NOVEMBER 1960
CIRCULAR NO. 26

ENGINEERING EXPERIMENT STATION
OREGON STATE COLLEGE
CORVALLIS, OREGON

Research Activities In the School of Engineering

By
J. G. KNUDSEN
Assistant Dean of Engineering
Oregon State College

THE Oregon State Engineering Experiment Station was established by act of the Board of Regents of Oregon State College 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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CORVALLIS, OREGON

RESEARCH ACTIVITIES IN THE SCHOOL OF ENGINEERING 1958-1960

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FOREWORD

This circular describes research activities of the Oregon State College School of Engineering during the school years 1958-59 and 1959-60. These activities are listed according to the engineering department in which the research is carried out. In each department section are described facilities of the department, research projects, and graduate degrees, including short theses abstracts.

The first section describes organization, facilities, and operation of the Oregon State College Engineering Experiment Station. The Station receives a budget with which it can provide several research assistantships and other limited support consisting of materials and supplies for worthwhile projects devoted to basic research in engineering or research beneficial to the State of Oregon. The Station also administers a number of research projects in the Engineering School which are sponsored by various state, federal, or industrial agencies. Normally, when the Engineering Experiment Station administers a research project supported by an outside agency, the research is carried on in the department with which the research director is associated. For this reason, no research projects are listed in the section describing the Engineering Experiment Station.

Description of each research project includes the source of financial support for the project. Where support is listed as the Engineering Experiment Station, the research project is being supported either partially or totally out of the regular budget from the State System of Higher Education. In some cases, a number of agencies are listed as supporting one project. This applies quite frequently on projects where the Engineering Experiment Station supplies the initial support, but sponsorship from other sources is obtained subsequently. Support of some projects is not indicated in their description. In these cases the engineering department concerned usually supports the research with a graduate asistantship, materials, and equipment.

RESEARCH ACTIVITIES IN THE SCHOOL OF ENGINEERING 1958-1960

ENGINEERING EXPERIMENT STATION

G. W. Gleeson, Dean, School of Engineering and Industrial Arts; 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 100 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 54 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, American Institute of Electrical Engineers, Institute of Radio Engineers, American Institute of Chemical Engineers, Society of Automotive Engineers, American Society of Heating 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 College 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.

Experts who are especially qualified by training and experience to advise on investigations in certain fields have been appointed to the staff as special technical counselors. Among these are executives and engineers representing major industries of Oregon and the Northwest, prominent consulting engineers, and leading engineers of federal agencies and state departments. Some assistants have been supported by manufacturers and industrial associations interested in working out specific problems.

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. An extensive laboratory for study of mineral dressing and carrying out assaying operations also is housed in this building.

When necessary, the Engineering Experiment Station may receive technical assistance from other departments on the campus. The Chemistry Department has a variety of precision analytical instruments. The Physics Department has an electron microscope available to those who require such an instrument in their research. A mass spectrometer belonging to the School of Science is also available for analytical work. Computing facilities on the campus include two computers in the Mechanical and Electrical departments. In addition, there is an ALWAC III-E digital computer in the Mathematics Department available for those wishing to process data or to solve complicated mathematical problems.

One of the most valuable of campus research facilities is the college library, which has an outstanding technical and scientific collection. The science section contains 69,000 volumes and the engineering and applied technology collections contain 40,000 volumes. In addition, library subscriptions to scientific and engineering periodical literature are exceptionally complete.

In carrying out research which involves fields outside of engineering, the Engineering Experiment Station may cooperate with the Agricultural Experiment Station, Oregon Forest Products Laboratory, Science Research Institute, and various federal agencies existing on the campus. As the list of various research projects described in the following pages will show, such federal agen-

cies as the Bureau of Public Roads, U.S. Public Health Service, Corps of Engineers, Bonneville Power Administration, and Bureau of Mines 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. Because funds are limited, Station-sponsored projects are critically reviewed before they are approved.

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 college. The sponsoring organization provides funds to pay for all direct and indirect costs.

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 college are included along with statements concerning records and reports, access of sponsor to facilities, records and accounts of the college, subcontracting, patent provisions, period of the contract, and any other pertinent general conditions that may be specified.

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 into 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 assignments 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 college 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 highest 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.

AGRICULTURAL ENGINEERING

J. B. Rodgers, Department Head

The Department of Agricultural Engineering is a joint department within the School of Engineering and the School of Agriculture. Facilities are provided in the Agricultural Engineering building for teaching and experimental work in these two fields. Research in Agricultural Engineering is supported and administered through the Oregon Agricultural Experiment Station. In addition, support for Agricultural Engineering research projects is obtained through the U. S. Department of Agriculture, U. S. Department of Interior, other federal and state agencies, and the Agricultural Engineering Research Foundation.

Facilities are available for research work on farm equipment, soil and water control and conservation, farm structures, rural electrification, and crop processing. Extensive work has been carried on by the staff in the fields of seed harvesting, seed cleaning, development of specialized farm machinery, crop processing, farm structures, and irrigation and drainage.

The following list of projects describes the engineering phases of research under way in the Department of Agricultural Engineering.

RESEARCH ACTIVITIES

Development of Improved Equipment and Methods for Harvesting and Processing Seed Crops—Design and Development of an Electrostatic Seed Separator

Investigators: D. E. Booster, Assistant Professor of Agricultural Engineering; J. E. Harmond, Principal Agricultural Engineer, USDA.

Support: Agricultural Experiment Station, U.S. Department of Agriculture.

An electrostatic seed separator has been built by the Agricultural Engineering Department for the purpose of making seed separations that are impossible or impracticable with conventional seed cleaning equipment. Work has consisted of determining what seed mixtures can be separated by this method, determining effect of seed moisture content on separation, and effects of exposure of high voltages on seed germination.

Development and Testing of Equipment for Seeding Grasses on Sagebrush-Bunchgrass Range

Investigators: D. E. Booster, Assistant Professor of Agricultural Engineering; D. N. Hyder, F. A. Sneva, Range Conservationists.

Support: Agricultural Experiment Station, U.S. Department of Agriculture.

A heavy-duty range seeder has been developed for use in range improvement programs. This machine is especially suited for use in areas where dry, loose soils prevail. Plans and specifications for a 12-row seeder are available to interested parties, and also have been turned over to the U.S. Forest Service Equipment Development Center, Arcadia, California, for further development for use by governmental agencies.

Development of Specialized Farm Machinery and Equipment—Design, Development, and Testing of a Mechanical Blackberry Harvester

Investigator: D. E. Booster, Assistant Professor of Agricultural Engineering.

Support: Agricultural Research Foundation, Agricultural Experiment Station.

A self-propelled, one-row, mechanical blackberry harvester has been constructed. The machine incorporates two powered picking heads, two hand-controlled picking heads; and a catching and conveying mechanism. The machine was tested for the first time in the summer of 1960.

Evaluation of Soil as a Source of Heat

Investigator: M. G. Cropsey, Professor of Agricultural Engineering.

Support: Agricultural Experiment Station.

An attempt is being made to predict the amount of heat that can be obtained from soil when conductivity, density, specific heat, and moisture content of the soil are known.

Determination of Effect of Cathode Ray Irradiation on the Germination, Respiration Rate, Microorganism, and Taste of Wheat

Investigator: M. G. Cropsey, Professor of Agricultural Engineering.

Support: Agricultural Experiment Station.

Tests are being made to determine effectiveness of cathode rays in prevention of spoilage of wheat without impairing taste or germination qualities.

Factors Affecting Character of Frozen Strawberries

Investigator: D. E. Kirk, Associate Professor of Agricultural Engineering.

Support: Agricultural Experiment Station.

This is a cooperative project with the Department of Food and Dairy Technology. Department of Agricultural Engineering is concerned with studying the mechanical damage currently suffered by frozen strawberries and recommending equipment and procedures for improving the final frozen product.

GRADUATE DEGREES: June 1959 and June 1960

Chen, Tsu-Fang. . . . . .MS, June 1959

Effect of Soil Moisture Tension on Transpiration Rate of a Young Sunflower When Irrigated by a Condensation Method

Adviser: John W. Wolfe

Soil moisture tension is directly related to moisture content of soil. In this study the transpiration rate of a young sunflower with respect to soil moisture tension under constant environment was studied by supplying moisture by a condensation method in an attempt to maintain constant and uniform moisture. It was found that an increase in soil moisture tension will cause a decrease in transpiration rate. Rate of change of transpiration rate was higher at a moisture tension lower than 15 atmospheres, and slowed down at higher tensions up to 30 atmospheres. It also was found that the condensation method in studying the relation between soil moisture tension and transpiration rate of a small plant was satisfactory, although effect of saturated airflow and compaction of soil needed further investigation.

Agricultural Engineering

Schoof, James Earl MS, June 1960

An Automatic Null-Type Piezometer for Measuring Positive and Negative Soil-Moisture Pressures in Soils with Low Permeability

Adviser: John W. Wolfe

An instrument has been developed to meet the need for a better means of measuring water pressure at specific locations in the soil, particularly as it relates to drainage investigations in tight stratified soils. Requirements for this instrument are such that a piezometer in the form of a null-type tensiometer appears to be satisfactory. This type of instrument uses a standard tensiometer cup as the porous unit in the soil. The null operation was obtained by adjusting the outer leg of a mercury manometer to balance any soil-water pressure variation, thus reducing the water transfer needed to establish pressure equilibrium. The instrument developed meets all requirements necessary to measure accurately soil-moisture pressure. It needs refinement, however, to reduce possible error in the recorded information.

