

THE UNIVERSITY OF MICHIGAN  
INDUSTRY PROGRAM  
OF THE  
COLLEGE OF ENGINEERING

*Industry Program Abstracts*

ELEVENTH COMPILATION

July 1960



ANN ARBOR

THE UNIVERSITY OF MICHIGAN  
INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

INDUSTRY PROGRAM ABSTRACTS

Eleventh Compilation

July 1960

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INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING  
ABSTRACTS FROM THE  
PROGRAMME OF THE 1959 DIVISIONAL MEETING OF  
THE DIVISION OF FLUID DYNAMICS. AMERICAN PHYSICAL  
SOCIETY 23-24-25 NOVEMBER, 1959

Arnold M. Kuethe

IP-403 Dated December, 1959

This publication contains abstracts of 50 papers presented at the 1959 meeting of the Division of Fluid Dynamics of the American Physical Society, November 23-25, 1959 in Ann Arbor.

Subjects include laminar and turbulent boundary layers, transition, super-fluidity, transport processes, plasma flow, magneto-hydrodynamics, low density aerodynamics, and kinetic theory. The abstracts range from 100 to 200 words.

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ABSTRACT OF THESIS

DIFFUSION OF GLYCEROL AND SODIUM CHLORIDE  
IN RESINS AND ANALYSIS OF ION EXCLUSION AND OTHER  
SOLID-LIQUID MASS TRANSFER PROCESSES

Muhammad Tayyabji Tayyabkhan

IP-404 Dated December, 1959

This paper is divided into two sections.

The experimental study reported in Part I indicated that diffusion according to Fick's Law is an adequate model for describing mass transfer of NaCl and glycerol in the solid phase Dowex 50. Several baskets, each containing one gram of uniform resin particles, were first saturated with a solution and then subjected, for different amounts of time, to a stream of distilled water that carried away the solutes diffusing out of the resin. The solutes remaining in the resin were extracted and their amounts were determined. Amounts absorbed at equilibrium and diffusivities were determined by making a two constant fit of the data to a "diffusion model." The variables studied were: (1) Resin Cross-Linkage - 2% to 12% DVB; (2) Temperature - 25 to 80°C; (3) Concentrations in the Equilibrating Solution; (4) Resin Particle Size; (5) Flow Rate of the Eluting Distilled Water.

In Part II eleven mathematical models of mass transfer processes, in which a liquid is passed over a fixed bed of solid particles, are discussed in increasing order of complexity. The effect of swelling and shrinkage of the solid with change in concentration and the effect of interdependent equilibria for solutes producing concentration and dilution effects are considered. Data available in literature on an ion exclusion column operation with the system ethylene glycol-water-Dowex 50 were reproduced within estimated experimental error by a model assuming linear equilibrium and "diffusion" in the solid phase as the controlling mass transfer resistance. Diffusivities of ethylene glycol in Dowex 50 obtained from "fitting" the data to the model are 2.1, 1.9, 1.3 and  $0.35 \times 10^{-6}$  cm<sup>2</sup>/sec for the resin with 2, 4, 8 and 24% DVB respectively.

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INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

ABSTRACT OF REPORT

- ACTIVATION ANALYSIS
- NUCLEAR CHEMICAL RESEARCH
- RADIOCHEMICAL SEPARATIONS

W. Wayne Meinke

IP-405 Dated December, 1959

In this paper the present facilities for research in nuclear chemistry at the University of Michigan are described. Discussed in detail is the operation of the Ford Nuclear Reactor pneumatic tube system used in irradiating material utilizing a new "bunny rabbit" system connecting the hot lab directly to the 3 x 3-inch NaI(Tl) crystal setup, and the new auxillary circuits added to the 100-channel analyzer.

Among further studies are included those made on short-lived fission product gases, radiochemical separation by means of vacuum distillation and by amalgam exchange, determining vanadium in cracking catalyst by activation analysis, preliminary studies of activation analysis on animal tissues, a new determination of the branching ratio of 2.4-min silver-108, and a search for rhodium-109.

Evaluation of a neutron generator for activation analyses is being made on a machine obtained on loan from the Texas Nuclear Corporation. Chemical separation procedures are also given for vanadium, cobalt, copper, niobium, technitium, tungsten, rhenium, gold and thallium.

