industrial Hygiene, (7)

- c) Water, (9), (49), (55)
 - d) River, (9), (61)
 - e) Waste Disposal, (44)
28. Soil Mechanics, (6), (60)
29. Stress Analysis
- a) Photoelastic, (14)
 - b) Experimental, (14)
 - c) Vibrations, (16)
 - d) Data Reduction, (16)
30. Structures
- a) Design, (34), (29)
 - b) Inspection, (50), (52), (34)
 - c) Testing, (25), (52)
 - d) Stability, (65)
 - e) Prestressed, (60)
 - f) Timber, (27), (42)
 - g) Dynamics, (37), (65)
 - h) Folded Plate, (14), (42)
 - i) Concrete, (42), (27), (29)
 - j) Steel, (27), (53)
 - k) Minimum Weight, (14)
31. Surveying, (23), (60)
32. Thermodynamics, (48)
- a) High Temperature, (74)
 - b) Metallurgical, (73)
 - c) Liquids and Gases, (11)
33. Water Supply, (44), (55)
- a) Quality, (9), (44), (49)
 - b) River Basin Analysis, (9), (61)
34. Waste Treatment
- a) Industrial, (9), (49)
 - b) Domestic, (9)
 - c) Sawmill, (49)
 - d) Bio-oxidation and Biological, (55)
 - e) Servers, (44)
35. Welding
- a) Arc, (21), (59)
 - b) Inert Gas, (59)
 - c) Resistance, (59)

SCHOOL OF ENGINEERING FACULTY

1. Albert, A. L. , (4a), (4b), (4d)
2. Alexander, G. C. , (4d), (21c)
3. Amort, D. L. , (10a), (10b), (10c)
4. Beecroft, G. W. , (7f), (7g), (7h), (7c)
5. Behlke, C. E. , (3), (13d)
6. Bell, J. R. , (7j), (7m), (28)
7. Boubel, R. W. , (27a), (27b)
8. Bucy, D. A. , (22a), (22b)
9. Burgess, F. J. , (27c), (27d), (33a), (33b), (34a), (34b)
10. Campbell, J. C. , (13c), (13e), (14)
11. Cochrane, G. F. , (6c), (6d), (26k), (32c)
12. Coopey, M. P. , (7g), (18d)
13. Croff, H. L. , (1), (14)
14. Dahlke, H. J. , (29a), (29b), (30h), (30k)
15. Daly, E. A. , (15), (24b), (26d)
16. Edelman, W. E. , (29c), (29d)
17. Engesser, W. F. , (8), (21a), (21b)
18. Engle, J. F. , (5d), (11b), (12b), (12e), (12f)
19. Feikert, G. S. , (4b), (4c), (4e), (4f), (8)
20. Frazier, L. M. , (26b)
21. Garrard, J. L. , (14a), (35a)
22. Geller, E. W. , (13)
23. Gray, J. L. , (10), (31)
24. Haith, M. R. , (14a)
25. Heath, C. O. , (12c), (19b), (19c), (19d), (19h), (24c), (30c)
26. Hoeye, W. D. , (7a), (26c), (26f)
27. Holcomb, G. W. , (7a), (7b), (7c), (7d), (7e), (30f), (30i), (30j)
28. Hughes, A. D. , (7k), (11a), (15a), (15b), (15c), (25a)
29. Jarvi, A. O. , (7b), (7e), (7l), (7o), (7w), (18c), (30a), (30i)
30. Jensen, L. C. , (5d)
31. Johnson, L. E. , (7n), (24d)
32. Jost, D. E. , (2a)
33. Knudsen, J. G. , (12a), (13), (21)
34. Kofoid, O. , (7l), (7m), (30a), (30b)
35. LaBaun, G. B. , (7v), (26j)
36. Larson, M. B. , (12a), (12c)
37. Laursen, H. I. , (19a), (21), (21c), (30g)
38. Levin, R. E. , (23a), (23b), (23c), (23d)
39. Looney, J. C. , (10a), (10b)
40. Magnusson, P. C. , (12b), (21)
41. Matthias, J. S. , (8), (18d)
42. McClellan, T. J. , (7a), (7e), (30f), (30h), (30i)
43. Meredith, R. E. , (9a), (9b), (9c), (9d), (9e), (11d)
44. Merryfield, F. , (17), (17b), (27e), (33), (33a), (34e)

45. Meyer, W. , (20a), (20b), (20c), (20d), (24e)
46. Michael, R. R. , (10d), (24a)
47. Mingle, J. G. , (7x), (11c), (25b), (27a)
48. Mrazek, R. V. , (12d), (32)
49. Northcraft, M. , (27c), (33a), (34a), (34c)
50. Olleman, R. D. , (19e), (19g), (19h), (19i), (22a), (30b)
51. Oorthuys, H. J. , (6f), (21), (21c)
52. Paasche, O. G. , (19b), (19f), (19g), (19i), (30b), (30c)
53. Pan, S. , (7b), (7c), (7l), (30j)
54. Paul, W. H. , (7x), (11c), (27a)
55. Phillips, D. C. , (27c), (33), (34d)
56. Richardson, R. L. , (7n), (17a)
57. Riesland, E. , (5d), (26a), (26e)
58. Riggs, J. L. , (8), (26i), (26j)
59. Robley, A. A. , (26e), (35a), (35b), (35c)
60. Schultz, R. J. , (7l), (28), (30e), (31)
61. Seaders, J. , (27d), (33b)
62. Sheely, M. C. , (7s), (7t), (26a)
63. Slegel, L. , (7n), (7p)
64. Slotta, L. S. , (13), (13a), (13b), (17a)
65. Smith, C. E. , (6e), (7y), (30d), (30g)
66. Smith, W. W. , (56), (7q), (7r)
67. Staton, W. , (7q), (10), (27)
68. Stone, L. N. , (5a), (5c), (6a), (16a), (16b)
69. Stone, S. A. , (6a), (6f)
70. Thornburgh, G. E. , (12a)
71. Walton, J. S. , (18b), (22c)
72. Weber, L. J. , (4), (10e), (10f), (10q)
73. Welty, J. R. , (12a), (12d), (32b)
74. Wicks, C. E. , (18a), (18b), (32a)
75. Wilson, R. E. , (12a), (21c)
76. Wilson, R. C. , (26c), (26e), (26g), (26h)
77. Gleeson, G. W. , (7o), (20e)

RESEARCH PROJECTS

On the following pages are listed 105 research projects which have been active during the period 1962-64. These are listed according to the engineering department in which they are conducted. A short description follows the title of the project, and the names following the description indicate the principal investigator (underlined) and research assistants. Names in parentheses indicate the source of financial support for the project.

Research described herein is supported in a variety of ways: by direct sponsorship of outside agencies, by federal training grants designed to augment research in specific areas, by limited support of state funds budgeted to the Engineering Experiment Station and to the various engineering departments, and by individual staff members themselves through contributing their time to conduct research.

Of the projects listed, 33 receive major financial support from federal agencies; 4 are sponsored by state agencies; 17 by private industry; 15 receive support from the Engineering Experiment Station, mainly through research assistantships to students and through a limited amount for supplies and materials; 8 receive some support from the General Research Fund of the University; and 41 have been supported with departmental funds, mainly through teaching assistantships to graduate students and through a limited amount for supplies and materials.

During the 1963-64 year, the total amount spent for research in the Engineering School amounted to over \$440,000. This figure may be broken down into the items shown in Table 1, which indicate the sources of support during the year. The major source of support of research projects comes mainly from federal agencies, which accounts for nearly 40 percent of the total. The next largest source of support is in the form of United State Public Health Service training grants in sanitary engineering, which accounts for over 20 percent of the total.

It will be noted from Table 1 that about 30 percent of the total financial support of research in the School of Engineering is derived from various federal grants. These training grants are designed to augment or initiate research and graduate training in specific engineering areas. A summary of the various training grants that are active in the School of Engineering is shown in Table 2. The School of Engineering receives training grant support from U. S. Public Health Service in the field of sanitary

Table 1.
Sources of Research Support in the School of Engineering

Source	Annual Expenditure 1963-64	Percent of Total
Direct sponsorship of research projects by state and federal agencies	\$175,000	39.5
Direct sponsorship by private industry	31,500	7.1
USPHS sanitary engineering training grants*	92,800	21.0
National Defense Education Act - Title IV (five fellowships plus cost of education allowance)	25,000	5.7
National Aeronautics and Space Agency training fellowships (two fellowships plus cost of education allowance)	12,000	2.7
Support through state funds (Engineering Experiment Station, General Research Fund, and departmental support)	40,000	9.0
Fellowships (sixteen fellowships plus cost of education allowance on several)	<u>66,500</u>	<u>15.0</u>
Total	\$442,800	100.0

*Does not include training grant in Air Pollution Control at \$34,000/year effective 4/1/64.

Table 2.
Summary of Training Grants in the School of Engineering

Grant	Purpose	Annual Amount 1963-64
US Public Health Service PHT-1-30	Program development and training in water supply, waste disposal, air pollution, etc.	\$ 26,000
USPHS WP-25 and WP-25-0351	Project training - water pollution control	50,100
USPHS SP-7	Graduate student stipends in environmental engi- neering	16,700
USPHS	Graduate student training in field of environmental control (effective 4/1/64)	34,000 (1964-65)
National Defense Edu- cation Act - Title IV	Training in water pol- lution control	10,200
NDEA - Title IV	Training in solid state electron devices	5,000
NDEA - Title IV	Training in chemical engineering	10,000
National Aeronautics and Space Administration	Training in space- oriented research (ma- terials science)	<u>12,000</u>
Total		\$164,000

engineering. The purpose of the several Public Health Service training grants listed in Table 2 is to develop research and graduate training programs in the field of water supply, waste disposal, air pollution, and environmental engineering. The program provides for support of graduate students, provision of a certain amount of facilities and equipment, and limited support of staff members during the period of the training grant. The grants normally extend over a period of five years, at the end of which a research and graduate program in the area is well established.

Another training grant program is carried out under the National Defense Education Act - Title IV, which is designed to train engineers and scientists in new areas and to facilitate the development of these new areas in the universities. The Act provides for a three-year stipend for the student and a cost of education allowance for the university. The cost of education allowance permits the university to provide the staff, facilities, equipment, and materials required to conduct research and training in the areas indicated. During the year 1963-64, there were five NDEA fellowships in the School of Engineering.

A third training program is under the sponsorship of the National Aeronautics and Space Agency. The program provides student stipends as well as a cost of education allowance, and is devoted to training fields related to space science and engineering. During the 1963-64 year, two NASA fellowships were active in the School of Engineering in the area of material science involving research in solid-state devices and in metallurgy.

A considerable amount of financial support of research is included in fellowships and research assistantships granted directly to graduate students. Table 3 summarizes the support granted to graduate students in the School of Engineering for the academic years 1962-63 and 1963-64. During the 1963-64 year, approximately \$200,000 was paid to graduate students in the form of the various types of support listed in the table. This amounts to nearly one-half of the total amount indicated in Table 1. This support was provided to 75 students, who constituted 60 percent of all the graduate students majoring in engineering.

Of the total support, it will be noted that \$61,000 is for teaching assistants, for which the students actually perform teaching duties. The remainder (\$162,500) is in the form of research assistantships and fellowships for which the students perform research usually connected with their dissertations. Of

the amount, approximately 90 percent is provided by federal agencies, state agencies, and by private industry.

This financial support of graduate students constitutes a significant factor in the graduate training program in the School of Engineering.

Table 3.
Summary of Graduate Student Support in the School of Engineering

Type of Support	1962-63			1963-64		
	No. Students	% of Total Graduate Students in Engineering	Annual Amount of Support	No. Students	% of Total Graduate Students in Engineering	Annual Amount of Support
Teaching assistants	21	20.2	\$ 44,000	29	23.4	\$ 61,000
Research assistants	20	19.2	40,000	17	13.7	35,500
Fellowships (industrial, etc)*	6	5.7	17,000	16	12.9	66,500
NDEA training fellowships*	7	6.7	35,000	5	4.0	25,000
NASA training fellowships*	0	0.0	0	2	1.6	12,000
USPHS traineeships	<u>5</u>	<u>4.8</u>	<u>14,000</u>	<u>6</u>	<u>4.8</u>	<u>23,500</u>
Total	59	56.6	150,000	75	60.4	223,500

*Includes cost of education allowance.

CHEMICAL ENGINEERING

J. S. Walton, Department Head

Kinetics of the Decomposition of Tungsten Carbonyl. The vapor phase thermal decomposition of tungsten carbonyl shows promise as a means of achieving high purity tungsten plates on various substrates. Detailed knowledge of the kinetics and mechanism of the reaction should lead to major improvements in tungsten plating processes. To this end, experiments are presently being conducted to measure the rate of the decomposition reaction over a range of experimental conditions. The effect of gamma radiation on the decomposition will be investigated also. D. E. Jost (U. S. Bureau of Mines).

Chemical Reaction Studies by Frequency-Response Methods. The objective is to measure chemical reaction rates under conditions of steady, sinusoidal concentration fluctuations. Data obtained in this manner over a wide range of fluctuation frequencies should yield precise information on (1) reaction rate, (2) activation energy, (3) reaction order, and (4) reaction mechanism. D. E. Jost, R. A. Knudsen (Engineering Experiment Station).

Heat Transfer and Flow Characteristics of Emulsions Made Up of Two Immiscible Liquids. This study involves the determination of momentum and heat transfer characteristics of emulsions made up of two immiscible liquids. Heat transfer coefficients, velocity profiles, temperature profiles, and laminar and turbulent viscosities are being determined from flow in a circular tube. J. G. Knudsen, J. P. Ward, S. B. Collins (National Science Foundation).

Nucleate Boiling Under Conditions of High Rates of Shear. This is a study of nucleate boiling on a fine wire located concentrically in a tube. Water flows at a high rate through this concentric annulus and rate of shear at the surface of the fine wire is extremely high. Initiation of nucleate boiling and transition from nucleate boiling to film boiling is to be studied and the effect of high wall shear rates will be determined. J. G. Knudsen, L. L. Nolan (Engineering Experiment Station, Dow Fellowship).

Mechanics of Climbing Film Flow. A study of the mechanics of climbing film flow in an annular duct in which the film flows only on the outer wall of the inner tubes. Such flow occurs in various regions of a boiling water nuclear reactor. J. G. Knudsen, D. H. Kim, A. M. Sutey (National Science Foundation).

Chemical Engineering

Heat Transfer in Fluidized Bed Heat Exchangers. Local heat transfer coefficients are determined in a rod bundle in which a granular solid is fluidized. The effects of bed height and particle size are determined from the standpoint of increasing the capacity of the heat exchanger. J. G. Knudsen, A. R. Noé (Texaco Fellowship).