CHEMICAL ENGINEERING

J. S. Walton, Department Head

In 1955, the Chemical Engineering Department occupied a new chemical engineering building and, therefore, possesses fine research and instructional facilities. Extensive additional equipment was provided with the new building, and research can be carried out in almost any field of chemical engineering.

The Chemical Engineering staff has a wide variety of interests, including petroleum, synthetic rubber, economics, mass transfer operations, electro-chemistry, high-temperature calorimetry, metallurgy of the "newer" metals and their compounds, fluid mechanics, heat transfer, two-phase flow, vapor liquid equilibrium, reaction kinetics, and nuclear processes. Department has facilities and equipment available for conducting research in any of the above subjects. Special equipment available includes a spectrophotometer, gas chromatograph, precision refractometer, high and low temperature thermostats, and precision temperature measuring equipment. The department recently obtained a hot-wire anemometer and all associated electronic equipment for study of turbulence in flowing gases and liquids. This equipment will be used to study effect of turbulence on rates of heat and mass transfer in the department's medium-speed wind tunnel.

RESEARCH ACTIVITIES

Local Shell-Side Heat Transfer Coefficients in Baffled Tubular Heat Exchangers

Investigators: J. G. Knudsen, Assistant Dean of Engineering; K. Narayanan, Graduate Assistant.

Support: National Science Foundation.

This project has been continuing for a number of years and is concerned with determination of local shell-side heat transfer coefficients in baffled tubular heat exchangers. Considerable information has been obtained on effect of baffle spacing, clearance between tube and baffle, and type of baffle. Work is continuing on effect of tube spacing and tube diameter. In addition, detailed information is being obtained in the vicinity of baffles to determine effect of various clearances associated with the baffles. Two types of heat transfer probes have been designed; one utilizing thermocouples and the other thermistors.

Local Rates of Heat Transfer in Vicinity of Annular Orifices

Investigators: J. G. Knudsen, Assistant Dean of Engineering; P. S. Williams, Graduate Assistant.

Objective of this research is to obtain a more thorough understanding of heat and momentum transfer processes occurring in multitube heat exchangers in vicinity of baffles at the point where the tube passes through the baffle. Previous work has shown that this is an area of high heat transfer coefficients, but effect of these on overall performance of the exchanger and their prediction from the shell-side flow rate and characteristics of the heat exchanger are not possible.

Rates of Natural Convection Heat Transfer from Finned Tubes

Investigators: J. G. Knudsen, Assistant Dean of Engineering; R. B. Pan, Graduate Assistant.

Support: Engineering Experiment Station.

Objective of investigation is to make a theoretical and experimental study of natural convection heat transfer to still air from heated finned tubes. Finned tubes are used extensively for space heating, but no published data have been found in which the natural convection heat transfer coefficient is determined as a function of fin size, tube size, type of fin, fin spacing, and temperature difference.

Heat Transfer and Flow Characteristics of Emulsions Made Up of Two Immiscible Liquids

Investigators: J. G. Knudsen, Assistant Dean of Engineering; A. A. Faruqui, Graduate Assistant.

Support: National Science Foundation.

This study involves determination of momentum and heat transfer characteristics of emulsions made up of two immiscible liquids. Heat transfer coefficients and laminar and turbulent viscosities are being determined from flow in a circular tube. Laminar and turbulent viscosities have been correlated with flow rate and concentration of the dispersed phase in the emulsion. In addition, velocity profiles are being obtained for both isothermal and nonisothermal flow, and temperature profiles are being obtained for nonisothermal flow.

A Study of Fuel Cells

Investigators: R. E. Meredith, Assistant Professor of Chemical Engineering; V. Hauser, Graduate Assistant.

Support: Engineering Experiment Station.

Potential uses of an operative fuel cell are extremely great. A large amount of research is being carried out at the present time in industry on this source of electric energy. Most of these investigators are solely interested in developing an economical device. Proposed research in this project will be designed to investigate electrode reactions and chemical mechanisms with which maximum power may be obtained from such a cell at the expense of economical geometry and operation.

Use of A-C Fields as a Source of Energy for Endothermic Reactions

Investigator: R. E. Meredith, Assistant Professor of Chemical Engineering.

Support: General Research Fund, Oregon State College.

Alternating current electrodes are used in conducting medium to supply heat or energy to a liquid for endothermic chemical reactions. This method of supplying energy is being compared to the more conventional method of transferring heat through the walls of a reaction vessel. In the former case, energy is generated within the body of the reacting liquid by alternating fields and thus is free of large temperature gradients and hot walls where secondary reactions could occur.

Optimum Power Generation in a Streaming Potential Cell

Investigator: R. E. Meredith, Assistant Professor of Chemical Engineering.

The streaming potential which is generated as liquid is forced to pass through a porous medium is being studied as a function of the ionic strength of the liquid. Largest potentials are obtained when ionic strength is zero. However, the current that one can draw from the cell under this condition is negligible. Research is being conducted to ascertain under what conditions one may realize the maximum power in the external circuit from such a cell.

Moving Bed Ion Exchange Recovery of Radio Cesium and Cerium

Investigator: W. Meyer, Instructor in Chemical Engineering.

Support: General Research Fund, Oregon State College.

Purpose of this work is to develop a moving bed ion exchange system and to investigate recovery of cesium and cerium from radioactive waste solutions with such a system.

Power Requirements in Mixing of Single- and Two-Phase Liquids at High Reynolds Numbers

Investigator: R. H. Moen, Assistant Professor of Chemical Engineering.

Support: National Science Foundation(Undergraduate Participation Program).

This is a study of power requirements and mixing behavior in baffled tanks at such high Reynolds numbers that surface entrainment of gases occurs. This entrainment is due to formation of small vortices which are cut off below the surface of the liquid, thus carrying gas bubbles into the liquid phase.

Solid-Vapor Equilibria of Metal Salts

Investigators: J. S. Walton, Head, Chemical Engineering Department; Arne Landsberg, R. J. Nelson, Graduate Assistants.

Support: National Science Foundation, Engineering Experiment Station.

Objective of this work is to eventually determine possibilities of effecting separations of metals by fractional sublimation. Before this, however, a study must be made on fundamental equilibrium data for vapor-solid mixtures.

Fractional Sublimation of Metal Salts

Investigator: J. S. Walton, Head, Chemical Engineering Department.

Support: National Science Foundation (Undergraduate Research Training Program).

This program is designed to provide research training and experience for undergraduates who will secure fundamental data on an experimental device for effecting separation of hafnium-zirconium tetrachlorides and/or niobium-tantalum pentachlorides by means of fractional sublimation.

High-Temperature, Calorimetric Measurements of Ferroalloy Compounds

Investigators: C. E. Wicks, Professor of Chemical Engineering; J. R. Welty, Instructor in Mechanical Engineering.

Support: U.S. Bureau of Mines.

This project involves design of a platinum resistance furnace which can be controlled to 1°F in the 298°-1800°K range, and an adiabatic ice calorimeter. A high-temperature calorimeter has been constructed to evaluate heat content and, in turn, to obtain heat capacity data.

Kinetics of Reduction of Columbium Oxychloride

Investigators: C. E. Wicks, Professor of Chemical Engineering; F. D. Stevenson, Graduate Assistant.

Support: Engineering Experiment Station, U.S. Bureau of Mines.

Mechanisms of reduction of columbium oxychloride to columbium pentachloride are being evaluated. Nature of compounds involved requires development of special handling equipment to provide an inert atmosphere.

Gas Chromatographic Analysis of Kraft Paper Mill Stack Gases

Investigators: C. E. Wicks, Professor of Chemical Engineering; R. Roberts, Graduate Assistant.

A new chromatographic method for convenient analysis of the malodors from a kraft paper mill has been developed. Sampling techniques and chromatography column packing were investigated.

Investigation of Performance Characteristics of a Mixer-Settler Extractor

Investigators: C. E. Wicks, Professor of Chemical Engineering; R. P. Romig, Graduate Assistant.

A three-stage, mixer-settler extractor has been designed and constructed. Efficiency of transferring acetic acid from organic liquid streams to an aqueous stream will be investigated under different operating conditions of the mixer-settler.

Effect of Tray Spacing Upon Optimum Amplitude and Frequency in a Pulsed, Sieve Tray, Liquid-Liquid Extraction Column

Investigators: C. E. Wicks, Professor of Chemical Engineering; J. A. Welch, Graduate Assistant.

Optimum amplitude and frequency used in pulsing a sieve tray, liquid-liquid extraction column will be studied using four different tray spacings. Three organic systems in which acetic acid is transferred to the aqueous stream will be investigated.

Computer Evaluation of Vapor-Liquid Equilibrium Data

Investigators: C. E. Wicks, Professor of Chemical Engineering; R. Bateman, Senior.

Support: National Science Foundation (Undergraduate Participation Program).

A literature search was conducted for binary vapor-liquid equilibrium data, and these data were tested for thermodynamic consistency using an available digital computer program. A computer program was written for the Antoinne vapor-pressure equation. Constants for a number of compounds were determined.