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INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

ABSTRACT OF THESIS

THE CORRELATION OF BINARY AND TERNARY LIQUID-LIQUID EQUILIBRIA

Thomas C. Boberg

IP-406 Dated December, 1959

In this paper a method was developed whereby engineers using high speed digital computers can for the first time predict, quantitatively, the behavior of systems consisting of two partially miscible liquids at equilibrium. The data which could formerly be obtained only through expensive experimental techniques are vitally important in the design of solvent extraction units.

In the method developed, equations are used to represent the equilibrium data, a set of constants in the equations having specific values for a given system. Sets of constants determined from experimental data for a series of a few similar systems may be used to predict a set of constants for a system in the series that has never been determined experimentally. In addition it was shown that those regions of the equilibrium curve known as critical points which cannot be determined experimentally can be predicted using the equations.

This paper contains a complete discussion of phase diagrams for liquid-liquid systems, the thermodynamics of phase equilibria, and curve fitting techniques which enable estimation of constants from experimental data where long, complicated equations are involved.



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ABSTRACT OF THESIS

RADIOCHEMICAL SEPARATION OF CADMIUM AND THE  
APPLICATION OF VACUUM DISTILLATION OF  
METALS TO RADIOCHEMICAL SEPARATIONS

James Rollo DeVoe

IP-407 Dated December, 1959

The purpose of this research was to evaluate and develop radiochemical separation procedures. Radioactive tracer techniques were used to measure the degree of separation of a desired element from a large number of elements, which have been selected on the basis of their being representative of the groupings in the periodic table.

An evaluation of the radiochemical separations of cadmium was made by studying the separation by solvent extraction with dithizone in basic media, by ion exchange in hydrochloric acid solution, and by two precipitation methods, one with a complex inorganic precipitant, (Reinecke salt) and the other with an organic precipitant [2-(o-hydroxyphenyl) benzoxazole]. The separation by dithizone and ion exchange resulted in a yield of cadmium of 78% with decontamination factors of  $10^3$  for twenty elements. Although the organic precipitant appeared to be selective for cadmium, a poor separation was obtained as a result of occlusion of the contaminants on the gelatinous, flocculent precipitate. In contrast to this, the precipitate of cadmium Reineckate was very crystalline, and a separation of cadmium with a yield of 78% and decontamination factors of  $10^3$  for fifteen elements was obtained.

In order to determine the feasibility of radiochemical separations by vacuum distillation of the elemental state, an exploratory evaluation of the method was made. A simple vacuum distillation apparatus was designed which consisted of a carbon rod furnace heated by induction. Separation procedures which were evaluated include the separation of trace amounts of mercury by chemical reduction onto a copper foil with subsequent distillation of the mercury, and by electrolysis of cadmium (1 mg.) onto copper foil (or into a mercury cathode with volatilization of the macro mercury) followed by distillation of the cadmium.

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ABSTRACT OF THESIS

A STUDY OF POOL BOILING IN AN ACCELERATING SYSTEM

Herman Merte, Jr.

IP 408 Dated December, 1959

In this paper a study was made of the influence of system acceleration (1 to 21 g's) on pool boiling heat transfer in saturated distilled water at approximately atmospheric pressure. To the author's knowledge, this is the first study made of heat transfer by boiling in the presence of a force field greater than that due to standard gravity.

A flat electrically heated chromium plated copper disc served as the heat transfer area, with a thin stainless steel skirt attached to the periphery of the disc to provide a continuous surface. The water depth was maintained constant at 2 1/2 inches, and a cooling coil on the underside of the cover condensed the vapor formed. Temperatures in the heating disc and water were measured with an uncertainty of  $\pm 0.1^{\circ}\text{F}$ .

Acceleration was attained by use of the centrifuge principle. The boiling system was pivoted from the cross arm on a vertical shaft such that the acceleration was always normal to the heating surface. The magnitude of the acceleration was varied from that due to one standard gravity up to 21 times gravitational acceleration. Heat flux rate was varied from approximately 5,000 to 100,000 Btu/hr-ft<sup>2</sup>. Several tests were also conducted with non-boiling convective heat transfer.

With boiling at heat flux values up to 50,000 Btu/hr-ft<sup>2</sup>, it was found that a small degree of subcooling significantly influenced the results with the system under acceleration. Data are presented showing the influence of subcooling for heat fluxes of 10,000 and 25,000 Btu/hr-ft<sup>2</sup> and for various accelerations.