Thermal Battery Development Using Solid Electrolytes. Use of stabilized zirconium oxide is being investigated as a possible solid-state electrolyte in high-temperature battery applications. Cells are constructed by vapor depositing or otherwise coating the electrolyte with various electrode reaction chemicals. Measurements indicate maximum current and power densities are subsequently obtained. R. E. Meredith, D. P. Clark (Naval Ordnance Laboratory, NDEA).

The Kelvin Water-Drop Device - Electrostatics of Jets. This device is being studied with the objective of understanding the electrostatic behavior and charge transfer involved in certain jet streams. R. E. Meredith, A. K. Postma.

A Study of High-Temperature Fuel Cells. This project covers research on the high-temperature, carbon-oxygen fuel cell. Studies are underway to determine to what extent this system can be catalyzed and thus find the maximum electrical power that may be obtained from such a cell. R. E. Meredith, V. E. Hauser (Engineering Experiment Station, Electrochemical Society, Dow Fellowship, Texaco Fellowship).

A Study of High-Speed Transient Reactions in Electrochemical Reactions. This research is aimed at understanding some of the electrochemical discharge characteristics in batteries. The current-potential relations involved in the first microsecond of discharge of various electrochemical cells are being examined and from these measurements attempts are being made to interpret the individual polarization and kinetic phenomena. R. E. Meredith.

A Study of Rotating Silver Silver-Chloride Electrodes. A silver silver-chloride reaction is being examined as a possible intermediate electrode mechanism whereby the electrochemical energy of chlorine and zinc may be realized in a "fuel cell" type device. Some energy is required to rotate the electrode. However, the net energy recovered by this semicontinuous process may be comparable to other electrochemical energy converters. R. E. Meredith, M. I. Gurian.

Chemical Engineering

Electrolytes Using Liquid Sulfur Dioxide. The purpose of this study is to ascertain whether electrolytes employing liquid sulfur dioxide might compete with water, liquid ammonia, and fused salt systems in battery application. R. E. Meredith, M. J. Schaer (U. S. Naval Ordnance Laboratory, Texaco Fellowship).

A Study of the Gravitational Effects of Mass Transfer Phenomena in Electrochemical Processes. An investigation is being conducted on the effects of high acceleration fields on electrochemical processes. Particular emphasis is being given to how limiting currents are affected in energy-producing devices by such unusual gravitational fields. R. E. Meredith, J. Divine (National Science Foundation, National Defense Education Act).

Moving Bed Ion Exchange Recovery of Cesium, Cerium, and Strontium. Purpose of this work is to develop a truly continuous countercurrent ion exchange system and to study in this system the recovery of and separation of the three cations: cerium, Ce^{+3} ; strontium, Sr^{+2} ; and cesium, C_s^{+1} . Walter Meyer (General Research Fund).

Development and Operation of a Continuous Countercurrent Ion Exchanger. This project has led to the development of a continuous countercurrent ion exchange system in which sustained liquid and resin flow rates of 5360 pounds of water and 2380 pounds of resin per hour, square foot of column cross section respectively, have been achieved. Heights of transfer units and numbers of transfer units have been measured. Current work includes the determination of controlling resistance in the ion exchange process and a correlation of transfer unit height data in terms of resin velocity and composition. W. Meyer, R. S. Olsen.

Liquid Ion Exchange Recovery of Thorium in a Pulsed Column. Recovery and purification of thorium from aqueous streams as an anionic sulfate complex using a mixture of primary amines dissolved in kerosene as a liquid ion exchanger have been studied. Equilibria in the system as a function of sulfate concentration has been determined and the effect of pH measured. In addition, analytical procedures for determining thorium concentrations in the range 3 or less ppm have been modified and refined. W. Meyer, B. E. Davis.

Chemical Engineering

Development and Operation Analysis of a Continuous Counter-current Crystallizer. The principle of separation and purification by crystallization and the advantages of adapting this process to a continuous countercurrent treatment have long been known. However, little is known about the mass transfer characteristics of such a process. Before efficient continuous countercurrent crystallizers can be designed and these designs extended to new chemical systems, basic information on the mechanism of mass transfer and mass transfer coefficients and equations must be developed. The subject of this project is the collection of this basic material. W. Meyer, D. M. Koenig (General Research Fund, National Science Foundation).

Chloride Anion Complex Recovery, Purification and Concentration of Copper, Zinc, and Other Ions From Mixed Oregon Ores by Continuous Ion Exchange. Ions of copper, zinc, nickel, iron, and other metals form chloride anion complexes whose stability is dependent on the solution pH. The complexes can be sorbed on an anion exchange resin and then selectively removed by pH control. The object of this research is to study the mass transfer characteristics, including controlling resistance and transfer unit height for the separation of such complexes by continuous countercurrent ion exchange. W. Meyer.

Purification of Raw Beet Sugar Molasses by Continuous Ion Exchange. One of the major problems in the refining of sugar beet molasses is the removal of salts, principally KCl, from the raw solution. This separation can be achieved by a process of ion exclusion whereby the sugar is adsorbed on a resinous cation ion exchanger. The inorganic salts are rejected or excluded from the resin phase and leave the separation system in the waste aqueous stream. The sugar is recovered as a refined solution by simply contacting the loaded resin with pure solvent and water. W. Meyer, R. S. Olsen, S. L. Kalwani (U. S. Dept of Agriculture).

Measurements of High-Temperature Heat Contents of Inorganic Compounds. Measurements are performed using a Bunsen ice calorimeter. Heat-capacity and entropy-increment data are calculated from measurements. C. E. Wicks, R. V. Mrazek (U. S. Bureau of Mines).

Measurement of Heat-of-Solution and Heat-of-Reaction Data of Inorganic Compounds. Heats of formation are calculated using measured values obtained using a solution calorimeter. C. E. Wicks, J. R. Welty (U. S. Bureau of Mines).

Chemical Engineering

Computer Evaluation of Vapor-Liquid Equilibrium Data.

Using Redlich-Kister's area and slope test and an orthogonal series test which was developed in an earlier investigation, a detailed analysis of 70 binary data previously published in the literature was made to determine thermodynamic consistency. An IBM 1620 computer was used to analyze the data. C. E. Wicks, R. P. Frutiger.

Influence of Turbulence Intensity on Mass Transfer. A fundamental investigation is being conducted on the effect of turbulence intensity at various Reynolds numbers on mass transfer from various geometrical shapes. Boundary layer and penetration theory models are being used to correlate data. C. E. Wicks, E. Elzy (National Defense Education Act).

Mass Transfer From Spheres. The local and average mass transfer coefficients are being measured for the sublimation of camphor in air. The investigation will involve a gradual increase in number of spheres present in an effort to simulate packed bed characteristics. C. E. Wicks, J. Denenholz.

Influence of Concentration Levels on Diffusion Coefficients. An Arnold cell will be used to measure gas diffusivities. Concentration levels will be varied in the gas phase to determine whether there are any concentration effects on the diffusion coefficient. C. E. Wicks, E. Larson, S. S. K. Prabhu.

Influence of High-Level Gamma Irradiation on Inorganic Chemical Reactions. The kinetics of inorganic, chemical reactions, including decomposition of carbonyls, hydrogenation, and chlorination will be investigated in a high gamma flux. These studies will be performed in the U. S. Bureau of Mines' cobalt-60 hot cell. C. E. Wicks, D. E. Jost, S. B. Knapp (U. S. Bureau of Mines).

CIVIL ENGINEERING

G. W. Holcomb, Department Head

Soil Survey. A program of soil sampling and testing is planned over a period of approximately five years in order to establish information regarding engineering properties of soils throughout the State of Oregon. It is expected that such information will be of value in highway design, studies of alternate routes, and economic analysis. The overall program of soil sampling and testing is under supervision of the U. S. Bureau of Roads. G. W. Beecroft (Oregon State Highway Dept).

A Comprehensive Study of Ocean Outfall Diffusers. This project studies the general problem of the discharge and dispersion of sewage and industrial wastes into the near-shore ocean waters of the Pacific Northwest. Studies on an effective method of pre-dilution and upon postdilution of sewage as affected by wave mixing are included. C. E. Behlke, H. D. Pritchett, L. S. Slotta (U. S. Public Health Service).

Fish Ladder Study. The purpose of this project is to develop a prototype unit for a fish pass device that will provide safe, attractive, and economical passage for migrating salmon and other anadromous fish. C. E. Behlke, D. C. Phillips (Oregon Fish Commission).

Supercritical Flow Channel Junction Research. To investigate flow phenomena which occur when two open channels join, each conveying water at supercritical velocities. This type of junction is frequently of interest for drainage channels operating in steep, sloping areas. This study will be aimed at an understanding of these complicated flow phenomena in order to give design engineers some fundamentally sound precepts upon which they may base their design computations. C. E. Behlke, H. D. Pritchett (U. S. Bureau of Public Roads).

Energy Requirements of Soil Compaction. This is a study of several methods used for the measurement of energy requirements of soil compaction. Various methods are used on one soil and the results compared. J. R. Bell, J. S. Matthias (Hyster Co).

Pulp Mill Waste Degradation in Marine Waters. This is a biological-engineering study of pulp mill waste degradation in marine waters. Factors investigated are time rate of degradation, functional relation between rate constants and temperature, effect

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of dilution, and degree of salinity upon rate constants. F. J. Burgess, D. C. Phillips (U. S. Public Health Service).

Physical-Chemical Aspects of Deep Trickling Filters. Long-term goal of the research is attainment of a more fundamental understanding of the role played by deep trickling filters in disposal of domestic and industrial wastes. It is recognized that physical, biological, and chemical factors are involved. The relative impact of the factors, however, is incompletely understood. F. J. Burgess, C. M. Gilmour, D. C. Phillips (Engineering Experiment Station, Civil Engineering Dept, Oregon State Sanitary Authority, U. S. Public Health Service).

Waste Water Lagoon Criteria for Maritime Climates.

Primary purpose of this work is to determine loading criteria that may be used for design of waste water oxidation lagoons in western Oregon. Also involved will be study of survival in oxidation lagoons of coliform organisms and other groups of bacteria associated with potential health hazards. It also will be possible to study feasibility of using waste water oxidation lagoons in western Oregon for treatment of colored food processing waste, particularly from canning of beets. An experimental lagoon, 2 acres in area and with a variable depth, has been installed at the Corvallis Sewage Treatment Plant on City of Corvallis property. F. J. Burgess, M. E. Northcraft (Engineering Experiment Station, Oregon State Sanitary Authority, City of Corvallis, U. S. Public Health Service).

Water Quality Management by Low Flow Augmentation.

Purpose of this project is to develop the criteria and program logic to determine by a digital computer the dissolved oxygen profiles that may be achieved in a complex stream system receiving various sources of pollution and "N" sources of flow augmentation from reservoir storage. Continuing research on water quality management by low flow augmentation is planned subsequent to program development. (F. J. Burgess, J. L. Worley, K. D. Feigner (U. S. Public Health Service).

An Economic Evaluation of Water Pollution Control. This is an interdepartmental research program. Primary purpose of the project is to develop an economical model that will delineate all factors in a pollutional problem. The model is to be tested using the Yaquina Bay Estuary. E. N. Castle, F. J. Burgess, H. H. Stoevener, R. E. Dimick, C. E. Warren (U. S. Public Health Service).

Investigation of the Effects of Skewed Contraction Joints in P. C. Concrete Roadway Slabs. Most contraction joints in concrete pavement have been at 90 degrees with the centerline of the roadway. By placing joints at a skew, better riding qualities are obtained. It is possible that certain structural advantages may also accrue. This investigation will attempt to evaluate these possibilities. M. P. Coopey.

Influence of the Level of Illumination on the Effectiveness of Highway Signs. The optimum level of illumination of highway signs has never been determined. It is possible to "over" illuminate a sign, which decreases the sign's efficiency in addition to increasing the cost of operation. This investigation will attempt to establish a working optimum level of illumination. M. P. Coopey.

Particle Migration in Asphaltic Concrete. From this initial test no direct results can be drawn. Due to too high an asphalt content (8 percent), too high a temperature (140° F), and too great a repetitive loading (70 psi), the asphalt test sample failed. From photographs it could be seen that the iron ore particles (the elements which were traced) did photograph from inside the asphalt sample. From this feature it was deduced that it was highly probable that particle migration in asphaltic concrete could be traced. M. P. Coopey, T. B. Muller (National Science Foundation).

Web Stresses in Vierendeel Girders. A preliminary phase investigation of strain distribution in the webs of welded steel girders with holes in the webs. This study is to determine magnitude of strain concentration at hole corners and optimum hole dimensions without web stiffeners. T. J. McClellan, W. B. Landers (Cooper and Rose, Columbia-Geneva Steel Co, Faught and Company).

Studies on Performance of Plywood Plate Structures. Comparisons of deflections determined by direct measurement and computed by finite-difference equations based on the theory of nonorthotropic plates are included in this research. Performance coefficients pertinent to plywood plates are to be developed on basis of tests. Sai-lung Pan, T. K. Aijala (Engineering Experiment Station).

High Pressure-High Shear Activated Sludge Treatment. Investigations are being made of the effects of increased pressures in the range from 0 to 60 psig and various mixing rates on the activated sludge process. The effects are being measured in terms of (1) rate of oxygen uptake, (2) sludge growth rate, and (3) removal rates of BOD and COD. The subsequent separation of the mixed liquor suspended solids by both gravity separation and air flotation is also being investigated. No definite results have been obtained other than the fact that pressures up to 60 psig have no adverse effect on the biological process. D. C. Phillips, Leale Streebin, Charles Coddington.

Factors Influencing Stream Temperatures. Two aspects of the heat energy budget for flowing streams are being investigated. These include evaporation from a turbulent stream surface and back radiation from streamside canyon walls and vegetation. Knowledge obtained from the study will permit a better understanding of stream temperature data and improve the ability to reliably determine reservoir regulation schemes so that maximum benefits may be obtained from existing or proposed water storage reservoirs. John Seaders (U. S. Public Health Service).

Turbulent Motion in Open Channel Flow. This is a boundary layer study to determine structure of open channel flow. It includes examination of velocity profiles, surface drag, and shear stress gradient throughout the boundary layer. Open channel data are to be compared with published data on duct flow. L. S. Slotta, W. B. Dye (Engineering Experiment Station).

GENERAL ENGINEERING

R. L. Richardson, Department Head

A Study of the Teaching of Engineering in Latin America.

Latin American countries, with exploding populations, are greatly in need of increased production. Increased production requires an increase in number of engineers and technicians. In a limited way these countries are doing their best to meet this need. Exchange programs such as that between the University of Wisconsin and Monterey (Mexico) Technical Institute are doing much to bring American engineering knowledge to Latin America. In the teaching of engineering itself, differences with the United States are partly due to Latin America's lower economic basis. Most of the professors there are on part-time employment, earning the bulk of their living by other means. Likewise, the students, supporting families and with other responsibilities, often require eight years to finish a six-year program of studies. Stress is put upon theory in engineering education. A limited amount of laboratory equipment is available in the older schools, but it is seldom used. In content, the courses are rather similar to those of the United States' schools of engineering. Less emphasis is placed upon teaching methods. Courses are for a complete year's duration. Passing or failing depends almost entirely upon the final examination. J. L. Garrard.