Abatement of Kraft Pulp Mill Odors by Black Liquor Oxidation

Investigators: C. E. Wicks, Professor of Chemical Engineering; S. Hill, Senior.

Support: National Science Foundation (Undergraduate Participation Program).

Kinetics of oxidation of kraft pulp mill effluent vapors were investigated. A high-temperature, packed-bed reactor was designed and constructed.

GRADUATE DEGREES: June 1959 and June 1960

Bodine, James Elmer, Jr. . . . . MS, June 1959

Construction and Test of a Solar Furnace

Adviser: C. E. Wicks

A solar furnace was constructed by modifying a war surplus military searchlight containing a 5-foot diameter parabolic reflector. The parabolic reflector was removed from the base and mounted, facing downward, over a stationary 45-degree plane reflector. Base of the searchlight was modified to accept a plane reflector which automatically tracked the sun. Back-silvered plate glass mirrors were used for reflecting surfaces of both plane reflectors. A test made with one-half of the mirrors in place indicated that a temperature of 1745°C was obtainable as indicated by melting pyrometric cones. Image at the focal point was well defined, measuring approximately 3/8-inch in diameter. This test was made during October, and it is estimated that for similar operation with all mirrors in place, a temperature of approximately 2500°C is available. Similar furnaces report temperatures in excess of 2800°C.

Cengel, John Anthony. . . . . MS, June 1960

Viscosity of Liquid-Liquid Dispersions in Laminar and Turbulent Flow

Adviser: James G. Knudsen

Viscosities of a dispersion of two immiscible liquids in laminar and turbulent flow were determined. Viscosities in laminar flow were found to be dependent upon dimensions of the capillary tube. In turbulent flow, the dispersions behaved in a pseudo-

plastic manner and could be expressed in terms of the viscosity of the continuous phase and a power function of the volume fraction of the discontinuous phase.

Cohn, Paul Daniel. . . . . .MS, June 1960

Heat Transfer Coefficients for Condensation of Liquid Metal Vapors Inside a Vertical Tube

Adviser: James G. Knudsen

Heat transfer coefficients were determined for condensation of water, cadmium, mercury, and solutions of 0.3 and 1 percent sodium in mercury inside a vertical tube. Results obtained for water were within the range of previous experimental results. Data for mercury and solutions of 0.3 and 1 percent sodium and mercury gave quite similar results. Experimental condensing coefficients were much lower than those predicted by the Nusselt condensing equation.

Faruqui, Azimuddin Ahmad. . . . . .MS, June 1959

Effect of Upstream Disturbances on Rate of Heat Transfer From a Short Section of Heated Pipe

Adviser: James G. Knudsen

Average heat transfer coefficients were measured for short sections of a heated pipe with various configurations of entrances upstream from the heated section. Correlations were obtained for predicting average heat transfer coefficients over the short sections for various upstream entrance conditions.

Fisher, Fred Dean. . . . . .PhD, June 1960

Construction and Operation of a High-Temperature Solar Furnace: Studies of Elemental Boron

Adviser: C. E. Wicks

Design, construction, and operation of a high-temperature solar furnace for solid-liquid studies are described. The furnace utilizes a downward facing paraboloidal concentrator mirror from a military searchlight. Sunlight is directed into the concentrator

by a heliostat and an inclined stationary mirror. Performance testing of the furnace is described. X-ray analyses of elemental boron melts produced in the furnace reconfirm the existence of a high-temperature, stable, rhombohedral boron. Attempts to further purify commercial grade elemental boron by fusion techniques are described.

Lee, Kyu Sung. . . . . .MS, June 1959

Local Shell-Side Heat Transfer Coefficients and Pressure Drop in a Tubular Heat Exchanger with Orifice Baffles

Adviser: James G. Knudsen

Local shell-side heat transfer coefficients and pressure drops were measured in a model tubular heat exchanger containing orifice baffles. Correlations were obtained for the average coefficient in the exchanger and the point coefficient in the orifice opening. Pressure losses were correlated in terms of an annular discharge coefficient.

Macan, John Warren. . . . . MS, June 1959

Computer Evaluation of Binary Vapor-Liquid Equilibrium Data

Adviser: C. E. Wicks

A new series of orthogonal polynomials was proposed to classify binary vapor-liquid equilibrium data and to help smooth experimental data. A program for this series was programmed on the ALWAC III-E digital computer and was used to check 29 sets of experimental data for thermodynamic consistency. Proposed series offered advantages over the previously used Redlich-Kistler equation.

Miller, Richard Linn. . . . . MS, June 1959

An Improved Vapor-Liquid Equilibrium Still

Adviser: C. E. Wicks

An Othmer type of recirculating vapor-liquid equilibrium still was modified to include a stirring mechanism in order to provide a uniform liquid composition in the body of the still. Ther-

modynamically consistent vapor-liquid data at 760 mm pressure were obtained for the three binary systems: ethyl acetate-ethylene dichloride, ethyl acetate-benzene, and ethyl acetate-cyclohexane.

Wright, Charles Harry. . . . . MS, June 1960

Pressure Drop and Heat Transfer for Liquid-Liquid Dispersions in Turbulent Flow in a Circular Tube

Adviser: James G. Knudsen

Heat transfer coefficients and pressure losses were determined for a liquid-liquid dispersion in turbulent flow in a horizontal tube. The mixtures were found to be pseudoplastic. Heat transfer data were correlated using the apparent viscosity calculated from pressure loss measurements and using thermal conductivity of the continuous phase.

CIVIL ENGINEERING

G. W. Holcomb, Department Head

The faculty of Civil Engineering embraces the main specialities normally associated with this field. These include structural engineering, waterworks, sanitary engineering, water supply and quality studies, hydraulics, highway and traffic engineering, and soil mechanics.

The Civil Engineering Department has adequate laboratory facilities for research work in all of the above specialities. The structural laboratory is equipped with a 30,000- and 60,000-pound testing machine with necessary gauging equipment to measure stress and strain in materials. Loading equipment for stresses and beams with spans up to 40 feet also is located in the structural laboratory. Electric strain gauge equipment consists of a strain indicator and analyzer, recording oscillograph, and a universal bridge with accessories.

For model studies and structures the department has a 4-1/2 photoelastic polariscope, Beggs deformator, and equipment for constructing plastic models.

The sanitary laboratory is equipped for testing bacteriological and chemical samples for both sanitary and water supply problems. The department also has an arrangement with the City of Corvallis whereby facilities of the modern water filtration and sewage treatment plants of the city are available for use in research studies in these fields.

The soil mechanics laboratory equipment for standard soil tests includes direct shear and triaxial apparatus and a Hveem stabilometer. Equipment also is available to make field studies in soil mechanics problems.

The hydraulics laboratory contains large weighing tanks for measuring flow of water over weirs and through pipes and fire hose. There also is space with pump facilities to supply water for hydraulic model studies.

Highway engineering personnel may use any of the various civil engineering laboratories for research on particular problems. A large shop, including both woodworking and machine tools, is available for use of laboratory workers.

Some problems that can be handled readily by the department's facilities are:

1. Small-scale model studies in hydraulics
2. Small-scale model studies in structures
3. Joint problems in structures
4. Full-scale trusses and arches to a 40-foot span
5. Calibration problems in hydraulics
6. Basic research in structures, mechanics, hydraulics, and sanitary engineering

RESEARCH ACTIVITIES

Cement Stabilization of Dune Sands Prevailing in Oregon Coastal Areas

Investigators: G. W. Beecroft, Assistant Professor of Civil Engineering; G. W. Holcomb, Head, Civil Engineering Department.

Support: Engineering Experiment Station.

This investigation concerns feasibility of using Portland cement to stabilize fine, uniformly-graded sand occurring in various localities along the Oregon coast. Desirability of determining an economic method of stabilizing sands for highway base course construction arises from the fact that in certain coastal areas suitable aggregates for highway construction are not available. An economic method of stabilizing natural sands would eliminate expense of importing base course aggregates.

Hydraulic Model Studies

Investigators: C. E. Behlke, Associate Professor of Civil Engineering; H. D. Pritchett, Instructor in Civil Engineering; J. E. Worth, Instructor in Civil Engineering.

Support: General Electric Company, Richland, Washington.

This project involves the study of flow distribution patterns in certain suction piping arrangements, suction wells, and inlet and outlet manifolds. Studies are carried out by means of models fabricated with clear plastics.

An Exploratory Study of Flow Patterns Resulting From Intersection of Two Supercritical Flow Rectangular Open Channels

Investigators: C. E. Behlke, Associate Professor of Civil Engineering; H. D. Pritchett, Instructor in Civil Engineering.

Support: Civil Engineering Department, Engineering Experiment Station, Oregon State System of Higher Education.

Objectives of this work are to make an exploratory study which may suggest an analysis method that can be used to design supercritical flow in open channel confluences. The study is being carried out on a small-scale model in order to obtain criteria for construction of larger models. Quantitative as well as photographic data are being obtained.

A Schwartz-Christoffel Analysis of Cavitating Flow in Two-Dimensional Elbows

Investigators: C. E. Behlke, Associate Professor of Civil Engineering; R. H. Shoemaker, Associate Professor of Civil Engineering.