As a means for obtaining a theoretical understanding of the process of boiling under the influence of high acceleration including the simultaneous effect of natural convection, a concept of the "Area of Influence" of the bubbles is defined and values calculated for the various accelerations and heat flux rates.

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ABSTRACT OF THESIS

THE EFFECTS OF POWER INPUT, AGITATION,  
AND AIR FLOW ON THE RATE OF OXYGEN  
TRANSFER IN FERMENTATION SYSTEMS

George Tsu Ning Tsao

IP-409 Dated December, 1959

In this paper the rates of oxygen transfer were studied in three selected systems. They are respiration of Pseudomonas ovalis, respiration Penicillium chrysogenum, and sulfite oxidation. The effects of power input, agitation, air flow, and liquid volume expansion on the rate of oxygen transfer were investigated in detail. The importance of these studies arises from the facts, among others, that (1) oxygen transfer is a unit process of basic importance in all submerged fermentations, (2) knowledge here accumulated will help further studies on the mechanisms of mass transfer in biological systems and the reaction kinetics concerning growing cells, and (3) the relationship among the rate of oxygen transfer and other factors such as power input, etc., are valuable in process and equipment design and scaling up of industrial fermentation processes. The systems were studied in standard laboratory fermentors.

A biological method for measuring oxygen transfer in actual fermentation broths was proposed. This method was illustrated by its applications to the Penicillium and Pseudomonas systems studied in the present research. Further studied on the relationship between liquid volume expansion and geometric configuration of fermentors was recommended. These studies might yield information useful in fermentor design.

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ABSTRACT OF SYMPOSIUM RECORD

PLANNING A DECISIVE EXPERIMENT

IP-410 Dated December, 1959

This is a transcript of the fourth Ann Arbor Industry-Education Symposium. The seven lectures presented are listed as follows:

The Theory of Decisive Experiments

Integral Versus Differential Experiments

Screening Solutions to Upgrade Quality

Approach to a Problem in Microbiological Conversion

Some Techniques for Optimizing an Experimental Design

The Use of Mathematical Models in Planning an Experimental Program

Good and Bad Research

INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

ABSTRACT OF PAPER

DESIGN STUDY OF A LIQUID AND  
A SOLID ROCKET PROPELLANT SYSTEM

William Whicher  
Theodore Petersen

IP-411 Dated January, 1960

This report presents concise design studies of two rocket propulsion systems, one a liquid propellant and the other a solid propellant, based on the same design objectives and employing the same techniques of construction.

The design studies were carried out by the authors as part of the requirements for the Aeronautical and Astronautical Department's course on Rocket Propulsion and presents the relative advantages and disadvantages of solid and liquid rocket motor systems as well as a preliminary design for both systems in terms of overall vehicle performance.

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ABSTRACT OF PAPER

A UNIVERSAL COMPUTER CAPABLE OF EXECUTING AN  
ARBITRARY NUMBER OF SUB-PROGRAMS SIMULTANEOUSLY

John Holland

IP-412 Dated January, 1960

The paper describes a universal computer capable of simultaneously executing an arbitrary number of sub-programs, the number of such sub-programs varying as a function of time under program control or as directed by input to the computer. Three features of the computer are:

- (1) The structure of the computer is a 2-dimensional modular (or iterative) network; thus, in a concrete realization, high density elements and "template" techniques now being developed would be efficiently used.
- (2) Sub-programs can be spatially organized and can act simultaneously thus facilitating simulation or direct control of "highly-parallel" systems with many points or parts interacting simultaneously (for example, magneto-hydrodynamic systems or pattern recognition problems).
- (3) The structure and behavior of the computer can be given a rigorous symbolic formulation. Thus by considering the rectangular grid to be infinite in each dimension (in analogy to the infinite tape of a Turing machine), many problems of automata theory can be expressed in a formal framework similar to that provided by the Turing machine for problems of computability. In particular, problems concerning growing automata (cf. Von Neumann's scheme for self-reproducing automata and Church's potentially infinite automata) can be investigated both directly and theoretically.