A Study of Engineering Graphics Curriculum. This is a study in engineering graphics curricula in which the needs in the field of graphics of many industrial companies and governmental agencies of the United States are determined as aids in establishing realistic subject matter and objectives for this aspect of engineering. In this study about 100 questionnaires were sent to large industrial companies and governmental agencies employing engineers. Eighty have been returned, many offering comments concerning the subject matter and objectives of graphics. As a secondary phase of the study; namely, to determine objectives for an advanced graphics course for secondary school teachers, 77 similar questionnaires were sent to high school drawing teachers throughout Oregon. Forty-eight have replied, indicating their subject matter training and levels of graphics they are teaching in high school. J. L. Garrard.

ELECTRICAL ENGINEERING

L. N. Stone, Department Head

Construction of Helium-Neon Maser and Auxiliary Equipment. Maser design is flexible enough to permit investigation of discharge tube diameters and length effects and to investigate various gas mixtures. G. C. Alexander (Engineering Experiment Station, General Research Fund).

High-Field Magnet and Current Supply. Design and construction of a variable-gap (up to 4 inches) electromagnet which will produce a maximum air gap flux density over a diameter of 10 inches consistent with currently available magnetic materials. A regulated current supply without d-c preamplification is being investigated as a means of maintaining time stability of one part in 10^5 . G. C. Alexander.

Research on Cryogenic Oscillator Circuits. It is the purpose of this study to investigate the design and performance of cryogenic oscillating electrical circuits. Final design of the cryogenic oscillator is dependent on the low temperature characteristics of dielectric materials and the dielectric strength of liquid helium. J. F. Engle (Engineering Experiment Station).

Use of a Digital Computer in Network Synthesis. The development of programs to test functions for realizability and for the realization of certain types of networks that will be applicable to both passive and active network synthesis. L. C. Jensen (Research Council).

Sonic Detection of Rot in Wood Poles. A study to evaluate the feasibility of using sonic or ultrasonic techniques to detect the presence of rot in wood poles and to determine the extent of the rot. L. C. Jensen (Portland General Electric Co, Pacific Power and Light Co, Bonneville Power Administration).

Percussive Welding of Metals to Semiconductors. This is a study of metal-semiconductor contacts made by an arc discharge between the two materials. The energy is obtained by a capacitor discharge process. J. C. Looney, J. A. Hunter, L. D. Heck.

Electron Devices Made with Unusual Semiconductor Materials. Available funds were used to purchase small quantities of semiconductor materials. An investigation of the characteristics of electronic devices made from these materials is in progress. J. C. Looney (General Research Fund).

Electrical Engineering

Zone Refining System for Semiconductor Materials. This project involves the design and construction of a zone-refining, zone-leveling, and crystal-growing system for use with semiconductor materials. J. C. Looney, G. A. Christensen.

Impact Ionization in Gold-Doped Silicon. When gold is introduced as an impurity in silicon, it has a high ionization energy and, consequently, most of the impurity atoms are not ionized at room temperature. Avalanche effects in this material were investigated with the objective of devising a bilateral, negative resistance switching device for use as a fast memory element. J. C. Looney, B. L. Frescura (Engineering Experiment Station).

Electric Analog for Spherical Wave Propagation in Solid Elastic Media. This investigation involves a theoretical analysis of spherically diverging seismic waves from a point of source, a study of the effects of medium variables on wave propagation, and simulation of the medium with an electric network analog. J. C. Looney, G. E. Papageorge.

Galaxy Memory System. This project involves the design of a random access memory system of 16,384 words of 59 bits each, with a cycle time of 1 microsecond or less. A linear-selection, ferrite-core matrix with transistors as active elements in the associated circuits is being investigated and seems to meet the requirements. J. C. Looney (National Science Foundation).

Concentration Profile of Diffused Radioactive Antimony in a Silicon Dioxide Layer. Silicon dioxide layers are used as diffusion masks for various impurities in the fabrication of semiconductor devices. This project is an investigation of the diffusion characteristics of a typical impurity through silicon dioxide. J. C. Looney, S. P. Khanna.

A Diffused Field-Effect Transistor. A study of the fabrication and characteristics of a diffused field-effect transistor. Initially, silicon will be used with possible later efforts applied to indium antimonide. J. C. Looney, T. M. Ou.

Multilayer Silicon Solar Cells. This investigation is concerned with using more than one pn junction in a solar cell to increase the efficiency of collection of light. J. C. Looney, T. E. Reynolds.

Electrical Engineering

Transmitter Power Requirements of Optical and Radio Communication Systems. This project involves a theoretical investigation of the requirements of optical communication systems using both laser and conventional sources. A comparison with existing radio systems shows that, in general, the laser systems offer no significant power advantage. J. C. Looney, C. B. Cordy.

An Oscilloscope Sampling Converter for Observing Nano-second Waveforms. Use of the sampling technique made possible the design and construction of a unit to convert a 1-megacycle bandwidth test oscilloscope to a 200-megacycle bandwidth instrument. The transistors used in the avalanche mode of operation provide the nanosecond pulse circuitry needed, so the converter unit may be designed using solid state elements only. Since some of the circuitry functions required to make the sampling technique operable are common to any laboratory oscilloscope, redundancy of effort was avoided by using oscilloscope controls where possible, thus giving a relatively inexpensive and simple converter unit design. J. C. Looney, D. P. Leabo.

Slow Diffusion of Zinc in Gallium Arsenide Diodes. This investigation is concerned with the reason for the degradation of zinc-diffused GaAs diode characteristics when operated at high temperatures. It may be possible that the pn junction is modified by continued diffusion of the zinc in the region of the junction. Movement of radioactive zinc in the junction region will be investigated. J. C. Looney, S. S. Matsuo (NASA Fellowship, Tektronix, Inc).

Ohmic Contacts to Gallium Arsenide. An investigation of resistivity characteristics of contacts between various materials and methods which will give the very low ohmic contacts needed for GaAs injection laser. J. C. Looney, G. Armantrout (Tektronix, Inc).

Impurity Concentration Profiles in Gallium Arsenide Transistors. An investigation of concentration profiles of zinc and tin and their influence on the characteristics of an alloy-diffused gallium arsenide transistor. J. C. Looney, H. L. Singer (Tektronix, Inc).

Electrical Engineering

Aspects of Stud Welding. This project is concerned with various aspects of percussive welding of steel and aluminum studs. A theoretical study of the percussive welding of steel and aluminum studs has been made. The areas investigated were: energy available from the arc, energy necessary to melt the desired volume of material, energy losses, arc duration, power supply requirements, velocity between stud and plate, and stud tip configuration. An investigation was made of the weldability of steel and two types of aluminum studs to plates of the same materials. Tensile strengths of the welds were correlated with measured values of the weld parameters. Evaluation of the voltage, current, and motion parameters of a Gramweld type percussive welder for a defined stud configuration and material was made. This work was done with cylindrical stud tips made of 6061-T6 and 1100 type aluminum alloys welded to 1/8-inch aluminum plates. Study was aimed at developing a technique for measuring the instantaneous electrical power delivered during a stud welding operation and the total associated energy. R. S. Mesecar, S. A. Stone, D. L. Amort, J. C. Looney, J. M. Comstock (Omark Industries).

Myoelectric Surface Potentials for Machine Control. The ability of an individual to initiate simple on-off operations through neuro-muscular potentials without actual body motion has been demonstrated. To further exploit this phenomenon, more detailed investigation is required on the nature of myoelectric surface potentials and their relationship to the individual and his conscious acts. R. R. Michael, F. R. Crawford, F. T. Churchill, J. M. Comstock (Engineering Experiment Station, General Research Fund).

Magnetic Powder Digital Memory. Investigation of the possibility of using magnetic powder, either in the form of thin film on tape or in bulk, for digital memory is being made. This is contrasted with the present core memories which are bulky and expensive. L. N. Stone.

Calibration of High-Voltage, Radio-Noise Measuring Circuits in the United States. A means has been devised whereby it is possible to calibrate high-voltage, radio-noise measuring circuits. This device will be sent to all high-voltage laboratories in the United States. Some inquiries have come in from Europe. This work is being done with the cooperation of the American Institute of Engineers. L. N. Stone.

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Aspects of Corona Formation and Radio Interference. Investigation includes the radio-noise characteristics and corona on-set voltage characteristics of high-voltage conductors and insulators. Work is continuing on the correlation between measurements made in the laboratory and those made in the field. L. N. Stone (Bonneville Power Administration).

Metal-Dielectric Junction, High-Voltage Phenomena in Vacuum. Investigation of breakdown phenomena in 10^{-6} mm Hg vacuum in voltage ranges from 10 kv to 200 kv, both d. c. and a. c. is being conducted. An understanding of the breakdown phenomena should lead to better control of high voltages in vacuum. L. N. Stone.

Digital Computer Design and Development (GALAXY). This project covers the logical design, engineering design, and construction of a computer for the Computer Research Center. It will be a parallel, asynchronous digital computer with 58 bit word. Memory cycle time will be 1 microsecond. The logical design is nearly completed and the "Galaxy" computer installation will be undertaken in the near future. L. N. Stone (National Science Foundation).

Design of High-Input Impedance, Wide-Band Transistorized Amplifiers. High-input impedance is a very desirable amplifier characteristic in many applications. Although conventional transistors can be used for high-input impedance amplifiers, a conflict exists between high-input impedance and wide-frequency band width. This project investigates the use of field effect transistors and positive feedback in the design of a high-input impedance, wide-band amplifier. L. J. Weber, R. H. Suluzar.

A Method of Design and Analysis of a Drift-Free, Direct-Coupled Transistor Amplifier. The object of this investigation is to show theoretically that a scheme for stabilizing the voltage amplification of a transistor amplifier is possible without adversely reducing the overall realizable voltage amplification. In this investigation a highly stabilized amplifier is desired. L. J. Weber, S. R. Bishop.

Electrical Circuit Reliability Study—Worst-Case Design Versus a Statistical Approach to Design. Objective of this study is to compare the performance of electrical circuits that have been designed on a worst-case basis with those that have been designed

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using a statistical approach. Three main steps are involved in the investigation: (1) construction of a switching circuit which will automatically test the performance of circuits when the components drift from their minimum to their maximum rated values, (2) formulation of a computer program which will predict the performance of a circuit when probability density functions are given for the values of the individual components, and (3) comparison of the results of 5 and 10 percent tolerance worst-case circuit designs with statistically designed circuits. L. J. Weber.

MECHANICAL AND INDUSTRIAL ENGINEERING

L. Slegel, Department Head

Pressure-Volume Characteristics of Plastic Bags. Plastic bags have recently come into widespread use for sampling, shipping, and storing gases. They also have been used for calibrating flow measuring devices. Concern has been expressed about the pressure build-up within the bag upon filling. A large plastic bag was supported in three different positions and the pressure within the bag and the volume of air contained in the bag accurately measured as the bag was filled. Results indicate that pressure within the bag remains close enough to atmospheric that corrections would be negligible for engineering calculations until the bag became extremely taut. The curves indicate that the bag position does cause a change in the pressure-volume characteristics. R. W. Boubel.

Study of the Effects of Gamma Radiation on Single Crystals. Changes of single crystals due to irradiation are determined by x-ray diffraction patterns involving the Laue technique and the Debye-Scherrer powder method, spectrophotometer absorption, and ionic conductivity with changes in temperature. The irradiation was 1.06×10^9 roentgens, and six crystals were used of the ionic type. E. A. Daly, R. S. Paige.

Hazard Analysis and Work Design for Contract Logging Operations. Analysis of micromotion, time-lapse, and regular work measurement data for the identification of job element effects, variable effects, and work hazards is being undertaken. W. F. Engesser.

Subsystem Logging Operation Studies. This involves construction of mathematical models to describe inputs, outputs, and subsystem states for the evaluation of crew skill levels and equipment. W. F. Engesser (Western Management Science Institute).

High-Lift Airfoil Design. Wind tunnel tests have shown that the boundary layer control suction requirements for a circular cylinder can be reduced considerably below those obtained in the pioneer work by Thwaites. However, they were still much larger than predicted by approximate boundary layer calculations according to S. Ando. The approximate method of M. R. Head broke down when applied to the circular cylinder. E. W. Geller, J. D. Dennon, V. R. Corsiglia (Engineering Experiment Station).

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Photographing a Boundary Layer Velocity Profile Using an a Source and a Spark Discharge. A new technique is proposed for recording the boundary layer velocity profile directly on a photograph taken of the flow. If perfected, the method will be particularly useful for thin boundary layers which are difficult, if not impossible, to survey by standard techniques. E. W. Geller, W. Watson (Engineering Experiment Station, General Research Fund).

Development of a Double Layer Circular Water Tank. A circular double layer water tank facility for application of the rheoelectric analog to potential flow problems with a uniform stream at infinity is being developed. Airfoil flow problems of current interest are to be studied with the facility. E. W. Geller, M. Sworakowski (National Science Foundation).

Effects of Lignin and Other Components of Sulfite Liquor on the Properties of Portland Cement Concrete. Effect of components on sulfite liquor on Portland cement concrete has been done in three areas: (1) relative adsorption using an ultraviolet spectrophotometer, (2) relative dispersing effect by means of a Wagner turbidometer, and (3) relative viscosity or workability using a Brookfield viscometer. C. O. Heath, D. W. Glennie (General Research Fund).

Convection Heat Transfer in Separated Regions - Subsonic Diffusers. This is an experimental study of the film coefficients which exist in a subsonic diffuser with varying diffuser angle and throat width. It has been found that flat plate correlation equations considering starting length may be used to predict heat transfer for regions of steady two-dimensional separation if appropriate velocities are used. In the regime of transitory stall the results have been correlated in terms of the throat Reynolds number. M. B. Larson, J. H. VanSant (National Science Foundation).

Effects of Oscillations on Low Velocity Flow Convection Heat Transfer from a Cylinder to a Liquid. Apparatus is being designed and constructed to evaluate any effects on the heat transfer coefficient from a cylindrical surface when oscillated at frequencies near the frequency of the shedding of the von Karman vortex street. M. B. Larson, Craig Thom.

Evaluation of Thermal Resistance Between a Casting and the Mold Wall. The thermal resistance between the casting and the mold wall is being studied for tin for various pouring

temperatures and pouring rates. It has been found that the resistance increases by more than 100 percent during the solidification processes. First results show that there appears to be an optimum pouring temperature; that is, a minimum in the resistance as the pouring temperature is increased. Variation of pouring rate has not yet been studied. M. B. Larson (U. S. Bureau of Mines).