This research involves a study of the Schwartz-Christoffel transformation and application of this principle to calculation of Euler numbers in a two-dimensional, 90-degree elbow under irrotational flow assumptions. Euler numbers were calculated with reference to an upstream section in which uniform velocity distribution was assumed to exist. Euler numbers also were determined experimentally. Those determined from the Schwartz-Christoffel analysis were consistently lower than experimental values with or without cavitation.

Physical-Chemical Aspects of Deep Trickling Filters

Investigators: F. J. Burgess, Associate Professor of Civil Engineering; C. M. Gilmour, Professor of Bacteriology; F. Merryfield, Professor of Civil Engineering.

Support: Engineering Experiment Station, Civil Engineering Department, Oregon State Sanitary Authority, U.S. Public Health Service.

The 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. Thus, the aims are to:

1. Further evaluate reliability of measurement techniques and mode of expression of data.
2. Expand past studies on nature and magnitude of biochemical reaction that contributes to filter efficiency.
3. Determine BOD or carbon loading maximum for various sewage types.
4. Obtain additional data relative to extent of substrate oxidation and various filter depths.

Waste Water Lagoon Criteria for Marine Climates

Investigators: F. J. Burgess, Associate Professor of Civil Engineering; M. E. Northcraft, Assistant Professor of Civil Engineering.

Support: Engineering Experiment Station, Oregon State Sanitary Authority, City of Corvallis, U.S. Public Health Service.

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. Studies are expected to continue over a period of at least three years.

Ecological Studies of a Polluted Experimental Stream

Investigators: F. J. Burgess, Associate Professor of Civil Engineering; C. E. Warren, Associate Professor of Fish & Game Management; H. K. Phinney, Associate Professor of Botany.

Support: U.S. Public Health Service.

This is part of a broad study to be made using a section of a test stream. Facilities have been completed to provide controlled water flow in a natural stream for research studies of effects of pollution on stream biota. The study will undertake to develop satisfactory methods for measuring velocity and quantity of flow through porous gravel deposits serving as aquatic insect habitats and salmonoid spawning beds. Determinations also will be made of effects of slime and sediment deposits upon these flow rates.

A Study of Design Criteria for Waste Water Lagoons

Investigators: F. J. Burgess, Associate Professor of Civil Engineering; Thomas L. Miksch, Glenn O. Briggs, K. R. Sherer, Harold Sawyer (Seniors).

Support: National Science Foundation (Undergraduate Participation Program).

Objectives of this research are to determine effect of sewage slime growths upon permeability and porosity of stream gravel and to determine loading criteria for sewage oxidation lagoons.

A Model Study of Structural Frames in Proposed Addition to Science Building at the University of Oregon

Investigators: G. W. Holcomb, Head, Civil Engineering Department; T. J. McClellan, Professor of Civil Engineering.

This study involves construction and testing of a scale model of a proposed addition to the Science Building at the University of Oregon. Model is instrumented with SR-4 strain gages so that strains may be determined in the model. It is proposed to continue the research to measure strains in the actual prototype.

Differential Thermal Analysis of Soils

Investigators: O. Kofoid, Associate Professor of Civil Engineering; H. B. Cheney, Head, Department of Soils.

Support: Agricultural Research Foundation.

This research is aimed at developing processes and equipment for applying thermal differentials to multiple soil samples

in a single block and obtaining graphs of the differentials for various classifications of soils.

Soil Survey

Investigator: G. L. Martin, Instructor in Civil Engineering.

Support: Oregon State Highway Department.

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 analyses. The overall program of soil sampling and testing is under supervision of the U. S. Bureau of Roads. Data obtained will be used as a basis for writing an engineering chapter in county or area soil survey reports that are prepared for publication by the U.S. Soil Conservation Service.

Creep Characteristics of Light-Weight Concrete

Investigators: T. J. McClellan, Professor of Civil Engineering; D. A. Bucy, Instructor in General Engineering; J. L. Gray, Associate Professor of General Engineering.

Support: Empire Building Materials Corporation, Engineering Experiment Station.

This is a long-term study of creep characteristics of prestressed concrete beams. Prestressed 5- by 5- by 108-inch lightweight beams are loaded to approximately 1600 psi. Creep in the concrete is measured by means of Ames dials on steel loading cells and also with 100-inch gage lengths on the beams.

Mathematical Study of Aerodynamic Effects of Wind on Response of Horizontally-Suspended Plates on Flexible Cable

Investigator: S. L. Pan, Associate Professor of Civil Engineering.

Support: General Research Fund, Oregon State College.

The flutter problem that exists for a plate suspended by two cables has previously been analyzed thoroughly. This system corresponds to the suspension of a bridge on two cables. Present

study involves aerodynamic response of a horizontally-suspended plate on a single cable and will extend the previous analytical work done on plates supported by two cables.

GRADUATE DEGREES: June 1959 and June 1960

Hickerson, Wallace Wayne. . . . . MS, June 1959

Broad-Crested Weir Design by Abrupt Contraction, Free-Streamline Analogy

Adviser: C. E. Behlke

Equations defining transition curves for a two-dimensional flow contraction are modified by use of various assumptions and apply to the design of a separation-free, broad-crested weir. Accelerated flow is assumed to have irrotational flow characteristics. Density variations of the fluid are considered insignificant and viscous effect is neglected because here it is not a primary factor. Gravity forces are avoided by assuming drop in water surface is insufficient to materially affect results. Satisfactory correlation was obtained between analytical and experimental results.

Kim, Jai Bin. . . . . .MS, June 1959

Investigation of a Hipped-Plate Roof Structure

Adviser: T. J. McClellan

A refinement of the existing analytical approach to hipped-plate structures is proposed, accounting for the nonlinearity of loading existing on the top surface and for the "out-of-plane" flexure existing in the vertical plates of this type of structure. Neither of these effects is included in present conventional analyses. An attempt is made to verify these theories by experiment on a plywood model.

Laursen, Harold Ivan. . . . . MS, June 1960

An Investigation of Retaining Wall Loadings

Adviser: O. Kofoid

This thesis presents assumptions associated with magnitude and location of resultant of retaining wall loadings by present methods. It also develops a new method predicated on shear properties of soils and basic soil mechanics in contrast to soil friction

angles as in Coulomb. Results agree with Coulomb as to magnitude, but in contrast locate directly both failure plane and resultant.

Mausshardt, Donald Bruce. . . . . MS, June 1960

Mechanics of Gas Transfer in Oxidation Lagoons

Adviser: F. J. Burgess

Work in this thesis concerned itself with oxygen transfer at the interface of a 2.13-acre lagoon, 3 feet in depth. A reaeration constant K_2 of a 0.0256 ppm-O_2/hr per ppm deficit was determined to apply in the equation, $dw/dt = - K_2D$. Based on these results, 20 pounds of atmospheric oxygen could be transferred to the lagoon per 24 hours at a lagoon temperature of 4°C and a dissolved oxygen content of 1 ppm. The critical nature of the testing limits studies to only a few days per year when low sunlight and low algal activity are present.

Reinikka, Everett Arnold. . . . . MS, June 1959

Plastic Behavior of Cover-Plated Aluminum and Steel Beams

Adviser: T. J. McClellan

Experiments were performed on small steel and aluminum wide-flange beam sections to determine comparative "moment-rotation" relationships and plastic hinge formation characteristics. Further tests were performed on similar beams with cover plates added to attempt to verify the "plastic" method of determining cover plate lengths. These tests also were performed on both materials.

Whitney, Gerald Lowell. . . . . MS, June 1959

Winter Design Criteria for Waste Water Stabilization Lagoons in Western Oregon

Adviser: F. J. Burgess

Lagoon studies in this thesis consisted of a 2.13-acre cell, 3 feet deep and loaded with raw domestic sewage. Results of study revealed: there is sufficient solar and reflected radiation in this vicinity to support algal protosynthesis; approximately 70 percent of oxygen is produced in upper 1 foot of water; average water temperature is about 8.5°C; there is a reduction of about 92 percent

of coliform bacteria concentration; precipitation can account for substantial reductions in detention time during periods of heavy precipitation; efficiency of lagoon, based on biochemical oxygen demand load, is about 80 percent for all loading rates; considerable foam will be produced at outlet if effluent must free-fall as it flows from the lagoon; and dissolved oxygen content and pH vary with algal concentrations. Effluent biochemical oxygen demand is approximately 10 percent lower when withdrawn from the surface than when withdrawn from the bottom. At no time during the operation of the test lagoon did a nuisance condition develop. Based on this study, a winter design load of 30 pounds of biochemical oxygen demand per acre per day appears to be workable.

ELECTRICAL ENGINEERING

L. N. Stone, Department Head

The staff of the Electrical Engineering Department is qualified for research in electronics, power machinery, power distribution, power systems, communications systems, servomechanisms and controls, and electrical measurements and high voltage associated with power transmission.

There are several electrical engineering laboratories that are used mainly for routine instructional purposes, but may be used occasionally for research work. These include the circuits, communications, power, and electronics laboratories. Other more specialized laboratories used for graduate instruction and research are the radiation, illumination, industrial electronics, control, high-voltage, and standards and measurements laboratories. General facilities of the electrical engineering laboratories serve the needs of both instruction and research projects as follows:

1. Substantial power capacity in a wide variety of a-c and d-c voltages.
2. Instruments for ordinary measurement of a-c and d-c voltages, currents, power, resistance, frequency, speed, and temperature; microvolts to kilovolts, microamperes to amperes, and microwatts to kilowatts.
3. Representative electrical machines and apparatus for practically all uses of electricity.