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ABSTRACT OF THESIS

RESONANCE RADIATION EFFECTS  
OR LOW ENERGY MONOCHROMATIC X-RAYS ON CATALASE

Ardath H. Emmons

IP-413 Dated January, 1960

This paper is concerned with a study of the variation of the damage per photon absorbed in the enzyme catalase subjected to monochromatic x-rays in the energy range of 5 to 10 kev. X-rays of discrete energies were obtained by two different techniques: 1) A number of studies were made using the x-rays from a crystal spectrometer. This technique provided energy resolutions of better than  $\pm 0.3$  kev. 2) A high-output beryllium window x-ray tube was used to obtain line spectra by fluorescence in selected target materials. The crystal spectrometer is a low output single-energy x-ray source, whereas the fluorescence generator provides a high output of discrete energies of x-rays.

The enzyme catalase was used as a test system. This enzyme catalyses the oxidation of hydrogen peroxide to water and oxygen. Catalase concentrations were determined with a Model DU Beckman Spectrophotometer, which was used to measure the rate of hydrogen peroxide oxidation; this rate is a function of the catalase concentration.

Samples of catalase solutions were irradiated with x-rays of energy 7.3 kev and 6.9 kev from the crystal spectrometer. Samples of catalase solutions were also irradiated with the emission line x-rays from targets of nickel, iron and manganese.

This work has shown that there are marked variations in the damage, per absorbed photon, produced in catalase by monochromatic x-rays in the energy range of 5 to 10 kev.

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ABSTRACT OF PAPER

ENGINEERING METEOROLOGY:  
THE EFFECTS OF WEATHER AND CLIMATE ON CONCRETE PAVEMENT

Fred V. Brock

IP-414 Dated January, 1960

This paper is concerned with the adverse effects of weather and climate, through the freezing process, on concrete pavements.

Concise discussions are presented on the benefits of using air-entrained cement, the deleterious effect of salt and other de-icing agents causing scaling of the concrete surface, loss of subsoil bearing strength, migration of subsoil, frost heave, frost action in both freshly laid and seasoned concrete, and loss of strength of the concrete itself. It is concluded that temperature and moisture are the dominant factors in concrete failure.



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ABSTRACT OF PAPER

SOME DETAILS OF THE TRANSITION TO  
TURBULENT FLOW IN POISEUILLE FLOW IN A TUBE

A. M. Kuethe  
K. R. Raman

IP-415 Dated January, 1960

In this paper measurements of velocity fluctuations, Reynolds stresses, and shearing stresses at the wall in the transition region of a tube are presented. The measurements were made in a tube at a Reynolds number of 6000 behind three disturbance generators placed in the fully developed laminar flow 620 diameters from the entrance.

The results show the way in which some of the statistical details of the transition depend on the nature of the disturbance generated. The Reynolds stresses and the shearing stress at the wall can reach very high values during the early stages of transition. Implications are pointed out regarding possible causes for the high temperature recovery factor during transition in high speed flow over surfaces.

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ABSTRACT OF THESIS

THE KINETICS OF CUMENE HYDROPEROXIDE DECOMPOSITION  
AS CATALYZED BY ACID ION EXCHANGE RESIN

James E. Marberry

IP-416 Dated February, 1960

In this investigation Dowex 50, an ion exchange resin, was used in acid form to catalyze the decomposition of cumene hydroperoxide to phenol and acetone. The rate of reaction was measured in a tubular flow reactor under steady state conditions as a function of the following variables: flow rate, temperature, composition, and catalyst type (particle size, degree of cross-linking, and resin grade). The rate data were correlated by an equation relating the diffusivity of cumene hydroperoxide from the liquid-solid interface into the catalyst particle and the first order kinetic coefficient at the acid groups which are spread fairly uniformly throughout the catalyst particle.

The gel structure of the catalyst absorbs some liquids, swelling the gel and giving an internal liquid phase. The concept of phase distribution coefficients, which relate the compositions in the external liquid and the resin phase, is important in interpreting the experimental results. These coefficients are considered to be functions of temperature, composition, and catalyst type. Changes in these variables may give phase changes simultaneously with changes in the rate processes. One consequence is that the true order of the reaction could not be determined in the range of variables studied, but the data were correlated satisfactorily using a first order model.

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ABSTRACT OF THESIS

ENGINEERING STUDY OF A PERFORATED  
PLATE PULSE COLUMN

Keshav S. Sanvordenker

IP-417 Dated February, 1960

In this paper a study of the perforated plate pulse column was undertaken to determine the effects of the operating variables on the rates of mass transfer.