Partial Recirculation of Diesel Engine Exhaust for the Reduction of Oxides of Nitrogen. Oxides of nitrogen are now being recognized as having a greater toxic effect on plants and humans than was thought in the past. The operation of diesel engines in mines, warehouses, and ship cargo holds constitutes a problem because of the concentration of the nitrogen oxides emitted from the engine exhaust. It is postulated that some reduction of the oxides of nitrogen might be achieved by recirculating a portion of the exhaust directly back into the air intake system of the engine. J. G. Mingle, D. J. Addicott (Hyster Fellowship).

Design and Construction of a Variable Strain Rate, Automatic Recording, Tensile Machine. This study involves the design and construction of a machine to function as part of a complete testing system which will facilitate economical testing at temperatures down to the temperature of liquid helium (4.2°K). R. D. Olleman, J. A. Mitchell (Engineering Experiment Station).

Control of Peak Stresses in Testing Machine Components Subjected to Impulsive Loading. The objectives of this study are to develop a satisfactory method for predicting impulse loads, and to devise at least one good method for controlling impulsive loading of the load cell of the new cryogenic tensile testing machine. The analysis and design will be checked by comparing predictions against actual measurements. R. D. Olleman, J. A. Mitchell.

Catastrophic Propagation of Ductile Cracks in Metallic Foils. The objectives of this work are: (1) verify current theories on the catastrophic propagation of ductile fractures, (2) investigate effect of metallurgical variables—primarily cold work—on susceptibility to catastrophic ductile fracture, and (3) obtain correlations between behavior in the special crack propagation test and characteristics that are more readily measured in conventional tests. R. D. Olleman, L. T. Elliott.

Fracture of Hardened, One-Phase Materials at Low Temperatures. Brittle fracture at low temperatures in normally ductile materials is a major engineering problem to which much study has been devoted. Most of this work has been done with one of two types of material: (1) ideal materials—pure materials and single crystals, and (2) commercial materials. The former work has resulted in some significant generalizations, but they have had limited application to practical engineering problems. The latter work has produced specific data on particular materials, but due to the complexity of the materials it has been difficult to make generalizations that would be useful guides to the development of better materials. It is felt that the generalizations of the fundamental studies can be extended in the direction of practical applications by studying the behavior of somewhat less ideal, but still relatively simple materials. It is planned to investigate the fracture behavior of relatively hard, single-phase solid solutions using temperatures down to the temperature of boiling liquid helium, 4.2°K. R. D. Olleman, D. G. Goodrich (NASA Traineeship).

Deformation of Tungsten Single Crystals. This is a study of the deformation characteristics of tungsten single crystals as influenced by the major variables that are inherent in metal working processes. These variables include: type of process used in producing the deformation, orientation of the crystal, and speed, amount, and temperature of deformation. Deformation behavior is interpreted from the crystal deformation textures as revealed by x-ray pole figures. Basic information from studies of this type provides increased understanding of the reasons for the deformation behavior of polycrystalline aggregates and facilitates prediction of suitable conditions for fabrication of these metals by commercial processes. R. D. Olleman, D. G. Goodrich.

Creep Tests of Aluminum Conductor Cable. Purpose of this research is to obtain creep characteristics on aluminum conductor cable under various conditions of prestress, tension, and time. O. G. Paasche, L. E. Johnson, Y. S. Shen (Bonneville Power Administration).

Study of a Quiet Internal Combustion Engine. This is an investigation of the possibility of developing a quiet internal combustion engine. Concentration of effort is on the exhaust noise. Diminishing this noise at the source (the exhaust valve seat) is the main problem. By operating an engine on the "more complete expansion" cycle, the terminal pressure in the cylinder after

expansion may be reduced to an order that will prevent sonic velocity in the port. W. H. Paul, W. R. Meloy.

Nitrogen Oxide Fate in the Direct Flame Afterburner. This is an investigation to determine the degree to which the oxides of nitrogen may be reduced by proper operation of a direct flame afterburner with secondary combustion air introduced after the exhaust valve. It is postulated that a method of operation of the afterburner will be found by controlling temperature and quench rate of the secondary combustion where the oxides of nitrogen are minimized. W. H. Paul, J. G. Mingle, G. Jaros (U.S. Public Health Service).

Study of a "Tracking Problem" Device. The design, construction, and preliminary evaluation of a "tracking problem" device to be used in a study of the effect of environmental conditions on human motor and mental performance is being studied. J. L. Riggs, L. E. Johnson (General Research Fund).

Effect of Interaction of Environmental Factors on Work Performance. Object of this research is to determine the main and interaction effects of environmental factors on human performance. Subjects tested were exposed to 18 combinations of levels of illumination, sound, and temperature in an environmental control booth. During exposure the subjects operated a joystick tracking device and foot controls. Cues for operations were provided by a variable networks mechanism. All responses were automatically tabulated. Results from the first 200 hours of testing are currently being analyzed for statistical significance. J. L. Riggs, C. S. Jacobson (American Society of Tool and Manufacturing Engineers).

Development of New Techniques for Critical Path Scheduling. A new approach to matrix solutions of scheduling problems has been developed which employs an activity-oriented rather than an event-oriented approach. An analog device and a counting board device are being developed for resource leveling. Line of balance, milestones, and probability techniques are being adapted to critical path analysis. J. L. Riggs.

Numerical Analysis of Structures Subjected to Moving Mass Loads. Numerical analysis is being carried out to determine the dynamic deformations of a beam, along which a mass particle is constrained to move. The errors resulting from simplifying

assumptions, inherent in presently used analyses, are being assessed. Results will be presented showing the effects of mass, speed of travel, and support stiffness. C. E. Smith, R. A. Sevilla (Engineering Experiment Station).

Unsteady Flows with Mass Addition. A one-dimensional model of fluid flow with mass addition has been formulated, the equations written, and the characteristics obtained. The rate of the mass addition in changing the velocity of propagation of large pressure distributions is receiving particular attention for the case where the mass addition rate is proportional to the pressure.

R. E. Wilson.

NATIONAL COUNCIL FOR STREAM IMPROVEMENT

The following projects are being carried on in the research laboratory of the National Council for Stream Improvement (of the Pulp, Paper, and Paperboard Industries), Inc. The work is supported by grants from the National Council for Stream Improvement, and funds for equipment, supplies, and services are administered by the Engineering Experiment Station. Research personnel include:

Russell O. Blosser, West Coast Regional Engineer
Eben L. Owens, Development Engineer
Daniel H. Longwell, Development Engineer

Laboratory Study of Pulp and Papermill Waste Disposal by Irrigation and Land Application. This project involves a study of influence of soil permeability, texture, and chemical composition on its capacity for treatment of various mill effluents. Also included are studies of importance of cover vegetation, effluent composition and pretreatment, and an evaluation of possibility of occurrence of ground water contamination from irrigation disposal of mill effluents.

Effect of Tidal Action in Lower Portland Harbor on Natural Self-Purification Characteristics of the Lower Willamette River. A continuation of work begun in the summer of 1959 designed to establish the manner in which observed tidal action in lower Portland Harbor affects the dissolved oxygen profile sag during critical low-flow period occurring each summer.

Characteristics of Kraft Mill Effluents. A study of characteristics of kraft mill effluents that may contribute to odor conditions in the mill vicinity or in the vicinity of the discharge into receiving waters.

Characteristics of Spent Sulphite Liquor. A fundamental study of the role of chemical and biological adsorbents in reducing the apparent toxicity of spent sulphite liquor to molluscan larval forms. This is a cooperative project conducted in conjunction with the Fish and Game Management Department.

Air Pollution Abatement. The identification, measurement, and evaluation of methods of control of gaseous and particulate matter emissions are being made.

ADVANCED DEGREES IN ENGINEERING

June 1963

(Names in parentheses denote major professor)

- AIJALA, Timo Kalervo. MS CE
"Deflections of Simply Supported Plywood Plate Under
Uniform Loading by Finite-Difference Equations."
(S. L. Pan).

This thesis offers a solution of the complicated equations for the deflections of nonorthotropic plates, specifically plywood plates made of Douglas fir. The partial differential equations are expressed in terms of finite differences and the simultaneous equations thus obtained are easily solved.

- BENEDETTI, Gerald Andrew. MS ME
"Pure Torsion of a Slotted Channel Member."
(C. E. Smith).

This investigation involved the study of the effect, on the rigidity of a channel member loaded in pure torsion, of rectangular slots of various sizes in the web. Equations were developed which would give the angle of twist at any distance along the length of the slotted channel beam. The equations can be used to predict with good accuracy the angles of twist along the length of the beam and the torsional rigidity of the slotted channel member.

- BENNETT, Marlin John. MS ChE
"A Study on Electrowinning Copper and Zinc From Low
Grade Ores." (R. E. Meredith).

A process was studied for extracting copper and zinc from low-grade ores. In ores of this type an ammonium hydroxide electrowinning process is shown to be more economical and more efficient than the conventional sulfuric method.

- BOLTON, Frederick Merret. ME CE
"The Removal of Beet Waste Color by Activated Sludge."
(D. C. Phillips).

This study concerns the ability of the activated sludge process to remove beet color from a waste and relates this ability to the factors of detention time, mixed-liquor

solids concentration and the color concentration in the influent waste. Two continuous-flow, completely-mixed activated sludge units were constructed for laboratory studies and an experimental plan was formulated to investigate the effect of these factors on color removal. It was found that the activated sludge process will remove over 80 percent of the beet color from a waste if the factors of detention time, mixed-liquor solids concentration and color concentration in the influent are controlled to operating conditions. BOD reductions of over 90 percent were obtained under all operating conditions.

CHAMBERS, Donald Ray. MS EE
"Schottky Emission Through Thin Aluminum-Oxide."
(J.C. Looney).

Aluminum-aluminum-oxide-gold, thin-film sandwiches constructed from materials of commercial purity and with modest equipment and techniques are shown to exhibit current transfer properties similar to those reported for structures fabricated under more stringent control.

CHENG, Dan Sang. MS EE
"Effect of Etches on Surface Recombination in Silicon."
(J. C. Looney).

This thesis presents a limited investigation of the effects of various etches on the surface properties of silicon. CP-4 etch yields the smallest surface recombination velocity in silicon; while sodium dichromate solution has the pronounced effect of reducing the minority carrier lifetimes in silicon. Ambient atmospheres have no obvious influence on the surface recombination velocity of silicon.

CHIANG, Chung. MS ME
"A Quantitative Study of Recirculation in Cooling."
(W. W. Smith).

A quantitative study of recirculation in cooling was made using models and the following similarity criteria: The similarity of the condition of the exit atmosphere of the model and the prototype, the similarity in the tower configurations and fluid mechanics characteristics, and the similarity of the exit conditions and the wind velocities. It was concluded that an increase in the height to width

ratio causes a decrease in recirculation, the effect of tower orientation on recirculation is modified by tower configuration, the V_s / V_w ratio appears to have an effect on downwash.

CLARK, Robert G. MS EE
"Monitoring Surface Temperature of Irradiated Fuel Elements." (R. R. Michael).

This thesis describes and evaluates a radiation thermometer using infrared techniques which were developed to monitor surface temperatures of irradiated fuel elements while they are undergoing physical examination. Such a probe is expected to provide extended service in a rather hostile environment and to be capable of monitoring reliably surface temperatures of recently irradiated fuel elements.

COENE, Ronald Francis. MS CE
"Relationship Between Residual Chlorine and Coliform Density in Water Distribution Systems." (D. C. Phillips).

In this study data were collected from seven cities throughout the country. In addition to the results of the coliform tests, the data included the results of total chlorine residual determinations made at the time bacteriological samples were taken. The results of the analyses show conclusively that a mathematically definable relationship does exist between residual chlorine and coliform density in water distribution systems.

COPLEY, Terry William. MS EE
"An Iterative Solution to the Approximation Problem of Network Synthesis." (H. J. Oorthuys).

The approximation problem of network synthesis is considered in four parts: the problem is identified, several existing methods of solving the problem are discussed, an iterative method of solving the problem is investigated, and finally the unsolved questions associated with the iterative method are considered.

CORDY, Clifford B., Jr MS EE
"Transmitter Power Requirements of Optical and Radio Communication Systems." (J. D. Looney).

Transmitter power requirements of optical and radio communication systems are compared. It is found that, in general, the laser systems offer no significant power advantage over radio systems despite the higher directivity of the optical antennas. Consequently, the largest demand for laser communication systems will occur when it is necessary to transmit extremely large information rates.

CORSIGLIA, Victor Robert. MS ME
"A Calculation of the Suction Requirements to Prevent Boundary Layer Separation on a Circular Cylinder." (E. W. Geller).

An investigation was made to test the method of head on the flow about a circular cylinder with suction. The method was adapted to the digital computer to facilitate performing the calculations, and a variety of suction distributions was studied. The method predicted a point of separation comparable to exact solutions for the case in which the suction velocity was zero. However, for the large suction velocities and large adverse pressure gradients associated with the circular cylinder, the method broke down.

DENNON, Jack Dwight. MS ME
"Boundary Layer Control Tests by Suction on a Circular Cylinder Wing Section." (E. W. Geller).

A three-inch diameter circular cylinder model with porous aft perimeter through which area suction was applied was tested in two-dimensional flow at diameter Reynolds numbers from 29,000 to 80,000. The distribution of suction inflow velocity was computed from measured static pressure distribution, the measured pressure inside the model, and the known porosity characteristics of the model's wall material. The distribution of inflow over the porous perimeter was nearly constant in all cases in which external flow separation was prevented.

FEIGNER, Kenneth Darrel. MS CE
"An Evaluation of Temperature Reduction on Low Flow Augmentation Requirements for Dissolved Oxygen Control." (F. J. Burgess).

The temperature of a stream influences many of the reactions that govern water quality. In view of this influence, an investigation was undertaken to provide an eval-

uation of temperature reduction on low flow augmentation requirements for dissolved oxygen control making use of an IBM 1620 computer. The study was conducted on the Willamette River and its tributaries, with a total of 91 different stream temperature, waste loading, and minimum dissolved oxygen conditions investigated.

FRESCURA, Bert Louis. MS EE
"Impact Ionization in Gold-Doped Silicon."
(J. C. Looney).

The objective of this study was to investigate the impact ionization of impurities in silicon at room temperature and, if possible, fabricate a device similar to the CRYOSAR that would operate at room temperature. Gold was chosen as the impurity because of the high energy level of the donor and acceptor impurities. Two types of breakdown were encountered. One with and the other without a negative-resistance region. The breakdown appeared to be a bulk effect due to the impact ionization of the gold impurities. A simple theory analogous to the breakdown in gases was formulated.

FRUTIGER, Richard Patrick. MS ChE
"Testing of Vapor-Liquid Equilibrium Data for Thermodynamic Consistency." (C. E. Wicks).