There are many specialized facilities that frequently can serve special needs for research projects. These are standard cells and high precision measuring instruments, cathode-ray and magnetic oscilloscopes, recording instruments, oscillators, high-voltage d-c supplies (0 to 100,000 volts), and high-voltage 60-cycle supply (0 to 350,000 volts).

In addition, facilities and well equipped shops are available to conduct fundamental research and investigations on characteristics of materials, acoustics, electroytic corrosion, dielectrics, electronic phenomena, electric bridge circuits, circuit and system analysis, corona and radio influence, illumination, instrumentation and recording of information, magnetic circuits and systems, microwave communication, electric machines, servomechanisms, computers, television and radio transmitters and antennas, wire communicating, and transistors.

The Department of Electrical Engineering also has an ESIAC

analog computer which may be used for solution of various types of mathematical problems and for study of electronic circuits for use in computers. The department also takes part in maintenance of the ALWAC III-E computer in the Mathematics Department and investigates means by which the circuitry of this computer may be modified in order to increase its versatility.

RESEARCH ACTIVITIES

Impulse Characteristics of Corona

Investigators: T. L. Churchill, Instructor in Electrical Engineering; G. A. Pearson, Graduate Assistant.

This investigation is centered around the use of the new Tektronix 519X 1000 mc oscilloscope to determine impulse characteristics of corona. One of the main parts of the investigation is to determine current waveform of the corona electron avalanche.

Application of Tensor Analysis and Vector Differential Equations to Electrical Engineering

Investigators: I. M. Hostetter, Professor of Mathematics; H. J. Oorthuys, Associate Professor of Electrical Engineering.

This study involves application of tensor analysis and differential equations to electrical engineering problems. Basic mathematical principles involved are being studied and their applications to various aspects of electrical engineering will be investigated. Basic information to the approach to the problem has been provided in cooperation with the Department of Mathematics.

Transistor Curve Tracer

Investigator: J. C. Looney, Instructor in Electrical Engineering.

Support: General Research Fund, Oregon State College.

This study involves investigation, design, construction, and testing of a device for visually displaying transistor characteristics on a conventional cathode-ray oscilloscope.

Investigation of Active Linear Network Synthesis with the Aid of Matrix Transformation Theory

Investigator: H. J. Oorthuys, Associate Professor of Electrical Engineering.

Support: Oregon State System of Higher Education.

This investigation involves the ways to partition and solve electrical feedback networks with the aid of the digital computer. Special attention is being given to partitioning of networks not having ideal isolation points (minimizing loading effects). Literature relating to application of synthesis with the aid of matrix methods is also being investigated.

Programing Subroutines on the ALWAC III-E Computer to Perform Matrix Transformations Involving Polynomials in the Computer Variable "S"

Investigators: H. J. Oorthuys, Associate Professor of Electrical Engineering; R. H. Hicks, Student Assistant.

Support: Engineering Experiment Station.

Objective of this project is to provide a set of subroutines programed on the ALWAC III-E digital computer to perform matrix transformations involving polynomials in the complex variable "S." It is believed that such routines can be employed effectively for circuit analysis and for developing methods of circuit synthesis with the aid of matrix theory.

Aspects of Corona Formation and Radio Interference

Investigator: L. N. Stone, Head, Electrical Engineering.

Support: Bonneville Power Administration.

This work is in its fifth year of operation. It presently consists of the following four phases:

1. An investigation of radio-noise characteristics, including magnitudes and attentuation of high-voltage transmission lines.
2. An investigation of corona formation and the associated

radio-influence voltage caused by various surface projections on high-voltage conductors and devices.

3. An investigation of nature and characteristics of insulator corona, its radio-influence voltage characteristics, and its effect on radio-noise level of transmission lines.

4. Correlation of laboratory and transmission line measurements with the object of predicting transmission line radio-noise levels from measurements made in the laboratory.

Design of High-Power Static Inverters

Investigators: L. J. Weber, Associate Professor of Electrical Engineering; R. A. Savage and T. E. Reynolds, Graduate Assistants.

Support: Engineering Experiment Station.

Object of this research is to develop new switching circuits to be used in high-power static inverters employing transistors, control rectifiers, and other semiconductor devices. New semiconductor devices such as silicone control rectifiers have made it possible to consider designing 10 kva or larger static inverters. Simple scaling up of present day low-power inverter designs will not do the job efficiently. New methods of switching power from source to load must be determined.

Control Circuits for High-Power Static Inverters

Investigators: L. J. Weber, Associate Professor of Electrical Engineering; John Keizur, Senior.

Support: National Science Foundation (Undergraduate Participation Program).

This study involves design of various transistor switching circuits that may be used to turn on and off controlled rectifiers or high-power transistors in order to generate a sinusoidal output voltage.

GRADUATE DEGREES: June 1959 and June 1960

Amort, Donald Louis. . . . . MS, June 1960

Utilization of Electrolytic Tank in Engineering Analysis and Synthesis

Adviser: L. N. Stone

An investigation was carried out on the use of an electrolytic tank for solution of field problems and problems involving complex variables. Errors peculiar to the electrolytic tank and the automatic plotting system were investigated in order to determine ultimate accuracy obtainable with the system.

Chow, Chung-Wei. . . . . MS, June 1960

Transient Characteristics of a Tuned Ground-Fault Neutralizer System

Adviser: J. F. Engle

An analysis of tuned ground-fault neutralizers was carried out. One of the important reasons for its effectiveness was found to be that the Peterson coil permits a very low rate of rise of the recovery voltage across the arc terminals. Factors influencing rate of rise of voltage were investigated.

Churchill, Thomas Lynn. . . . . MS, June 1959

Characteristics of Corona Under Alternating Current Conditions

Adviser: L. N. Stone

Point-to-plane 60-cps corona was investigated to further identify the behavior of some of the various corona mechanisms present in electrically overstressed air. Multiple corona sources were studied with respect to pulse coincidence phenomena.

Dubinski, George Anthony. . . . . MS, June 1960

Systems Analysis of ALWAC III-E Digital Computer

Adviser: L. N. Stone

After a thorough system analysis of this computer it was possible to design modifications to increase its effectiveness. Cer-

tain of these modifications were installed and effectively doubled the computing speed.

Looney, James Chester. . . . . .MS, June 1960

Nonsaturating Amplifier Theory

Adviser: L. N. Stone

For certain applications it is necessary to have amplifiers that can handle a large dynamic range of input without saturating or blocking. To provide this capability, the gain must be able to change instantaneously and inversely with the signal amplitude. Several feedback amplifying systems were designed to produce various types of desired outputs. Characteristics of a number of nonlinear elements were investigated.

McGowan, Gerald Frank. . . . . MS, June 1960

Transistor D-C Amplifier Design Theory

Adviser: L. J. Weber

This study was undertaken to establish design theory for d-c transistor operational amplifiers. Possible solutions to this design problem are discussed. A chopper-stabilized amplifier was determined to be most suitable in this application. Design theory was established and an amplifier was constructed and successfully tested. Its characteristics were as follows:

Voltage amplification:	26,500
Thermal drift:	0.25v for $55°F < T < 85°F$
Input impedance:	2000 ohms

Neuman, Frank. . . . . .MS, June 1960

Speech Compression and Expansion Using Match Thermistors

Adviser: A. L. Albert

In telephone communication, amplitude of speech signals is compressed at the sending end and expanded at the receiving end as an aid in reducing noise and crosstalk. Possibility of using thermistors for this purpose was investigated and found practicable. Thermistors having the necessary thermal sensitivity and low thermal time lag, however, were not commercially available.

Pearson, Gary Arthur. . . . . MS, June 1960

Interaction of Discharge Mechanisms in A-C Corona

Adviser: L. N. Stone

An investigation of interaction among various basic corona mechanisms when 60-cps voltage was applied to a large concentric-cylinder configuration. Characteristics of positive half-cycle pulseless corona also were investigated.

Schuh, Paul. . . . . MS, June 1959

Network Synthesis by a Matrix Transformation

Adviser: H. J. Oorthuys

A method of passive network synthesis from the pole-zero plot in the S-plane is developed by a matrix collinearity transformation. This investigation has been limited to the two-by-two transformation, which allows the synthesis of Tee and Pi networks. It is shown, however, that the separate branches can be made complex to realize the desired poles.

Vincent, Larry William. . . . . MS, June 1960

Design of a Random Number Generator

Adviser: L. N. Stone

Solution of a stochastic model of a physical or mathematical process by the Monte Carlo method depends upon use of random numbers. Various sources of random numbers were investigated and verified. A random number generator was designed for use on the ALWAC III-E digital computer.

INDUSTRIAL ENGINEERING

G. B. Cox, Department Head

Staff and facilities of the Department of Industrial Engineering are suitable for conducting research projects in method and motion studies, management and supervisor training programs, paper work simplification, organization structure and cost control studies, statistical techniques and engineering economy studies, work sampling studies and cost reduction packaging, machine tool application, and production design.