The column was 1-inch in diameter, 32 inches long, made out of precision bore glass tube. The pulser consisted of Teflon bellows driven by an eccentric and a variable speed motor. The system used was Methyl isobutyl ketone, acetic acid and water; the transfer of the solute being from the water into the ketone. The concentration of the acid feed was maintained constant at 1 Normal. The ratio of the flow rates of the two liquid phases was kept constant so that the slope of the operating line was the same as that of the equilibrium line, the sum of the two liquid rates being considered as a variable. The two types of plates used (stainless steel and brass) were supported on a center rod and kept in position by spacers.

In order to determine the relative effects of the operating variables a factorial design of experiments was used. Since the column could not be operated with the combinations of all the variables and their respective levels, the experiments were conducted by completing the factorial designs on a few of the variables at a time.

The condition of the plate surface was found to have a predominant effect on the behavior of the column, and due to the favorable plate condition, the mass transfer rates obtained in this study were much higher than those reported by previous investigators.

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ABSTRACT OF THESIS

GRANULATION BY EXTRUSION

Prabhakar R. Sheth

IP-418 Dated February, 1960

In spite of the greatly increased demand for compressed tablets of medicinal substances, one phase of the tablet making process, granulation, has seen little improvement. In this paper a study was undertaken to devise a method which would furnish tablet granules of greater uniformity and which would be suited to modern production systems. Extrusion was selected as being most likely to fit these requirements, and investigations were planned to evaluate granulation of dry solids, of solids with aqueous binders and solids with non-aqueous binders.

Extrusion of dry solids into granules was found to be impractical with available equipment, extremely high frictional forces being involved. Extrusion with both aqueous and non-aqueous binders was successful and was investigated in detail. Extrusion rate-pressure relationships were examined with a 2-inch laboratory extruder using various substances, and incorporating several different lubricants and binders. Yield values and plastic viscosities were calculated from shear-stress data when uniform flow was obtained.

It was found that tablets made from extruded granules were less friable than with standard granules using either aqueous or non-aqueous binders, and by the utilization of non-aqueous extrusion it was shown that the drying procedure can be shortened or eliminated. This makes possible the preparation of granules of water-sensitive materials such as vitamins and antibiotics.

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ABSTRACT OF THESIS

THE THEORY OF EJECTORS

Henry H. Hicks, Jr.

IP-419 Dated February, 1960

The purpose of this work was an attempt to discover the basic process which accounts for the operation of an ejector. Current theory has been examined, and was found to predict ambiguous results by ignoring the internal ejector process. By considering the internal process, this study predicts one general and two special cases for ejector operation. One special case, where the driving and induced gases are identical, reduces the ejector to a kind of heat engine which has a thermodynamic cycle. The other special case for dissimilar gases reduces to a diffusion operation. The general case consists of simultaneous fluid shear, heat transfer, and diffusion between the driving and induced streams. An analytical solution to this case has not been obtained, so an alternate approximate general case is proposed. All cases lead to unambiguous results with the evident conclusions that turbulent mixing is not a part of the basic ejector process.

The approximate general case has been tested by experiment and is found to satisfactorily account for the basic ejector process. Both theory and experiment show that hydrodynamic shock profoundly influences ejector performance.

It is concluded that proper attention to design will considerably improve ejector performance in specific applications, but it is unlikely that increased flexibility of operation can be attained at the same time.

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ABSTRACT OF PAPER

LIQUID METAL CAVITATION - PROBLEMS  
AND DESIRED RESEARCH

Frederick G. Hammitt

IP-420 Dated February 1960

In this paper the anticipated effects of the unique physical properties of liquid metals in the various areas of cavitation are examined. Also the peculiar advantages and disadvantages of cavitation research using liquid metals are considered.

Research in liquid-metal cavitation is motivated not only by strong technical interest in applications where cavitation performance and damage effects are critical, but also by a basic fundamental interest in fluids exhibiting a wide range of physical properties quite different from those of water, thus providing a broader range of data against which to test theoretical applications.

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ABSTRACT OF THESIS

STABILIZATION OF GASEOUS DETONATION WAVES  
WITH EMPHASIS ON THE IGNITION DELAY ZONE

James Arthur Nicholls

IP-421 Dated February 1960

In this paper the characteristics of gaseous detonation waves are considered insofar as they influence the dynamic conditions that must be met in order to generate a standing gaseous detonation wave. In view of these requirements, a few possible methods of stabilization are presented and discussed. The method adopted for the experimental study consists of mixing unheated hydrogen with heated air in the supersonic portion of an axisymmetric convergent-divergent nozzle. The nozzle is operated underexpanded so that acceleration of the mixture to the required high Mach number is realized in the open jet. Combustion occurs downstream of the normal shock wave that exists in such underexpanded jets. The experimental facility which evolved from these studies is described.