An IBM 1620 digital computer was used to check the thermodynamic consistency of seventy-two sets of experimental data. The results of this investigation indicated that the majority of the data satisfied the slope test, but did not satisfy the area test. It was also found that the percentage of the area, as well as the magnitude should be used in evaluating the area test.

GIFFORD, Raymond W. MS ME
"Structural Factors Affecting Wear of Cobalt Base Hard Facing Alloys." (O. G. Paasche).

An attempt was made to correlate wear tests made on a cobalt base hard facing alloy (Stellite 6) deposited by oxy-acetylene welding techniques with the microstructure of the deposited metal. Wear tests indicated inconsistent wear properties. The cause of the inconsistent wearing qualities appears to be lack of adequate control of the oxy-acetylene welding flame and possibly inconsistent cooling after welding.

GODSIL, Patrick James. MS CE
"The Effect of Elevated Pressure on the Activated Sludge Process." (D. C. Phillips).

A study of the effect of elevated pressure on the activated sludge waste treatment process is presented. The method of study involved a comparison of two laboratory, batch type, activated sludge units. One unit was operated at atmospheric pressure as a base control and the other operated at elevated pressures up to 60 psig. This study is one phase of an investigation to determine the feasibility of increasing the reaction rates of the activated sludge process by subjecting the process to both high pressure and high shear mixing.

HENSHAW, Thomas Lamond. MS CE
"The Fate of Specific Organisms in a Receiving Stream." (D. C. Phillips).

This thesis presents a study of the die-off of certain specific organisms in a stream receiving treated sewage. The study was accomplished by drawing samples of the receiving stream at specified sampling stations and determining the density of the organisms Escherichia-coli and fecal streptococci, and the total number of viable cells present in the sample. Curves showing bacterial pollution versus river miles were obtained relating the die-off of the bacteria to miles below the sewer outfall.

JAENICKE, Richard Alex. MS EE
"A Transistorized Sonic Generator and Detector For Finding Young's Modulus of Wood Beams." (L. J. Weber).

This paper presents a background on the measurement of Young's modulus. From this background a non-destructive test which senses the reactions of a beam when it is excited by its natural resonant frequency is selected for further study. Operation of the equipment is fully outlined as is the method of computing Young's modulus from the resonant frequency. Also, data from a short series of measurements made with the equipment are presented.

JOHNSON, Ronald Ernest. MS CE
"Pressure Distribution Around a Circular Cylinder Resting on a Flat Boundary in an Oscillating Fluid." (L. S. Slotta).

This study was undertaken to provide information needed in the design of ocean outfalls. A solution for pressure distribution about a circular cylinder resting on a flat boundary in an oscillatory fluid is derived. The pressure distribution equation is integrated graphically and the resulting net force differs from the corresponding experimental force by 16 to 70 percent.

KARI, Earl Nyhus. MS CE
"An Evaluation of the Oxygen Resources in the Lower Willamette River During a Critical Low Flow Period." (F. J. Burgess).

The lower Willamette River, located between river mile 4.0 and 26.5, is the most seriously polluted section of the Willamette River Basin. Results of this study indicate that the source of this pollutional loading originates between river miles 26.5 and 19.0. It is further indicated that a detailed on-site survey of this section of the stream and possible waste contributors should be undertaken to provide information necessary for restoration of water quality.

KIM, Joong Chung. MS EE
"Determination of Transformer Leakage Reactance by Using an Impulse Driving Function." (J. F. Engle).

The leakage reactance of power transformers was determined by using an impulse driving function as the energy source. For a comparison, the leakage reactance was also obtained by using the standard short circuit test. From this investigation the impulse driving function method of determining transformer leakage reactance is simple procedure and seems applicable to most power transformers.

LEABO, Dell Patrick. ME EE
"Oscilloscope Sampling Converter for Observing Nanosecond Waveforms." (J. C. Looney).

This thesis is the culmination of a project to design and build a unit to convert an ordinary one megacycle oscilloscope to the sampling mode of operation using solid state elements only. Wherever possible, the circuitry and controls available on a conventional oscilloscope were used in an effort to make an inexpensive yet effective instrument capable of monitoring the nanosecond waveforms

so prevalent in today's electronic laboratories.

LENAHAN, Earl Leonard. MS CE
"The Effects of Gravity on the Oblique Hydraulic Jump." (C. E. Behlke).

The undulating wave type of oblique hydraulic jump was studied. The Boussinesq equation for the approximate theoretical wave was solved by numerical integration with laboratory data. The theoretical wave was in close agreement with the actual wave.

MC CLARY, Terry George. MS ChE
"The Effect of Tubular Reactor Geometry on the Saponification of Ethyl Acetate When Operating at Fixed Residence Times." (C. E. Wicks).

The effect of reactor geometry on the percent completion of a second order reaction was studied in four different tubular reactors. Comparison of the experimental data with the data calculated for a theoretical laminar flow reactor showed that the 1-, 1-1/4-, and 1-1/2-inch diameter reactors approached the theoretical results only at the very low flow rates. At high flow rates all four experimental reactors gave results very close to those calculated for a plug flow reactor.

MACKIE, Keith Leroy. MS ME
"The Conversion of Solar Radiation to Heat Energy Using a Trough-Type Parabolic Mirror." (A. D. Hughes).

This investigation was concerned with the design, construction, and testing of a solar energy collector capable of supplying medium-level heat energy to a heat engine. Different reflective surfaces, working fluids, and wind shields were studied to improve the effectiveness of the collector.

MAGNUSON, Waldo George, Jr. MS EE
"A Charge Sensitive Amplifier for Use with Piezoelectric Transducers." (L. N. Stone).

In this thesis the concept of a charge amplifier is discussed and a practical expression is derived in terms of frequency response, input impedance, amplifier gain, and feedback capacitor value. It is shown that modest input impedances may be used and low frequency response

maintained, using this concept. A practical amplifier design is illustrated and its performance is described.

MATTHIAS, Judson Stillman. MS CE
"Investigation of the Effects of Skewed Contraction Joints on Concrete Roadway Slabs." (M. C. Coopey).

The effects on the internal flexural stress of a concrete pavement caused by axle loads crossing skewed contraction joints were studied. The analytical solution was based on data from a model slab which was tested using SR-4 strain gages to record the strains caused by axle loads. There are indications that for the skewed joint, transfer of load will reduce the impact stresses across the joints due to the fact that the wheels of an axle cross the joint at different times.

MOON, Laurence L. MS EE
"Analysis of Nuclear Reactor Period Measurements." (R. R. Michael).

An experiment was performed with the Aerojet-General AGN 201 reactor to determine the distribution followed by the statistical fluctuations present in the counts per unit time interval obtained from a pulse type neutron detector. A chi-squared test, assuming a Poisson distribution, was performed with the experimental data. The results show that the fluctuations can be assumed to follow a Poisson distribution.

OZOLS, Vitauts. MS CE
"The Influence of the Level of Illumination on the Effectiveness of Highway Signs." (M. C. Coopey).

The influence of the level of illumination on legibility distance and viewing comfort was studied for a standard, illuminated Oregon State Highway Department sign placed in a moderately illuminated rural interchange near Salem, Oregon. The average message legibility distances for all of the three sizes of lamps used were about 650 feet. The average route shield legibility distances, when both route shields were legible, were about 480 feet for all the three sizes of lamps used.

PAIGE, Rudolph Stanley. MS ME
"Effects of Gamma Radiation on Selected Single Crystals." (E. A. Daly).

Single crystals of potassium aluminum sulfate dodecahydrate, $KAl(SO_4)_2 \cdot 12H_2O$, potassium ferricyanide, $K_3Fe(CN)_6$, potassium sodium tartrate tetrahydrate, $KNaC_4H_4O_6 \cdot 4H_2O$, sodium nitrate, $NaNO_3$, potassium chromium sulfate dodecahydrate, $KCr(SO_4)_2 \cdot 12H_2O$, and sodium chlorate, $NaClO_3$, were grown and irradiated with Co^{60} gamma rays up 1.06×10^9 roentgens at $14^\circ C$. A variety of effects was noted in the specimens varying from decomposition to no observable changes.

PUTNICKI, George John. MS CE
"Design Criteria for Waste Water Lagoons in Oregon."
(F. J. Burgess).

The objects of this thesis are to review and evaluate the research, design, and operational data of waste water lagoons in Oregon and in other locations. Results of this study reveal that climatic conditions prevalent in the State of Oregon do not preclude the use of waste water lagoons. The study reveals that the waste water lagoon process is especially adaptable in smaller communities where other means are economically infeasible.

RIGGS, James Lear. PhD ME
"Influence of Environmental Factors on Human Mental and Motor Performance in Console Operations."
(L. Slegel).

The intent of this study was to determine the dominant environmental factors influencing mental and motor performance, and to investigate the existence of interaction between environmental factors. A console requiring several cue and response operations was constructed. The cue sequences were programmed to be repeated and the responses were automatically recorded. For the environmental factor levels tested of motion, noise, illumination, and temperature, the motion factor appears dominant in adversely affecting motor performance. There was no evidence of environmental interaction effects on motor performance.

SEADERS, John. MS CE
"Kinetics of Biological Contact Beds." (F. J. Burgess).

The influence of media size upon the effective removal of organic waste from a liquid substrate was studied by the use of three experimental trickling filters under a set of

uniform operating conditions. The media size, and thus surface area, is shown to be of great influence in the establishing of optimum treatment conditions. The media size should be small enough to provide for a large amount of surface area per unit volume of media yet large enough to provide for a pore space giving adequate reaeration and fluid passing channels.

SERPANOS, James Evan. MS CE
"Stiffness Matrix Analysis of Structures by Electronic Digital Computer." (Orville Kofoid).

This thesis presents a matrix method for analyzing civil engineering structures. Emphasis has been given to the use of stiffness influence coefficients. Although the stiffness influence coefficients for an individual beam element are readily obtained from structural handbooks, a derivation is provided using the strain energy principles.

SHEN, Chung-Yi. MS ME
"The Distribution of Moisture Condensed from Saturated Air Flowing Through Cooled Porous Media." (M. B. Larson).

A theoretical study of the heat and mass transfer between saturated air and a cooled porous bed was made and experimental verification is presented. Qualitative agreement between the experimental results and the theoretical prediction was good. The quantitative agreement of temperature, pressure, and moisture distribution was within 10 to 20 percent.

SMITH, Roy John. MS EE
"Protection of Semiconductor Devices from Electrical Transients." (L. J. Weber).

Many techniques have been devised for the protection of semiconductor devices from various types of transients. A summary of the sources and the nature of these transients and the protection techniques is given in this thesis. The main cause of damage to semiconductor devices is overheating due to excessive power dissipation. Pulse tests performed using several types of transistors indicate that the theoretically predicted maximum allowable power dissipation at pulse widths from one second to one microsecond is realistic if second breakdown does not occur.

SWAN, Robert J. MS IE
"Investment Decisions by the Use of Present and Simulated Mathematical Models." (W. F. Engesser).

This study of investment decisions by the use of mathematical models verifies how models aid in accumulating and presenting information to management in the evaluation of a complete sub system. Construction of models uncovers more comprehensive data than the information usually collected in the conventional analysis approach. Most important, simulated models can be used to effectively appraise the overall efficiency of a sub system. Mathematical models were applied to a window and door frame factory; theoretically workable and ultimate systems were developed.

SWANSON, Vernon Hugo. MS ME
"Effect of Oscillation and Gas Content on Free Convection from Horizontal Cylinders in Water." (M. B. Larson).

An experimental study has been made of the effects of a change of the gas content of water on the natural convection heat transfer coefficient from an oscillating surface. The oscillation was found to increase the Nusselt number of the cylinder in most cases when compared with stationary data. These results were comparable to those of Martinelli and Boelter in similar work in which the gas content of the bath was not altered.

WILSON, Laurence Martin. MS ME
"Laboratory Creep Studies on 'Pheasant' and 'Expanded' Aluminum Conductors." (O. G. Paasche).

This thesis was to determine the following factors involved in conductor creep of 460 KV expanded conductors: effects of various combinations of pretension and pretension-hold time on conductor creep stabilization and long time creep, effects of conductor creep on the initial (E_i) and final (E_f) modulus of elasticity, cumulative effects of non-elastic elongation of a conductor from creep and from a temporary load increase involving the difference in E_i and E_f . Several factors concerning creep of conductor cables are reported.

WOO, Kwang Bang. MS EE
"Performance Considerations of Parallel Control Systems." (L. N. Stone).

Performance considerations of the positional control system consisting of two systems in parallel for the control of a common output load are investigated. The transient response to various combinations of control systems are considered in which the motor and load time constants are varied by changing the d-c motor design factors and the source impedance of the d-c motor power supply.

WORLEY, John Larry. MS CE
"A System Analysis Method for Water Quality Management by Flow Augmentation." (F. J. Burgess).

The objective of this thesis was to develop a digital computer program which would investigate the dissolved oxygen relationships in flowing streams and provide for automatic adjustment of flows to maintain minimum dissolved oxygen requirements. The computer program developed was applied to the Willamette River Basin in northwestern Oregon to illustrate its use, but it is general in character so that it may be applied to any drainage basin.

ADVANCED DEGREES IN ENGINEERING

June 1964

- ARPS, Ronald Barthold. MS EE
"Optical Character Recognition Using Mechanical Mask Matching." (Solon A. Stone).

This is a report describing limitations of optical character recognition using the mask-matching principle. Conclusions are supported by the results of an experimental system built for the purpose of reduction to practice. Formulas are derived describing the limitations of a mask-matching system. Given desired character reading speed, a specified character set, and reliability requirements, system specifications such as disc size, rpm, mask size, light source intensity, and output signal levels can be obtained.

- BERNHARDT, Donn Eugene. MS EE
"A Fast Carry Binary Adder." (Donald L. Amort).

This thesis describes the adder to be used with the Galaxy computer. Both the logical design and circuit design of the Galaxy Fast Carry Adder are discussed. Operating speed measurements for a 3 bit adder are presented and used to predict operating speeds of a 49 bit adder. Reliability considerations are discussed, and a set of worst-case resistor value calculations is included as an appendix.

- BISHOP, Stanley Robert. MS EE
"A Method For Analysis of Direct-Coupled Transistor Amplifiers." (L. J. Weber).

The demand for transistor circuitry to perform within more exacting specifications has created the need for a method to accurately predict transistor circuit performance. A method utilizing an electronic digital computer for the analysis of direct-coupled transistor amplifiers is explained. The d. c. bias levels and the midband a. c. voltage amplification of a circuit are discussed. The dependence of these parameters upon changes in value of circuit components is investigated. The method for analysis generated a mathematical model consisting of a system of simultaneous equations for the physical model of the circuit. The predicted theoretical values and experimental results showed good correspondence.

- BUFORD, Gary Manford. MS CE
"Jet Diffusion as Related to Ocean Outfall Systems."
(C. E. Behlke).