The department is equipped with both a laboratory and small production-size furnaces for preparation of experimental alloys. Available for research is a full complement of analytical motion picture equipment, including stop-motion and lapse-time devices for methods and motion analysis. The department has a fairly complete assortment of precision machine tools; nonferrous and ferrous metal foundrys, woodworking, forging, and welding shops; and a large complete machine shop.

MECHANICAL ENGINEERING

L. Slegel, Department Head

Knowledge and experience of the Mechanical Engineering staff embraces a broad area of subject material, including machine design and machinery development, thermodynamic analysis and refrigeration, heat-power devices and machines, gas turbines, steam plants, heating and air conditioning equipment, cooling power design and performance, mathematical analysis, vibrations, fluid mechanics, structures and machine parts under dynamic as well as static loading, ferrous and nonferrous metallurgy, and automotive and internal combustion.

The department has a wide range and variety of materials, testing, and analyzing equipment, including tension, torsion, and compression machines; and photoelastic, strain gage, stress analysis, metallurgical, and x-ray equipment machines. Creep machines are equipped to handle metallic cable of various sizes, and the larger machines recently have been modified to increase their capacities to 20,000 pounds.

Other research equipment and facilities in the department include a fuels and lubricants laboratory; a complete internal combustion engines laboratory which contains a special research engine, indicators, and dynamometers; and an engine with complete accessories for determining engine wear through use of radioactive engine parts.

A wide variety of research on fuels, lubricants, and engines is possible with this equipment. This includes determination of many properties of fuels and lubricants and engine performance characteristics under various loads, speeds, fuel and air ratio conditions, etc.

Departmental facilities also include heat transfer apparatus, air conditioning and refrigeration apparatus and equipment, combustion analyzers, and air-moving apparatus which includes blowers, fans, and wind tunnels. Another departmental facility is a complete electronic analog computer with various accessories, including a two-channel Sanforn recorder and accelerometers. The computer, known as the OSCEAC, consists of two units. The units were built by students in 1951, and contain 12 operational amplifiers, 30 coefficient potentiometers, 6 limiters, and a constant amplitude sinusoidal oscillator. A standard Boeing analog computer, purchased in 1954, includes 8 sign changers, xy

multiplier, and an operational servo unit. This unit can operate 20 additional operational amplifiers if it becomes necessary to expand it.

Units comprising the OSCEAC can be used separately or together for simple or complicated problems. The units, together with recording equipment, are valued at approximately $12,000. The machine is most useful for performing integrations or solving differential equations.

RESEARCH ACTIVITIES

Application of Humphrey Spiral in Beneficiation of Sulfite Ores at the Musick Mine in Bohemia Mining District

Investigators: W. E. Caldwell, Professor of Chemistry; G. W. Gleeson, Dean of Engineering; G. S. Koch, Assistant Professor of Geology; W. D. Wilkinson, Chairman, Department of Geology; D. A. Lauritsen, Research Assistant.

Support: Engineering Experiment Station.

Object of this project is to determine economic feasibility of sulfite ore separation and concentration by use of the Humphrey spiral. This method of benefaction should provide a low initial cost and low operating cost methods for processing Oregon's relatively high-grade sulfite mineral deposits. It also will be applicable to process existing mine dumps of base ore that cannot be processed economically by flotation methods.

Improvement of Combustion in Low-Grade Waste Woods

Investigators: A. D. Hughes, Professor of Mechanical Engineering; A. Wynans, Graduate Assistant.

This research involves a study to determine the best ways to burn high-moisture waste woods such as hemlock, tamarack, wet bark, and sander dust. Various methods to be studied involve forced draft, preheated air, and predrying of the wood with exhaust gases.

Oil Resistant Gasket Material

Investigator: A. D. Hughes, Professor of Mechanical Engineering.

This study involves research for flexible tubing and sponge-type gasket material resistant to peppermint and spearmint oils.

Use of Solar Energy for Production of Mechanical Power

Investigator: A. D. Hughes, Professor of Mechanical Engineering.

This is a study of use of a model hot-air engine and of attempts to operate it on solar energy.

Creep Tests of Aluminum Conductor Cable

Investigators: O. G. Paasche, Professor of Mechanical Eneering; J. G. Croeni, Assistant Professor of Mechanical Engineering.

Support: Kaiser Aluminum and Chemical Corporation.

Purpose of this research was to obtain creep data on aluminum conductor cable and to determine effect of such factors as temperature and load on creep properties of cable.

Quasi Two-Dimensional Temperature Distribution in an Idealized Wing Section by Means of Biot's Variational Principle of Heat Flow

Investigator: M. Levinson, Assistant Professor of Mechanical Engineering.

Support: Engineering Experiment Station.

This problem has been solved both analytically and numerically for the one-dimensional approximation. It has been shown experimentally that results can lead to an error of 30 percent in calculation of thermostresses. It is hoped the proposed method of solution will provide an analytical solution which is in close agreement with the experiment.

GRADUATE DEGREES: June 1959 and June 1960

Balch, Robert Lyle. . . . . MS, June 1959

An Experimental Nondestructive Method for Determining Buckling Load of a Column with Arbitrary End Condition

Adviser: R. E. Wilson

Buckling loads of columns are determined by extrapolation of the frequency load curve to zero frequency. Experimental results are compared to theoretical buckling loads for various end conditions and column shapes.

Bonsu, Osei Kwabena. . . . . MS, June 1960

Forming Dimensionless Products by Using an Algorithm Developed from Matrix Theory

Adviser: E. W. Geller

According to Buckingham's theorem, the functional relation between variables in a physical problem can be reduced to a form involving dimensionless products. An algorithm is developed for obtaining dimensionless products using matrix algebra. Examples are worked out, and some new products are obtained.

Chiou, Jiunn Perng. . . . . MS, June 1960

Study of Static Performance of a Turbojet Engine

Adviser: A. D. Hughes

An attempt was made to instrument and run static tests on a General Electric 1-16 turbojet engine. Three methods of measuring static thrust were devised and exhaust velocity profiles of the jet itself were obtained. Compressor performance as well as fuel consumption and thermal efficiency were determined for a wide range of speeds.

Dunham, James Tallus. . . . . MS, June 1960

Stress-Corrosion Cracking Susceptibility of Zirconium in Ferric-Chloride Solution

Mechanical Engineering

Adviser: O. G. Paasche

Tests for the susceptibility of reactor grade zirconium to stress-corrosion cracking were conducted to show effect of stress, solution concentration, air aeration of the solution, and the method of mechanical processing. Zirconium was shown to be susceptible when applied tensile stress was above 19,000 psi; stronger solutions (10 to 25 percent ferric-chloride) reduced time to fracture by increasing crack nucleation; air aeration reduced time to fracture by increasing rate of crack propogation; mechanical processing by either hot rolling or cold rolling and annealing appeared to have little effect.

Gorski, Saul Bohdan. . . . . MS, June 1960

An Analytic Approach to Temperature Distribution in a Thin-Walled Combustion Chamber

Adviser: R. F. Zaworski

An equation for steady-state temperature distribution is given for a thin-walled circular duct with airflow through and over it and heat addition over the aft inside half. An example problem utilizing typical values of system parameters is worked out in detail and the results are discussed. Approximate or bounding expressions are derived for the transient temperature distribution over parts of the duct.

Henry, Calvin Scott. . . . . MS, June 1960

Development of Characteristic Grid for Supersonic Diverging Jets Exhausting into a Hypersonic Parallel Flowing Stream

Adviser: E. W. Geller

The method of characteristics is applied to problem of determining properties of jet flow exhausting into a uniform hypersonic stream from a conical nozzle. Location and fluid properties of jet boundary between jet flow and exterior flow are determined. Programing of problem on the ALWAC III-E electronic digital computer is discussed.

Hugelman, Rodney Dale. . . . . MS, June 1959

A Multichannel, Single-Frequency, Radio-Control System

Adviser: L. Slegel

An improved multichannel, radio-control system is proposed, after preliminary consideration of desirable features of such systems, and an evaluation of existing equipment is made. Proposed system consists of a set of coding and decoding relays actuated by a pair of synchronized continuously rotating cams. Synchronization is maintained by one channel of a commercial two-channel radio-control system, while control actuation is accomplished by the other. Recommendations for improvement of the eleven-channel prototype system are included.

Lange, Vincent Thomas. . . . . .MS, June 1960

Artificial Satellite Life Duration in Near-Earth Orbits

Adviser: E. W. Geller

Satellite lifetimes are determined using a simplified solution to the general equation of motion. Results are presented graphically for elliptical orbits with eccentricities less than 0.2 and perigee heights up to 600 miles. Accuracy of solution is indicated by a comparison between predicted and actual lifetimes of several recent earth satellites.

McLellan, Dale Lawrence. . . . . .MS, June 1960

Application of Statistical Techniques to Piston Ring Wear as Influenced by Gasoline Additives and Jacket Temperature

Adviser: M. Popovich

In this investigation piston ring wear was studied under the influence of various gasoline additives at high and low jacket temperatures. A single-cylinder Lauson engine fitted with two irradiated compression rings was used at normal operating conditions. Amounts of radioactive iron in an external crankcase oil system were determined by an immersion type Geiger counter. Continuous recordings of wear were made on appropriate instruments. A two-factorial experiment using a randomized block design with

four replications was used to basically analyze experimental data. Purpose of investigating wear produced by various blends was to determine whether fuel sulfur is the main cause of piston ring wear as encountered in typical automotive fuels. It was shown that the sulfur constituent of typical fuels is the main contributor to low jacket temperature wear. Methods used to illustrate this point indicate advantages statistical techniques have in various phases of an experiment, including designing of tests, handling of data, and methods available for producing general results.