Experiments are described wherein stationary shock wave-combustion configurations were realized. These experiments covered the mixture stagnation temperature range of about 1800°R - 2430°R and a wide fuel-air range. A theoretical analysis of the ignition delay zone of hydrogen-oxygen combustion is also presented.

In this experiment standing detonation waves have been successfully generated, a new experimental technique for the study of ignition time delays of gaseous mixtures at high temperatures has evolved, and a theoretical prediction of ignition time delay of hydrogen-oxygen mixtures is presented consistent with the experimental results of this and other investigations.

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ABSTRACT OF THESIS

TIME DEPENDENT NEUTRON ENERGY SPECTRA IN PULSED MEDIA

Surendra Nath Purohit

IP-422 Dated February, 1960

In this paper analytical and numerical methods have been used to study the time dependent energy spectra of a pulse of neutrons during thermalization and diffusion periods. A relation between the diffusion cooling coefficient and the thermalization time constant in the infinite non-absorbing medium has been derived and the heavy gas model has been studied in detail.

The energy spectra for times greater than the slowing down time have been generated by following a pulse of neutrons in a heavy gas medium with the help of an analog computer. The numerical results for the infinite non-absorbing medium case was compared with the analytical results and the various characteristics of the energy spectra in media of different sizes have been studied in detail. The existence of an equilibrium spectrum, after the thermalization time, has been established.



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ABSTRACT OF PAPER

REVERBERATION-ROOM ANECHOIC CHAMBER  
TRANSMISSION-MEASUREMENT TECHNIQUE

S. S. Kushner  
N. E. Barnett

IP-423 Dated February, 1960

In this report a preliminary investigation was undertaken to characterize several parameters involved in a reverberant source room-anechoic termination method for measuring acoustic transmission. This method appears potentially capable of evaluating the acoustic transmission in great detail of samples possessing widely divergent physical characteristics.

Exploratory experimentation included examination of reverberation-room diffusion, termination diffraction and directionality, effects of sample mass on transmission, and transmission of various stiff-panel configurations. The futility of using the Small-Sample Aircraft-Transmission-Test Apparatus for making transmission measurements for stiff samples was demonstrated.

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ABSTRACT OF PAPER

COMMENTS ON THE USE OF SEMI-RIGID CONNECTIONS IN STEEL FRAMES

Lawrence C. Maugh

IP-424 Dated March, 1960

In this paper the importance of considering the deformation of beam connections in the design of steel frames has again been emphasized. A laboratory procedure for determining the  $M, \phi$  diagram for any type of beam connection has been discussed. This method involves measuring only a single vertical displacement by means of dial gages.

Analytical methods for incorporating the properties of the connections into the slope-deflection equations are presented. It has been shown that the stiffness of the beam and the magnitude of the end couples may be modified considerably by the rotational restraint factor  $\psi$  of the connections. Therefore the actual beam coefficients and fixed-end moments, for the particular beam and connection should be determined from test results and used in the structural analysis.

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ABSTRACT OF THESIS

MASS TRANSFER BETWEEN ISOBUTANOL AND WATER IN  
CONCURRENT FLOW THROUGH A PACKED COLUMN

James Albert Leacock

IP-425 Dated March, 1960

In this paper mass transfer between isobutanol and water has been studied in concurrent, upward flow in a packed column. Previous studies of this and other two-component liquid systems have been limited to counter-current flow.

The column used was 1/2-inch I.D. gauge glass and the packing was 3 mm glass spheres. Distilled water and commercial grade isobutanol were used for the two phases. The dispersed phases were led from the top of the column to a round-bottom flask where they separated and from which phase samples were taken. Analysis was by refractive index. The amount of transfer taking place in the receiver was determined to be negligible both by an experiment designed to estimate it and through inspection of the data from the experiment varying the column packing length.

The results show that concurrent flow through a packed bed is an effective means for obtaining mass transfer in liquid systems. This effectiveness increases as the flow rates in the column are increased. In contrast to countercurrent operation, concurrent flow in a packed column is not limited by column flooding, and flow rates are limited only by the allowable pressure drop across the bed.