This study discusses important aspects of the ocean that should be considered in the design of a sewage outfall system. Conditions are restricted to those of the Oregon coastal area. They include predominant currents, upwelling tendencies, and ocean bottom characteristics. Major emphasis is placed upon investigation of diffusion characteristics of a horizontal fluid jet, with particular interest in the cone-of-diffusion, the cone formed by mixing of the jet fluid with surrounding fluid. Graphs are presented which show the effect of initial jet density and velocity and surrounding fluid density and velocity upon the position of the cone-of-diffusion axis. Values of densities and velocities are limited to those which would apply to an ocean outfall system used for disposal of domestic sewage and kraft mill effluent.

- CATO, Stuart Leslie. MS CE
"Web Buckling Failure of Built-Up Girders With Rectangular Holes." (T. J. McClellan).

This thesis describes the methods of failure in the webs of built-up girders. The beams had rectangular holes 5-1/2 inches wide and 7-1/2 inches high with rounded corners in a web 14 inches deep between flanges. The longitudinal position of the hole edge varied from 4 to 16 inches from the support. Results of the test were compared to analytical analysis for failure by column action, plate buckling, and shear in the web. Failure occurred by local crippling in the web in the test beams with holes 4 and 8 inches from the support. The test beams with holes 12 and 16 inches from the support failed by yielding of the web under the applied load.

- CHRISTENSEN, Gerald Albert. MS EE
"A Low-Power, Zone-Refining System for Semiconductor Materials." (J. C. Looney).

This paper presents an investigation of the power needs and impedance-matching techniques involved when heating small charges of relatively high-resistivity semiconductor materials. Considerable emphasis is placed on the efficiency of coupling between the induction heater and the load. Different methods of coupling the power

into loads of silicon and germanium are indicated. Discussion is on coupling centers around two work coil designs. An induction heater capable of delivering 4 kw output power was found sufficient for melting a zone 2 cm long in a 1.5 cm diameter ingot.

DENENHOLZ, Ira Marshall..... MS ChE
"Effect of Neighboring Spheres on Mass Transfer From a Single Sphere." (C. E. Wicks).

The effect of neighboring spheres on mass transfer from a single sphere is presented. One, two, three, and four additional spheres were geometrically placed near the sphere of interest. All spheres were 1.5 inches in diameter. Mass transfer from the camphor spheres into the airstream was measured over a Reynolds number range of 8,000 to 33,000. The Schmidt number was relatively constant, varying from 2.57 to 2.67. The mass transfer data were correlated using the Chilton-Colburn j-factor. The j-factor refers only to the single sphere of interest.

ELLIOTT, Leonard Thomas..... MS ME
"Catastrophic Propagation of Ductile Cracks in Metallic Foils." (R. D. Olleman).

The sudden failure of metal structures under load is characterized by a crack propagation rate which approaches the speed of sound in the material. Objective of this thesis was to investigate the factors which affect the tendency for a ductile crack to propagate catastrophically. An attempt was made to obtain catastrophic failure in 18- by 32-inch uniaxially stressed sheets of commercial household aluminum foil by introducing a crack in the center of the sheet in such a manner that the crack was elongated outwards in each direction. The catastrophic failure which was observed, however, was due to the addition of extra energy to the system boundaries which was not accounted for in the theory. Slow crack propagation was also observed. The plastic deformation at the crack tip was studied by visual observation using a metallograph and by actual measurement of the amount of deformation occurring during crack growth. This was done with a Tukon microhardness tester in which indentations were placed on the foil specimens, which were later given a small crack at the center, and which were mounted in a drill press vice on the tester.

Calculations of the strain energy needed to satisfy the plastic deformation energy requirements showed that a crack length of about 49 inches would be needed to cause catastrophic failure.

EVANS, David Roland..... MS CE
"Aircraft Washrack Wastes, Their Characteristics and Treatment." (D. C. Phillips).

Oils, greases, and grit which collect on an aircraft during flight are removed on the U. S. Air Force washracks using an alkaline, water-base cleaner. A study of aircraft washrack waste characteristics and treatment methods is presented in this thesis. Oil concentration, 5-day BOD, suspended solids, total solids, and effluent overflow are used to measure the waste characteristics and flow and to determine the efficiency of a gravity oil separator at the Portland Base. A testing procedure for determining oil concentrations is developed.

FULMER, Allen Lee..... MS EE
"A Digital Computer for Instructional Use."
(L. N. Stone).

The impact of the electronic computer on the teaching of mathematics, science, and engineering has created the need for a relatively low-cost instructional digital computer. SPEDTAC (Stored Program Educational Digital Transistorized Automatic Computer) was designed specifically to fulfill this need. The prototype described is a serial, solid-state, single-address, binary-type stored program digital computer. The magnetic disc memory has a capacity of 256, 13-bit words, with an average access time of 8.3 milliseconds. Operation over a period of a year has shown reliability and results in the classroom to be good.

GURIAN, Marshall Irvin..... MS ChE
"Rotating Silver-Silver Chloride Electrode Studies in Gaseous Chlorine Environments." (R. E. Meredith).

The mechanism of continuously chlorinated silver-silver chloride electrode performance was studied by using a wiped, rotating, partially submerged, cylindrical silver cathode. The cell performance using a zinc anode was measured, and the rate of chlorination of silver was calculated for several water-saturated chlorine atmospheres. Chlorination of silver followed a linear

equation. At lower chlorine partial pressures, growth of chloride film was found to follow logarithmic growth equations.

HARRIS, Dennis Roy..... MS CE
"Diffusion in a Variable Density Liquid Under Conditions of Turbulent, Steady Flow." (C. E. Behlke).

The diffusion process in a variable density, turbulent flow is a factor which greatly influences the waste disposal characteristics of tidal estuaries. Accurate prediction of the effects of proposed waste outfalls in well-mixed estuaries is desirable. For the purpose of providing a tool for predicting cyclical variation of waste concentrations and improving our understanding of the diffusion process, a dimensional analysis for the instantaneous diffusion coefficient (considering only bottom shear and longitudinal density gradients) was made. Experimental work was designed to determine relationships between dimensionless parameters obtained by the systematic method of Buckingham. Nature of the relationships obtained indicated they could serve as the correspondence between model and prototype for determining the longitudinal density gradient effects on the diffusion coefficient in well-mixed estuaries.

HECK, Lyle Daniel..... MS EE
"The Percussive Welding of Metal-Semiconductor Contacts." (J. C. Looney).

Application of automatic production techniques to fabrication of semiconductor devices has been somewhat limited by the requirements of conventional alloying techniques. This thesis investigates the feasibility of applying percussive welding to the fabrication of metal-semiconductor contacts as a solution to the problem of handling. The theory and technology of metal-semiconductor alloyed contacts, including both rectifying and ohmic contacts, are presented to determine the requirements for fabricating such contacts. Ohmic and rectifying contacts were fabricated by the percussive welding of gold and aluminum wires on silicon and germanium semiconductor materials.

HESPELT, George G. MS EE
"Control Circuitry for a Telemetry System." (L. N. Stone).

This thesis describes the control circuitry for a telemetry system to report hydrologic information from remote locations. The multiparameter, on-call system operates on a single frequency. Each remote station responds to a predetermined number of pulses from the master station. In the preliminary planning, careful consideration was given to the system reliability, the energy requirements of the remote station, and to system flexibility. The system is shown to be flexible in a variety of ways, is compatible with a wide variety of measurement transducers, and should prove satisfactory for many applications, in addition to the one for which it was designed.

HILL, James Carver. MS EE
"Logarithmic Generation by Binary Decoding." (L. N. Stone).

This thesis presents a method which uses combinatorial logic to perform the linear-to-logarithmic scale change before the digital-to-analog conversion is made (using a ladder of high-precision resistors). The reversal of operations results in greatly improved accuracy and range (integral linearities of one percent for ranges as great as 100 octaves). The method is used in the design of a display for a Nuclear Data 160 M multiparameter pulse-height analyzer and is applicable in any system which presents the initial data in a binary register with parallel access.

HUACCHO-SALAZAR, Reynaldo. MS EE
"Design of High-Input Impedance, Wide-Band Transistorized Amplifiers." (L. J. Weber).

This thesis describes an investigation of both field effect transistors and positive feedback as applied to high-input impedance, wide-band amplifier design. The field effect transistor, in the source-follower configuration, is shown to offer high-input impedance, wide-band amplification, and low-output impedance. Positive feedback is shown to increase considerably the input impedance without any danger of self-oscillations. The generalized theory is presented using a model amplifier consisting of an input stage containing the field effect transistor,

followed by two transistor stages. An experimental amplifier was built and tested in the laboratory to check the validity of the theoretical analysis.

INOUE, Michael Shigeru. MS IE
"Critical Path Scheduling: Tableau Method."
(J. L. Riggs).

The concept of a Critical Path Scheduling Tableau is introduced as an integrating tool for solving industrial engineering problems involving the application of transitive graphs. The Tableau is a combination of a precedence matrix and boundary time table which may be used to construct graphical representations for critical path scheduling such as: an arrow network, a bar chart, a time chart, and a manpower diagram. The dual network concept is developed and the construction of a dual circuit for a time chart is described. Finally, it is shown how a combination of a C. P. S. Tableau, time chart, and its dual network may lead to the construction of the time-cost curve for the project.

KATO, Howard Tsuneyuki. MS ME
"Correlation of Steam-to-Air and Hot Water-to-Air Heat Transfer Rates for a Finned Tube Heat Exchanger."
(A. D. Hughes).

This investigation was directed toward the development of a correlation for steam and hot water heat transfer rates. Experiments were conducted with a finned tube heat exchanger similar in construction to those used in central fan and fan-coil systems. The experimental equipment was designed such that either steam or hot water could be supplied to the heat exchanger, while air, drawn into the duct by a centrifugal fan, flowed over the finned surface. The experimental phase of the investigation was supported by a preliminary heat transfer analysis for a finned tube heat exchanger employing steam and hot water as the heating mediums. Results of the analysis anticipated several parametric forms for correlation of steam and hot water heat transfer rates. These results were applied to the analysis and correlation of experimental data.

- KHANNA, Satya Pal. MS EE
"The Concentration Profile of Diffused Radioactive Antimony in a Silicon-Dioxide Layer." (J. C. Looney).

The selective masking effect of a thermally-grown layer of silicon dioxide has been widely utilized as a technique for controlling the geometry and impurity concentration in semiconductor device technology. Very little work has been done in this field. The mechanism of chemical reduction of the impurity oxide in the silicon dioxide layer, and its distribution therein, should have a strong influence on the concentration of the impurity in silicon. This research was concerned with finding the distribution of antimony, one of the donor elements, in the oxide layer. Experimental evidence indicates that the migration of antimony through silicon dioxide is a diffusion controlled reaction, and that its concentration profile can be broken up into two regions.

- KING, Chia-Cheng. MS EE
"A Digital Computer Analysis and Synthesis of Linear Feedback Control Systems by Use of Superposition Integrals." (S. A. Stone).

Theoretical bases and techniques are discussed in this paper for practical numerical analysis and synthesis of linear feedback control systems. Criterion is based on the superposition integrals. A synthesis method is introduced to find the impulse response of a system or a part of the system. The existing system can be analyzed by using these impulse responses for unity or non-unity feedback systems. A method for compensation of an existing system is also introduced, and the transfer function of the required compensating network can be computed directly from its computed impulse function. Several examples for each kind of problem have been computed by using IBM 1620. Information on how to determine the required time increment is given to assure computational accuracy.

- KNUDSEN, Robert Allen. MS ChE
"Study of Chemical Reaction Studies by Frequency Response Methods." (D. E. Jost).

A method for measuring the chemical reaction rates in order to distinguish between different reaction mechanisms is presented. This method was used to study zero-, first-, and second-order reactions by analyzing

the output response to a sinusoidal input of reactant concentrations in an isothermal continuously stirred tank reactor. Results showed that only zero- and first-order reactions produce a pure sinusoidal output, and that the harmonics of a modified Fourier series are less than ten percent of the fundamental for a second-order reaction. A complex rate expression was also investigated, but the trial and error technique performed on an IBM 7090 digital computer did not converge.

LARSON, Edward Marshall. MS ChE
"Diffusion Coefficients of Chlorinated Hydrocarbons in Air." (C. E. Wicks).

The diffusion coefficients of several chlorinated hydrocarbons in air were determined by using an Arnold cell. The chlorinated hydrocarbons used were carbon tetrachloride, chloroform, 1, 2-dichloroethane and dichloromethane. To determine the reliability of the experimental method, diffusion coefficients were obtained for benzene and ethanol. These were compared with diffusion coefficients measured by other investigators. End effects due to turbulent eddies at the mouth of the tube and the surface tension of the liquid were accounted for in the determination of the diffusion coefficients.

MEYER, Walter. PhD ChE
"Equilibria in Ion Exchange Systems." (C. E. Wicks).

A new method for determining ion exchange equilibrium data by liquid scintillation counting of the equilibrated solution phase is described. This method has been applied to determine equilibria between Dowex 50W X8, a commercial strong cation exchange resin, and binary and ternary solution containing the varying combinations of H^{+1} , Cs^{+1} , Sr^{+2} , and Ce^{+3} . Equilibrium isotherms at room temperature are presented for total solution normalities of 0.1, 0.5, 1.5, 2.5, and 3.0. These data are correlated and examined in terms of phase, chemical, and Donnan equilibrium theories. Finally, feasibility of determining ternary equilibrium data from binary data is examined.

MITCHELL, Jack Alan. MS ME
"Control of Peak Stresses in Tensile Testing Machine
Components Subjected to Shock Loading."
(R. D. Olleman).

The mechanical properties of materials at cryogenic temperatures have been the subjects of increasing interest during the past few years, although very little actual materials testing has been done at extremely low temperatures because of the high cost and low heat of vaporization of liquid helium. A specially designed cryogenic tensile testing machine has been built employing a variable rate of loading and an electronic chart drive recorder. Object of this thesis is to analyze the effects of shock loading on the cryogenic tensile testing machine and to develop a means of reducing any shock environment seen by the load cell. A theoretical analysis of the response of the tensile rod and load cell to specimen fracture was made using the mathematical model of a long, slender rod with fixed-free end conditions and a suddenly removed axial load. In order to verify the problem of a shock environment imposed on the load cell and to check the theoretical results, an experimental study of the actual system was made. After studying many methods of absorbing and damping the shock loading, it was decided to design and fabricate a shock absorber having a piston and cylinder arrangement with a shock absorbing medium placed between the piston and cylinder head. Polyethylene and polyester urethane foams were chosen as possible shock absorbing mediums because of their excellent energy dissipation properties in compression. Polyethylene foam proved to be a substantially superior solution to the problem under consideration.

NOË, Alphonse Roman. MS ChE
"Local and Average Heat Transfer Coefficients in a Fluidized Bed Heat Exchanger." (J. G. Knudsen).