Mullen, Charles Robert. . . . . .MS, June 1960

Effects of Creep on Structure and Mechanical Properties of Zirconium

Adviser: O. G. Paasche

Ultimate and yield strengths of zirconium were found to increase due to prior creep at 498°F. Elastic modulus and ductility decreased. X-ray analysis showed a subgrain structure was formed by fragmentation of larger grains. Fragmentation was shown to be related to nonuniform stresses and their relief by polygonization and recovery processes.

Newton, John Francis. . . . . .MS, June 1959

An Application of Newtonian Boundary Condition to Supersonic Jets Exhausting into a Hypersonic Stream

Adviser: R. E. Wilson

The Newtonian pressure coefficient is used to determine velocity and flow angle at the boundary of a supersonic jet. Method of characteristics is used to calculate flow field. Computer logic and sample solutions are presented.

Prasad, Prem. . . . . .MS, June 1959

Creep Tests of Aluminum and Aluminum Alloy Conductors

Adviser: O. G. Paasche

Creep tests of AAAC (All Aluminum Alloy Conductor), AAC (All Aluminum Conductor) and ACSR (Aluminum Conductor Steel

Reinforced) were conducted at 15 percent of ultimate rated strength and 75°F. Creep characteristics of all three appeared to be much the same when variability between manufacturing lots of the same conductor was considered. One lot of AAAC showed lower creep strain than any other lot of the same material or other types of conductors.

Rayl, Stephen Christopher. . . . . MS, June 1959

Method of Characteristics for Irrotational Flow of a Semi-Perfect Gas

Advisers: R. E. Wilson and H. D. Christensen

Effect of a varying specific heat on shape of an ideal nozzle is calculated using the method of characteristics. Energy equation is represented as an enthalpy-speed of sound curve. Results are given for hydrogen.

Rasmussen, Maurice Lee. . . . . MS, June 1959

Effect of a Canard Surface on Total Lift of an Unswept Wing in Subsonic Flow

Adviser: R. E. Wilson

A method is presented for predicting induced lift for unswept elliptical span load wings lying directly in the wake of the canard. Thin wing theory and reciprocity relations are used. Theoretical results are given as a function of wing spacing and aspect ratio.

Reisland, Edward Ernest. . . . . MS, June 1960

Effects of Stress and Temperature on Creep of Aluminum Alloy Conductor Wire

Adviser: J. G. Croeni

Constant load creep tests were conducted at temperatures of 144°F, 204°F, and 258°F under stresses ranging from 15 to 75 percent UTS. Data analyzed on the basis of an empirical equation indicated that both creep and creep rate vary expotentially with temperature and stress. Information was also obtained on third-

stage creep and extrapolation of creep curves.

Schmitz, Bruce Wayne. . . . . MS, June 1959

An Analytical Study of Effect of Characteristic Engine Performance Parameters on Payload Capability of Various High Performance Missiles

Adviser: R. E. Wilson

Effect of specific impulse and engine thrust to weight ratio on payload capabilities is determined for both high and low altitude satellites.

Tschang, Pin-Seng. . . . . MS, June 1959

An Exact Method of Determining Spreading of a Supersonic Jet Exhausting Into a Supersonic Free Stream

Adviser: R. E. Wilson

Boundary of a supersonic jet in a supersonic stream is determined by the method of characteristics. Sample solutions and comparisons with the Newtonian approximation are given for the two-dimensional case. Iteration methods are given for boundary point in axisymmetric flow.

Waterhouse, Alvin Sidney. . . . . .MS, June 1960

Some Factors Affecting Heat Transfer in a Finned Tube Radiator Using Low-Pressure Steam and Hot Water as Heat Sources

Adviser: A. D. Hughes

In this series of experiments the main factors affecting the overall heat transfer rate of a given length of finned tube radiator were investigated with both hot water and steam as heat sources. Fluid velocity, pressure, temperature differentials, air entrainment, and surface fouling were major factors controlling heat output of the radiator section.

Welty, James Richard. . . . . .MS, June 1959

Physical Properties of JP-5 Fuel at Elevated Temperatures

Mechanical Engineering

Adviser: M. Popovich

Data available for the behavior of JP-5 fuel are extremely scarce and accuracy of available data is questionable. Purpose of this work was to investigate physical properties of this fuel in the temperature range 250°F to 500°F and compare these experimental values with calculated values available in technical literature. Physical properties investigated were vapor pressure, viscosity, and density. Vapor pressure values compared well with those reported in the technical literature. Experimental values of viscosity were 4 percent lower than those published in the literature. Density variation was found to be linear with temperature. Coefficient of thermal expansion for the test fuel was 4.45×10^{-4}, which is well within JP-5 fuel specifications.

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.

Investigators: Isaiah Gellman, West Coast Regional Engineer; Eben L. Owens, 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. Another aspect of this project is a study of the possibility of disposal of pulp and papermill waste treatment sludges in the soil and the most feasible means of accomplishing this objective.

Characteristics of Pulpmill Bleach Plant Effluents

A study of sanitary characteristics of bleach plant effluents from a number of pulp mills, including measurement of color content and organic strength, in order to permit prediction of effects of discharge on receiving streams. One aspect includes determination of effect of soil filtration on color content of such effluents.

Relationship Between Pulp and Papermill Effluents and Receiving Stream Characteristics and Incidence of Stream Bottom Growth

A field study of various factors that may be correlated with occurrence of stream bottom growth below papermill outfalls. Included are field measurements of bottom growth location and extent, hydrographic features of receiving streams, and type, quantity, and method of discharge of effluents involved.

National Council for Stream Improvement

Effect of Tidal Action in Lower Portland Harbor on Natural Self-Purification Characteristics of 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 the critical low flow period occurring each summer. Included also is an attempt to determine effect of tide-induced mixing on sanitary characteristics of downstream flow in Multnomah Channel.

RECENT PUBLICATIONS OF THE ENGINEERING STAFF

Barduhn, A.J., B.S. Patel, W. Meyer, and B.B. Smura, "Adsorption of Halogenated Fire Extinguishing Agents on Powders," NASA Technical Report R-51 (1960).

Beecroft, G.W., "Time Deformation Studies on Two Expanded Shale Concretes," Highway Research Board Proceedings, 37:90-105 (1958).

Booster, D.E., "Electrostatic Seed Separation," Seed Processing published by Oregon State College in cooperation with Small Seed Harvesting and Processing Section, AERD, ARS, USDA, pp. 36-38 (June 1958).

Booster, D.E., "Seed Cleaning Based on Electrical Properties," paper presented at Seed Processors Short Course held at Oregon State College, February 5-7, 1959.

Booster, D.E., "Oregon Range Reseeding Experiments," paper presented at Pacific Northwest Section of American Society of Agricultural Engineers held at Oregon State College, October 22-24, 1958.

Booster, D.E., "Experimental Seeder for Soft Rangeland Seedbeds," Western Feed and Seed, 14:30, 84 (April 1959).

Cooley, C.R. and W. Meyer, "Dissolution of Stainless Steel Clad Power Reactor Fuels with Nitric and Hydrofluoric Acid," Hanford Atomic Products Operation, HW-62199 (October 1959).

Edgerton, R.C. and G.W. Beecroft, "Dynamic Stresses in Continuous Plate Girder Bridges," Transactions of American Society of Civil Engineers, 123:226-292 (1958).

Engle, J.F. and H.J. Oorthuys, "Introductory Notes to Electric and Magnetic Fields," Oregon State College Cooperative Association (1959).

Fisher, F.D. and J.G. Knudsen, "Heat Transfer from Isothermal Flat Plates: An Extension of Polhausen's Solution to Low and High Prandtl Number Fluids," Chemical Engineering Progress, Symposium Series No. 29, 55:209-213 (1959). (Reprint No. 58, Engineering Experiment Station, Oregon State College.)

Gilmour, C.M., F. Merryfield, F. Burgess, L. Purkerson, and K. Carswell, "Persulfate Oxidizable Carbon and BOD as a Measure of Organic Pollution in Water," Proceedings of 15th Purdue Industrial Waste Conference, Purdue University, Lafayette, Indiana (May 1960).

Gurushankariah, M.S. and J.G. Knudsen, "Local Shell-Side Heat Transfer Coefficients in the Vicinity of Segmental Baffles in Tubular Heat Exchangers," Chemical Engineering Progress Symposium Series No. 28, 55:29-36 (1958). (Reprint No. 56, Engineering Experiment Station, Oregon State College.)

Harmond, J.E., D.E. Booster, N.R. Brandenburg, "Application of Electrostatic Separation to Seed Cleaning," paper presented at 1960 Annual Meeting of American Society of Agricultural Engineers held in Columbus, Ohio, June 12-15, 1960.

Kirk, D.E., "Column Thickness for Shelfed Corn Driers," Transactions of the American Society of Agricultural Engineers, 2:42-43 (1959).

Looney, J.C., "Analysis of Effects of Positive Feedback in a Multi-Loop Transistor Amplifier," pamphlet published by Electro-Scientific Industries, Portland, Oregon (December 1959).

Magnusson, P.C., M.M. Kirk, and G.L. Schmidt, "Air-Cooled Crucibles for Cold-Mold Arc Melting," U.S. Bureau of Mines, Report of Investigations 5443 (1959).

McCluer, H.K. and J.G. Knudsen, "Hard-Water Scaling of Finned Tubes at Moderate Temperatures," Chemical Engineering Progress Symposium Series No. 29, 55:1-4 (1959). (Reprint No. 57, Engineering Experiment Station, Oregon State College.)

Meredith, R.E., "Studies on the Conductivities of Dispersions," University of California Radiation Laboratory, UCRL-8667 (1959).

Meredith, R.E., "An Extension of Henry's Law to Higher Concentrations," University of California Radiation Laboratory, UCRL-8426 (1958).

Meredith, R.E. and C.E. Tobias, "Resistance to Potential Flow Through a Cubical Array of Spheres," Journal of Applied Physics (in press).

Meyer, W., "Solution of the Brunauer, Emmett, and Teller Multimolecular Adsorption Equation," Computer Program Abstract, Chemical Engineering Progress 55, 90 (1959).

Olleman, R.D. and G.C. Wolfer, "New Aluminum Alloy Not Prone to Brittle Fracture," Welding Engineer, p. 42 (Nov 1959).

Olleman, R.D. and G.C. Wolfer, "The Tensile and Impact Properties of Plate and Welds of Aluminum Alloy 5083-H113 Between 75°F and -320°F," Proceedings of the 1959 Cryogenic Engineering Conference.

Polhamus, E.C., E.W. Geller, and K.J. Grunwald, "Pressure and Force Characteristics of Noncircular Cylinders as Affected by Reynolds Number with a Method Included for Determining Potential Flow About Arbitrary Shapes," NASA Technical Report R-46 (1959).

Smith, W.W., "Tests Compare Heat Transfer of Five Cooling Tower Packings," Heating, Piping, and Air Conditioning, 32, No. 4, pp. 143-145 (1960).

Stone, L.N., "Radio Interference Attenuation on Energized High-Voltage Transmission Lines: Measurement and Application," Power Apparatus and Systems (Dec 1959). (Reprint No. 59, Engineering Experiment Station, Oregon State College.)

OREGON STATE COLLEGE
ENGINEERING EXPERIMENT STATION
CORVALLIS, OREGON

LIST OF PUBLICATIONS

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. Pozzolanic 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¢.

No. 6. The Use of a Technical Library, by W. E. Jorgenson. 1942. 25¢.

No. 7. Saving Fuel in Oregon Homes, by E. C. Willey. 1942. 25¢.

No. 8. Technical Approach to the Utilization of Wartime Motor Fuels, by W. H. Paul. 1944. 25¢.

No. 9. Electric and Other Types of House Heating Systems, by Louis Slegel. 1946. 25¢.

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. 25c.

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¢.

No. 24. Proceedings of the 1957 Northwest Conference on Road Building. July 1957. $1.00.

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¢.

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¢.

No. 3. Asphalt Emulsion Treatment Prevents Radio Interference, by F. O. McMillan. Reprinted from Electrical West. Jan 1935. None available.

No. 4. Some Characteristics of A-C Conductor Corona, by F. O. McMillan. Reprinted from Electrical Engineering. Mar 1935. None available.

No. 5. A Radio Interference Measuring Instrument, by F. O. McMillan and H. G. Barnett. Reprinted from Electrical Engineering. Aug. 1935. 10¢.

No. 6. Water-Gas Reaction Apparently Controls Engine Exhaust Gas Composition, by G. W. Gleeson and W. H. Paul. Reprinted from National Petroleum News. Feb 1936. None available.

No. 7. Steam Generation by Burning Wood, by R. E. Summers. Reprinted from Heating and Ventilating. Apr 1936. 10¢.

No. 8. The Piezo Electric Engine Indicator, by W. H. Paul and K. R. Eldredge. Reprinted from Oregon State Technical Record. Nov 1935. 10¢.

No. 9. Humidity and Low Temperature, by W. H. Martin and E. C. Willey. Reprinted from Power Plant Engineering. Feb 1937. None available.

No. 10. Heat Transfer Efficiency of Range Units, by W. J. Walsh. Reprinted from Electrical Engineering. Aug 1937. None available.

No. 11. Design of Concrete Mixtures, by I. F. Waterman. Reprinted from Concrete. Nov 1937. None available.

No. 12. Water-Wise Refrigeration, by W. H. Martin and R. E. Summers. Reprinted from Power. July 1938. 10¢.

No. 13. Polarity Limits of the Sphere Gap, by F. O. McMillan. Reprinted from AIEE Transactions, Vol 58. Mar 1939. 10¢.

No. 14. Influence of Utensils on Heat Transfer, by W. G. Short. Reprinted from Electrical Engineering. Nov 1938. 10¢.

No. 15. Corrosion and Self-Protection of Metals, by R. E. Summers. Reprinted from Industrial Power. Sept and Oct 1938. 10¢.

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No. 17. The Photoelastic Method as an Aid in Stress Analysis and Structural Design, by B. F. Ruffner. Reprinted from Aero Digest. Apr 1939. 10¢.

No. 18. Fuel Value of Old-Growth vs. Second-Growth Douglas Fir, by Lee Gabie. Reprinted from The Timberman. June 1939. 10¢.

No. 19. Stoichiometric Calculations of Exhaust Gas, by G. W. Gleeson and F. W. Woodfield, Jr. Reprinted from National Petroleum News. Nov 1939. 10¢.

No. 20. The Application of Feedback to Wide-Band Output Amplifiers, by F. A. Everest and H. R. Johnston. Reprinted from Proc of the Institute of Radio Engineers. Feb 1940. 10¢.

No. 21. Stresses Due to Secondary Bending, by B. F. Ruffner. Reprinted from Proc of First Northwest Photoelasticity Conference, University of Washington. Mar 1940. 10¢.

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No. 23. Stress Concentration Factors in Main Members Due to Welded Stiffeners, by W. R. Cherry. Reprinted from the Welding Journal, Research Supplement. Dec 1941. 10¢.

No. 24. Horizontal-Polar-Pattern Tracer for Directional Broadcast Antennas, by F. A. Everest and W. S. Pritchett. Reprinted from Proc of The Institute of Radio Engineers. May 1942. 10¢.

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No. 26. Broadcast Antennas and Arrays. Calculation of Radiation Patterns; Impedance Relationships, by Wilson Pritchett. Reprinted from Communications. Aug and Sept 1944. None available.

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No. 28. Electric Power in China, by F. O. McMillan. Reprinted from Electrical Engineering. Jan 1947. 10¢.

No. 29. The Transient Energy Method of Calculating Stability, by P. C. Magnusson. Reprinted from AIEE Transactions, Vol 66. 1947. 10¢.

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No. 31. Long-Range Planning for Power Supply, by F. O. McMillan. Reprinted from Electrical Engineering. Dec 1948. 10¢.

No. 32. Heat Transfer Coefficients in Beds of Moving Solids, by O. Levenspiel and J. S. Walton. Reprinted from Proc of the Heat Transfer and Fluid Mechanics Institute. 1949. 10¢.

No. 33. Catalytic Dehydrogenation of Ethane by Selective Oxidation, by J. P. McCullough and J. S. Walton. Reprinted from Industrial and Engineering Chemistry. July 1949. 10¢.

No. 34. Diffusion Coefficients of Organic Liquids in Solution from Surface Tension Measurements, by R. L. Olson and J. S. Walton. Reprinted from Industrial Engineering Chemistry. Mar 1951. 10¢.

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No. 36. Geometric Mean Distance of Angle-Shaped Conductors, by P. C. Magnusson. Reprinted from Vol 70, AIEE Transactions. 1951. 10¢.

No. 37. Energy—Choose It Wisely Today for Safety Tomorrow, by G. W. Gleeson. Reprinted from ASHVE Journal Section of Heating, Piping, and Air Conditioning. Aug 1951. 10¢.

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¢.

No. 45. Shunt Capacitors in Large Transmission Networks, by E. C. Starr and E. J. Harrington. Reprinted from Power Apparatus and Systems. Dec 1953. 10¢.

No. 46. The Design and Effectiveness of an Underwater Diffusion Line for the Disposal of Spent Sulphite Liquor, by H. R. Amberg and A. G. Strang. Reprinted from TAPPI. July 1954. 10¢.

No. 47. Compare Your Methods with this Survey, by Arthur L. Roberts and Lyle E. Weatherbee. Reprinted from Western Industry. Dec 1953. 10¢.

No. 48. Some Stream Pollution Problems and Abatement Measures Undertaken in the Pacific Northwest, by H. R. Amberg. Reprinted from TAPPI. Feb. 1955. 10¢.

No. 49. Fabrication of a Zirconium-Lined Reaction Vessel, by O. G. Paasche and A. J. Killin. Reprinted from The Welding Journal. Feb 1954. 20¢.

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 Sulfite Liquor, by Herman R. Amberg and Robert Elder. April 1956. 10¢.

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