Local and average heat transfer coefficients for heat transfer from internal tubes to a fluidized bed were investigated. A fluidized bed heat exchanger was compared to a baffled and an unbaffled exchanger in terms of power and heat transfer surface area requirements. The fluidized bed consisted of areas of dense and sparse solids concentration. In the dense section of the bed, local coefficients were essentially constant and higher

values of the coefficients were obtained at lower flow rates. The opposite was true in the sparse section of the bed, and variation of heat transfer coefficient with flow rate was similar to that for single phase fluids. The average heat transfer coefficients were found to increase as a power function of the solids concentration. The ratio of the heat transfer capacity of the fluidized bed exchanger to that of the unbaffled and baffled exchangers was considerably greater than unity, indicating its advantage as far as space requirements were concerned.

PAPAGEORGE, George Elefterios. MS EE
"The Design of an Electrical Analog for Spherical Wave Propagation in Solid Elastic Media." (L. C. Jensen).

With the advent of underground testing, the study of the propagation of seismic signals has become of great importance. This thesis describes the design of electrical analogs to represent the propagation of seismic waves. The analogs developed allowed for study of the effects of variations in the characteristic constants of the medium through which the wave propagates and further allow for the characteristics of the source to be imposed upon the compressional displacement propagation. To include the effects of multiple layering, a second analog was designed. This was accomplished by connecting, in tandem, analogs representing single layers of specified thickness.

RICHARDSON, Dennis Waring. MS EE
"Predicting Transistor Switching Time,"
(D. L. Amort).

This thesis describes the development of two sets of equations for predicting the switching times of a saturated transistor. The first set of equations defines the rise, storage, and fall times at a single operating point where the transistor beta, cutoff frequency and collector capacitance are known. The second set of equations is for use with a manufacturers specification sheet describing the transistor parameters and the test conditions of a specified set of switching times.

- RUX, Peter Turner. MS EE
"The Field-Effect Transistor as a Medium-Speed, Low-Level Chopper." (D. L. Amort).

The field-effect transistor offers advantages as a chopping device since it does not have an offset voltage and it is not speed limited by its response time. Offset and drift are caused by leakage current and capacitive coupling between the control gate and the signal path. The capacitive component of this drift is proportional to frequency, so in order to increase the chopping frequency and maintain low drift, it is necessary to compensate for the capacitive drifts. Two techniques of balancing a second capacitor against the detrimental gate-drain capacitance of the chopper are investigated.

- SENK, Frederick Martin, Jr. MS EE
"Design and Evaluation of an Electronic Estimator of Probability Density Distributions." (L. J. Weber).

This thesis discusses the design and evaluation of an instrument that can estimate the probability density distribution of band-limited, aperiodic, electrical phenomena. This estimator can obtain the probability density estimates of signals that are contained within the frequency range of 100 cps to 20 kcs. However, the basic design logic of the instrument can serve as a design foundation for a device that should be capable of estimating the distributions of signals that range in frequency from a fraction of a cycle to 50 kcs. Transistors and solid-state diodes are used in the instrument's circuitry. An evaluation technique (the pseudo-impulse test) is introduced that involves the use of a test signal that has a theoretical probability density distribution which contains a series of impulse functions. The pseudo-impulse test is a powerful technique which will reveal the operating capabilities of an instrument.

- SHEN, Yuan-Shou. MS ME
"Creep Studies on Expanded, Chukar, and Drake Aluminum Conductors." (O. G. Paasche).

This thesis presents the creep properties and the relations between stress and strain of "Expanded 460 KV", "Chukar", and "Drake" conductors. Basic theories of the effect of load, material, and temperature on the conductor are also briefly discussed. The long-time creep

curve of a conductor appears as a straight line in log-log plot. The stable period of this curve after prestressing is directly affected by the prestress load and time. The conductor's initial strain is increased if the conductor is reeled or severely bent. The slope of the stress-strain curve of a conductor is only slightly affected by the long time creep. It is also slightly influenced by the initial condition of the conductor. However, the complete stress-strain curve will move to the right of where it should be if the conductor is severely reeled or bent.

SWORAKOWSKI, Michael Thomas.....MS EE
"Electrolytic Simulation of Airfoil Flow."
(L. N. Stone).

Airfoil flow simulation tests were carried out in a 20-inch diameter, double layer, circular electrolytic tank. Results of the tests indicate that the tank very closely approximates ideal conditions. The double layer, circular electrolytic tank is shown to generate a very large rectangular tank. Formulas were derived to show that this double layer tank is valid for the analogy between fluid velocity and voltage gradient. The first series of tests was performed with the ground plane very far from the model surface. Electrical current to the model was adjusted so that circulation and lift could be calculated for different angles of stagnation point on the model. The second series of tests was performed with suitable electrodes so the model would be near the ground plane. The purpose of these tests was to investigate how circulation, lift, and effective velocity varied when model to ground plane distance was varied.

TRENT, Donald Stephen.....MS ME
"The Control of Moisture Condensed from Saturated Air
Flowing Through Cooled Porous Media."
(M. B. Larson).

A theoretical study of the heat and mass transfer occurring in a cooled bed of unconsolidated porous material permeated by a flow of warm saturated air is presented and experimentally verified. Numerical solutions of the governing nonlinear differential equation indicate that perfect moisture uniformity is nearly impossible to attain. However, the ultimate use of this condensation process is for vapor irrigation, and although perfect

moisture uniformity is desirable, it is not necessary. Generally, it is shown that the moisture distribution may be predicted and controlled. However, thermal conductivity of most porous materials is so low that the required flow rate is too small to yield a satisfactory condensation rate. To increase the condensation rate, metal pins have been placed in the bed to improve the thermal conductivity, thus accommodating high mass flow rates. These pins, when properly shaped, yield an acceptable moisture distribution and may increase the condensation rate as much as 300 times. For this reason, pins find great utility in practical applications where rapid condensation is required. Experimental results were in good agreement with the theoretical predictions.

WARD, John Philip.....PhD ChE
"Turbulent Flow of Liquid-Liquid Dispersions: Drop Size, Friction Losses, and Velocity Distributions."
(J. G. Knudsen).

The momentum transfer characteristics of liquid-liquid dispersions were studied under conditions of turbulent flow in a circular conduit. Experiments were conducted to obtain drop size, friction factors, and velocity profiles for three organic phases dispersed in water. A photographic method of drop size determination was developed. Excellent results were obtained for drop diameters in the range 5-800 microns. Dispersions with concentrations from 1 to 50 volume percent were photographed. Drop size and shape of the drop size distributions depended strongly on dispersed phase viscosity. Range of drop diameters was found to increase with dispersed phase viscosity. Velocity profile data were obtained in the turbulent core for three flow rates and four concentrations for the light oil dispersions and two flow rates and three concentrations for the heavy oil dispersions. Results were combined with the drop size data and a previously proposed criteria for treating dispersions as a single phase fluids. Dispersions which do not meet this criterion are presumed to have a "slip" velocity; i. e., the larger drops move relative to the fluid element in which they are contained.

WATSON, William Paul. MS ME
"Fatigue of the Alloy Columbium (Niobium) - One Per-
cent Zirconium." (O. G. Paasche).

This paper concerns a study of the fatigue properties of the alloy columbium - one percent zirconium in reverse bending. This paper also concerns a design study of a satisfactory plate reverse bending fatigue specimen configuration for use with the General Electric PRB pneumatic testing machine. Selected tensile tests were also run on columbium - one percent zirconium to provide reference strength data with which to compare the results of the fatigue tests. The fatigue tests showed the fatigue strength of columbium - one percent zirconium to be higher than that of pure columbium. No endurance limit was found for the alloy in the range of testing from 10^5 to 10^7 cycles of reverse bending.

WILSON, Robert Elliot. PhD ME
"Relaxation Effects on Stagnation Point Heat Transfer."
(M. B. Larson).

Stagnation point heat transfer in a gas undergoing relaxation of its internal energy is examined by solution of the equations of motion using the two-temperature approach of Wang Chang and Uhlenbeck. The results are presented in parametric form and show that relaxation effects produce an adiabatic wall temperature above the free stream stagnation temperature, which is related to the thermal conductivity of the "inert" mode, the dimensionless relaxation length, the ratio of the translational mode temperature to the temperature of the relaxing mode at the edge of the boundary layer, and the magnitude of the internal energy undergoing relaxation. An experiment is described whereby the thermal conductivity of the "inert" mode, which is unknown, may be determined from adiabatic wall temperature measurements.

YOUNG, Clarence Robert. MS EE
"Circuit Parameter Influence on Transistor-Coupled
Logic." (L. N. Stone).

This thesis describes an investigation of the characteristics of transistor-coupled logic using both theoretical and experimental methods. The investigation included steady state and transient behavior of the transistor,

especially as applied to the common emitter configuration, the characteristics of a number of commonly used logic circuits. Characteristics of transistor-coupled logic circuits are investigated. For purposes of illustration a particular transistor is selected and a worst-case design performed using it. Transistor-coupled logic is found to be a fast, simple, reliable logic circuit; the main disadvantage being that of cost.

OREGON STATE UNIVERSITY
ENGINEERING EXPERIMENT STATION
CORVALLIS, OREGON

PARTIAL LIST OF PUBLICATIONS

(For a complete listing write the Engineering Experiment Station.)

Bulletins—

- No. 1. Preliminary Report on the Control of Stream Pollution in Oregon, by C. V. Langton and H. S. Rogers. 1929. 15¢.
- No. 2. A Sanitary Survey of the Willamette Valley, by H. S. Rogers, C. A. Mockmore, and C. D. Adams. 1930. 40¢.
- No. 3. The Properties of Cement-Sawdust Mortars, Plain and with Various Admixtures, by S. H. Graf and R. H. Johnson. 1930. 40¢.
- No. 4. Interpretation of Exhaust Gas Analyses, by S. H. Graf, G. W. Gleeson, and W. H. Paul. 1934. 25¢.
- No. 5. Boiler-Water Troubles and Treatments with Special Reference to Problems in Western Oregon, by R. E. Summers. 1935. None available.
- No. 6. A Sanitary Survey of the Willamette River from Sellwood Bridge to the Columbia, by G. W. Gleeson. 1936. 25¢.
- No. 7. Industrial and Domestic Wastes of the Willamette Valley, by G. W. Gleeson and F. Merryfield. 1936. 50¢.
- No. 8. An Investigation of Some Oregon Sands with a Statistical Study of the Predictive Values of Tests, by C. E. Thomas and S. H. Graf. 1937. 50¢.
- No. 9. Preservative Treatments of Fence Posts. 1938 Progress Report on the Post Farm, by T. J. Starker. 1938. 25¢. Yearly progress reports, 9-A, 9-B, 9-C, 9-D, 9-E, 9-F, 9-G. 15¢.
- No. 10. Precipitation-Static Radio Interference Phenomena Originating on Aircraft, by E. C. Starr. 1939. 75¢.
- No. 11. Electric Fence Controllers with Special Reference to Equipment Developed for Measuring Their Characteristics, by F. A. Everest. 1939. 40¢.
- No. 12. Mathematics of Alignment Chart Construction Without the Use of Determinants, by J. R. Griffith. 1940. 25¢.
- No. 13. Oil-Tar Creosote for Wood Preservation, by Glenn Voorhies. 1940. 25¢.
- No. 14. Optimum Power and Economy Air-Fuel Ratios for Liquefied Petroleum Gases, by W. H. Paul and M. Popovich. 1941. 25¢.
- No. 15. Rating and Care of Domestic Sawdust Burners, by E. C. Willey. 1941. 25¢.
- No. 16. The Improvement of Reversible Dry Kiln Fans, by A. D. Hughes. 1941. 25¢.
- No. 17. An Inventory of Sawmill Waste in Oregon, by Glenn Voorhies. 1942. 25¢.
- No. 18. The Use of the Fourier Series in the Solution of Beam Problems, by B. F. Ruffner. 1944. 50¢.
- No. 19. 1945 Progress Report on Pollution of Oregon Streams, by Fred Merryfield and W. G. Wilmot. 1945. 40¢.
- No. 20. The Fishes of the Willamette River System in Relation to Pollution, by R. E. Dimick and Fred Merryfield. 1945. 40¢.
- No. 21. The Use of the Fourier Series in the Solution of Beam-Column Problems, by B. F. Ruffner. 1945. 25¢.
- No. 22. Industrial and City Wastes, by Fred Merryfield, W. B. Bollen, and F. C. Kachelhoffer. 1947. 40¢.
- No. 23. Ten-Year Mortar Strength Tests of Some Oregon Sands, by C. E. Thomas and S. H. Graf. 1948. 25¢.
- No. 24. Space Heating by Electric Radiant Panels and by Reverse-Cycle, by Louis Slegel. 1948. 50¢.
- No. 25. The Banki Water Turbine, by C. A. Mockmore and Fred Merryfield. Feb 1949. 40¢.
- No. 26. Ignition Temperatures of Various Papers, Woods, and Fabrics, by S. H. Graf. Mar 1949. 60¢.
- No. 27. Cylinder Head Temperatures in Four Airplanes with Continental A-65 Engines, by S. H. Lowy. July 1949.
- No. 28. Dielectric Properties of Douglas Fir at High Frequencies, by J. J. Wittkopf and M. D. Macdonald. July 1949. 40¢.
- No. 29. Dielectric Properties of Ponderosa Pine at High Frequencies, by J. J. Wittkopf and M. D. Macdonald. September 1949. 40¢.
- No. 30. Expanded Shale Aggregate in Structural Concrete, by D. D. Ritchie and S. H. Graf. Aug 1951. 60¢.
- No. 31. Improvements in the Field Distillation of Peppermint Oil, by A. D. Hughes. Aug 1952. 60¢.

- No. 32. A Gage for the Measurement of Transient Hydraulic Pressures, by E. F. Rice. Oct 1952. 40¢.
- No. 33. The Effect of Fuel Sulfur and Jacket Temperature on Piston Ring Wear as Determined by Radioactive Tracer, by M. Popovich and R. W. Peterson. July 1953. 40¢.
- No. 34. Pozzolan Properties of Several Oregon Pumicites, by C. O. Heath, Jr. and N. R. Brandenburg. 1953. 50¢.
- No. 35. Model Studies of Inlet Designs for Pipe Culverts on Steep Grades, by Malcolm H. Karr and Leslie A. Clayton. June 1954. 40¢.
- No. 36. A Study of Ductile Iron and Its Response to Welding, by W. R. Rice and O. G. Paasche. Mar 1955. 60¢.
- No. 37. Evaluation of Typical Oregon Base-Course Materials by Triaxial Testing, by M. A. Ring, Jr. July 1956. 50¢.
- No. 38. Bacterial Fermentation of Spent Sulfite Liquor for the Production of Protein Concentrate Animal Feed Supplement, by Herman R. Amberg. Oct. 1956. 50¢.
- No. 39. Wood Waste Disposal and Utilization, by R. W. Boubel, M. Northcraft, A. Van Vliet, M. Popovich. Aug. 1958. \$1.00

Circulars—

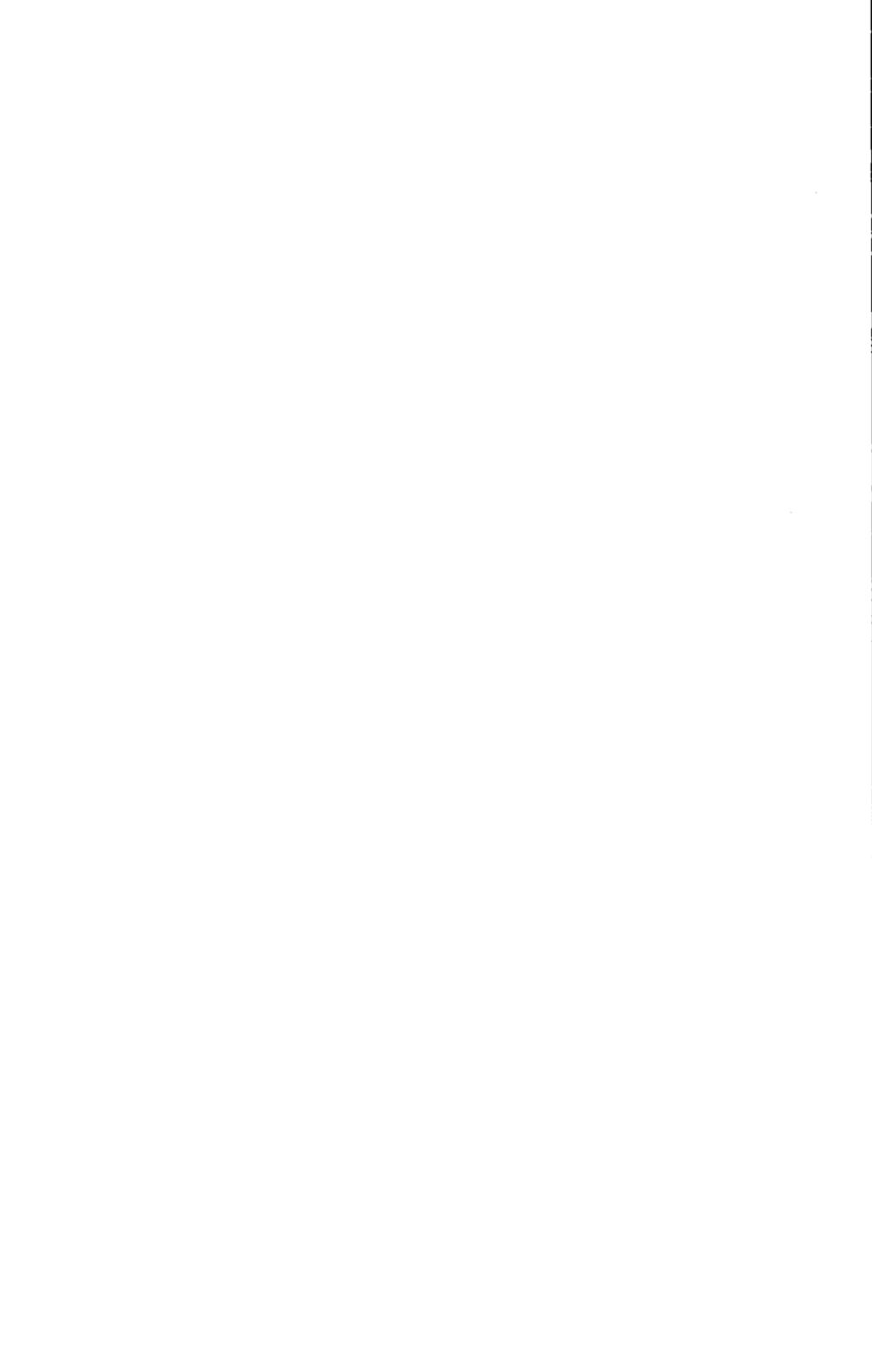
- No. 1. A Discussion of the Properties and Economics of Fuels Used in Oregon, by C. E. Thomas and G. D. Keerins. 1929. 25¢.
- No. 2. Adjustment of Automotive Carburetors for Economy, by S. H. Graf and G. W. Gleeson. 1930. None available.
- No. 3. Elements of Refrigeration for Small Commercial Plants, by W. H. Martin. 1935. None available.
- No. 4. Some Engineering Aspects of Locker and Home Cold-Storage Plants, by W. H. Martin. 1938. 25¢.
- No. 5. Refrigeration Applications to Certain Oregon Industries, by W. H. Martin. 1940. 25¢.
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- No. 10. Economics of Personal Airplane Operation, by W. J. Skinner. 1947. 25¢.
- No. 11. Digest of Oregon Land Surveying Laws, by C. A. Mockmore, M. P. Coopey, B. B. Irving, and E. A. Buckhorn. 1948. 25¢.
- No. 12. The Aluminum Industry of the Northwest, by J. Granville Jensen. 1950. 25¢.
- No. 13. Fuel Oil Requirements of Oregon and Southern Washington, by Chester K. Sterrett. 1950. 25¢.
- No. 14. Market for Glass Containers in Oregon and Southern Washington, by Chester K. Sterrett. 1951. 25¢.
- No. 15. Proceedings of the 1951 Oregon State Conference on Roads and Streets. April 1951. 60¢.
- No. 16. Water Works Operators' Manual, by Warren C. Westgarth. Mar 1953. 75¢.
- No. 17. Proceedings of the 1953 Northwest Conference on Road Building. July 1953. 60¢.
- No. 18. Proceedings of the 1955 Northwest Conference on Road Building. June 1955. 60¢.
- No. 19. Review for Engineering Registration, 1. Fundamentals Section, by Leslie A. Clayton. Dec 1955. 60¢.
- No. 20. Digest of Oregon Land Surveying Laws, by Kenneth J. O'Connell. June 1956. 75¢.
- No. 21. Review for Engineering Registration, 2. Civil Engineering, by Leslie A. Clayton and Marvin A. Ring. July 1956. \$1.25.
- No. 22. Review for Engineering Registration, 3. Mechanical Engineering, by Charles O. Heath, Jr. Feb 1957. \$1.25.
- No. 23. Research and Testing in the School of Engineering, by M. Popovich. May 1957. 25¢.
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- No. 25. Proceedings of the 1959 Northwest Conference on Road Building, Aug 1959. \$1.00.
- No. 26. Research Activities in the School of Engineering, by J. G. Knudsen, Nov 1960. 25¢.
- No. 27. Proceedings of the 1960 Northwest Highway Engineering Conference, Dec 1960. \$1.00.
- No. 28. Proceedings of the 1962 Northwest Roads and Street Conference, Mar 1962. \$1.00.
- No. 29. Proceedings of the Eleventh Pacific Northwest Industrial Waste Conference—1963, Sept 1963. \$1.00.
- No. 30. Proceedings of the 1964 Northwest Roads and Streets Conference, June 1964. \$1.00.
- No. 31. Research Activities in the School of Engineering, by J. G. Knudsen, Sept. 1964. 35¢.

Reprints—

- No. 1. Methods of Live Line Insulator Testing and Results of Tests with Different Instruments, by F. O. McMillan. Reprinted from Proc NW Elec Lt and Power Assoc. 1927. 20¢.
- No. 2. Some Anomalies of Siliceous Matter in Boiler Water Chemistry, by R. E. Summers. Reprinted from Combustion. Jan 1935. 10¢.
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- No. 19. Stoichiometric Calculations of Exhaust Gas, by G. W. Gleeson and F. W. Woodfield, Jr. Reprinted from National Petroleum News. Nov 1939. 10¢.
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- No. 27. Heat Losses Through Wetted Walls, by E. C. Willey. Reprinted from ASHVE Journal Section of Heating, Piping, and Air Conditioning. June 1946. 10¢.
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- No. 35. Transients in Coupled Inductance-Capacitance Circuits Analyzed in Terms of a Rolling-Ball Analogue, by P. C. Magnusson. Reprinted from Vol 69, AIEE Transactions. 1950. 10¢.
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- No. 38. An Analysis of Conductor Vibration Field Data, by R. F. Steidel, Jr. and M. B. Elton. AIEE conference paper presented at Pacific General Meeting, Portland, Oregon. Aug 23, 1951. 10¢.
- No. 39. The Humphreys Constant-Compression Engine, by W. H. Paul and I. B. Humphreys. Reprinted from SAE Quarterly Transactions. April 1952. 10¢.
- No. 40. Gas-Solid Film Coefficients of Heat Transfer in Fluidized Coal Beds, by J. S. Walton, R. L. Olson, and Octave Levenspiel. Reprinted from Industrial and Engineering Chemistry. June 1952. 10¢.
- No. 41. Restaurant Ventilation, by W. H. Martin. Reprinted from The Sanitarian, Vol 14, No. 6. May-June 1952. 10¢.
- No. 42. Electrochemistry in the Pacific Northwest, by Joseph Schulein. Reprinted from Journal of the Electrochemical Society. June 1953. 20¢.
- No. 43. Model Studies of Tapered Inlets for Box Culverts, by Roy H. Shoemaker and Leslie A. Clayton. Reprinted from Research Report 15-B, Highway Research Board, Washington, D. C. 1953. 20¢.
- No. 44. Bed-Wall Heat Transfer in Fluidized Systems, by O. Levenspiel and J. S. Walton. Reprints from Heat Transfer-Research Studies. 1954. 10¢.
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- No. 50. Heat Transfer Between Immiscible Liquids, by S. S. Grover and J. G. Knudsen. Reprinted from Chemical Engineering, No. 17, Vol 51. 10¢.
- No. 51. How Oil Viscosity Affects Piston Ring Wear, by M. Popovich and L. E. Johnson. Reprinted from Automotive Industries. January 1956. 10¢.
- No. 52. Intermittent Discharge of Spent Sulphite Liquor, by Herman R. Amberg and Robert Elder. April 1956. 10¢.
- No. 53. Hydraulics of Box Culverts with Fish-Ladder Baffles, by Roy H. Shoemaker, Jr. Reprinted from Proceedings of the Highway Research Board, Vol 35. 1956. 25¢.
- No. 54. A Numerical Solution to Dimensional Analysis, by O. Levenspiel, N. J. Weinstein, J. C. R. Li. Reprinted from Industrial and Engineering Chemistry, Vol 48. Feb 1956. 25¢.
- No. 55. Thermal Conductivity of Liquid-Liquid Emulsions, by R. H. Wang and James G. Knudsen. Reprinted from Industrial and Engineering Chemistry, Nov 1958. 10¢.
- No. 56. Local Shell-Side Heat Transfer Coefficients in the Vicinity of Segmental Baffles in Tubular Heat Exchangers, by M. S. Gurusankariah and J. G. Knudsen. Reprinted from Heat Transfer-Chicago issue of AIChE Symposium Series. 1959. 10¢.
- No. 57. Hard-Water Scaling of Finned Tubes at Moderate Temperatures, by H. K. McCluer and J. G. Knudsen. Reprinted from Heat Transfer-Chicago issue of AIChE Symposium Series. 1959. 10¢.
- No. 58. Heat Transfer from Isothermal Flat Plates: An Extension of Pohlhausen's Solution to Low and High Prandtl Number Fluids, by F. D. Fisher and J. G. Knudsen. Reprinted from Chemical Engineering Progress Symposium Series No. 29. 1959. 10¢.

- No. 59. Radio Interference Attenuation on Energized High-Voltage Transmission Lines: Measurement and Application, by L. N. Stone, E. H. Gehrig, and R. S. Gens. Reprinted from Power Apparatus Systems, Dec 1959. 10¢.
- No. 60. EHV Single and Twin Bundle Conductors—Influence of Conductor Diameter and Strand Diameter on Radio Influence Voltage and Corona Initiation Voltage, by L. N. Stone. Reprinted from Power Apparatus and Systems, Dec 1959. 10¢.
- No. 61. Local Shell-Side Heat Transfer Coefficients and Pressure Drop in a Tubular Heat Exchanger with Orifice Baffles, by K. S. Lee and J. G. Knudsen. Reprinted from AIChE Journal, Dec 1960. 10¢.
- No. 62. Rates of Heat Transfer from Short Sections of an Isothermal Pipe, by A. A. Faruqui and J. G. Knudsen. Reprinted from Heat Transfer-Buffalo issue of AIChE Symposium Series, Mar 1961. 10¢.
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- No. 65. Evaluation Criteria for Deep Trickling Filters, by F. J. Burgess, F. Merryfield, J. K. Carswell, and C. M. Gilmour. Reprinted from Journ Water Pollution Control Federation, Aug 1961. 10¢.
- No. 66. Effect of Negative Corona Upon Formation of Positive Corona, by G. A. Pearson. Reprinted from Power Apparatus & Systems, Dec 1961.
- No. 67. Design of the ESAC Algebraic Computer, by J. C. Looney and M. L. Morgan. Reprinted from IRE Transactions on Electronic Computers, Sept 1961. 10¢.
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- No. 69. The ESAC Potential-Plane Analog Computer, by J. C. Looney. Reprinted from Automatic Control, May 1961. 10¢.
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- No. 71. The Role of Current Distribution in Cathodic Protection, by R. E. Meredith. Reprinted from Materials Protection, Feb 1963. 10¢.
- No. 72. Local Rates of Heat Transfer and Pressure Losses in the Vicinity of Annular Orifices, by P. S. Williams and J. G. Knudsen. Reprinted from The Canadian Journal of Chemical Engineering, April 1963. 10¢.
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- No. 76. Evaluating the Effective Resistances of Diaphragms or Electrolytic Separators, by R. E. Meredith and C. W. Tobias. Reprinted from Journal of the Electrochemical Society, Dec 1963. 10¢.



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Forestry (M.S., M.F., Ph.D. degrees)

Home Economics (M.A., M.S., M.H.Ec., Ph.D. degrees)

Pharmacy (M.A., M.S., M.Pharm., Ph.D. degrees)

Summer Sessions

Short Courses, Institutes, Workshops

RESEARCH AND EXPERIMENTATION

General Research (established 1932)

Agricultural Experiment Station (established 1888)

Agricultural Research Division

Forest Research Division

Branch Stations at Astoria, Aurora, Burns, Hermiston, Hood River and The Dalles, Klamath Falls, Medford, Moro, Ontario, Oregon City, Pendleton, Redmond, and Union.

Engineering Experiment Station (established 1927)

Science Research Institute (established 1952)

Transportation Research Institute (established 1960)

Water Resources Institute (established 1960)

Radiation Center (established 1964)

EXTENSION

Federal Cooperative Extension (Agriculture and Home Economics)

Division of Continuing Education, State System of Higher Education