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ABSTRACT OF THESIS

INVERSION-VIBRATION AND INVERSION-ROTATION  
INTERACTIONS IN THE AMMONIA MOLECULE

William T. Weeks

IP-426 Dated March, 1960

Recent experimental studies of the infrared spectrum of ammonia have revealed a wealth of new information regarding the dependence of the inversion splittings on the vibrational and rotational quantum numbers. The present investigation attempts to account for some of the new data by extending the theory of ammonia inversion to include inversion-vibration and inversion-rotation interactions.

The potential energy of ammonia is approximated in this investigation by a double minimum potential. The potential function used in this investigation leads to a fair overall description of the "pure inversion" levels and accounts rather well for the dependence of the inversion-vibration splittings on the vibrational quantum numbers associated with the two doubly degenerate modes. Unfortunately, the potential fails to describe properly the interaction between the inversion coordinates and the remaining non-degenerate vibrational coordinate.

The inversion-rotation constants calculated from the lowest order vibration-rotation-inversion Hamiltonian in most cases compare surprisingly well with the observed numbers. Examination of the complete vibration-rotation-inversion Hamiltonian suggests that some of this agreement may be fortuitous. The task of diagonalizing the complete Hamiltonian is complicated by the presence of several resonances, and, although it has been done for the first two pure inversion states, it has not been accomplished in general.

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ABSTRACT OF THESIS

LABORATORY TECHNIQUES FOR THE DESIGN AND  
EVALUATION OF AUTOMATIC SYSTEMS TO  
ALLEVIATE AIRCRAFT RESPONSE TO ROUGH AIR

Rollin G. Lemm

IP-427 Dated March, 1960

The purpose of this study was to develop laboratory techniques for the implementation of a new approach to the problem of alleviation of airplane response to rough air. The theoretical consideration of the new approach and the test program to obtain the required experimental data are outlined.

A dynamically scaled model airplane was used in conducting this program, and servo systems were designed to operate the movable control surfaces in the model in response to electrical input signals. A method of obtaining sustained oscillations of a moving-bump type gust generator was developed to simulate sinusoidal atmospheric disturbances in a wind tunnel.

The components which were designed and tested were generally found to be satisfactory; however, some modifications to the dynamic suspension system are suggested to improve its operation.

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ABSTRACT OF THESIS

REACTIONS OF SOME NORTROPANE DERIVATIVES

Harry A. Smith

IP-428 Dated April, 1960

This work was undertaken in an effort to determine whether a nitrogen atom or sulfur atom in the ring system of an organic compound can assist in the removal of a leaving group on the opposite side of the ring.

For this purpose two pairs of isomers were investigated. These were  $3\alpha$  and  $3\beta$  mesyloxy-8-azabicyclo (3-2-1) octane and  $3\alpha$  and  $3\beta$  tosyloxy-8-thiabicyclo (3-2-1) octane. The rate of reaction of these compounds with the solvent was measured by titration of the sulfonic acid liberated in an effort to determine whether the hetero atom did exert an influence on the reactivity of these compounds.

It was found that the two azabicyclic compounds did indeed show assistance by the nitrogen in the reaction, both by the increased reactivity and by the reaction products. In the case of the sulfur compounds, assistance occurred only after loss of the sulfonate ion. The only other effect of the sulfur was a rate retarding effect.

Therefore, it appears that an electron rich group, whose electrons are readily available, can exert an enhancing effect on the reactivity of a negative leaving group.

The data and information presented can be of importance in the synthesis of drugs in the solanaceous alkaloid field of which the compounds investigated are derivatives. Also included in this same family of compounds are the well known drugs, atropine and cocaine. The investigation also suggests a route to possible cancer chemotherapy drugs, azetidines derivatives, which contain a nitrogen in a four member carbon ring system.

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ABSTRACT OF PAPER

INDUSTRIAL AIR POLLUTION METEOROLOGY

E. Wendell Hewson

IP-429 Dated April, 1960

The paper is concerned with the broad problem of air pollution: how meteorology may be used by industry in the control of air pollution from a single industrial plant or from a group of plants in a limited area owned by a single company or corporation. The presentation assumes no previous acquaintance with meteorology, the basic concepts such as lapse rate, inversion, atmospheric stability, mechanical and thermal turbulence, etc. being developed as they are needed.

The basic premise of the paper is that there are clean cut advantages to industry, financial and otherwise, in working with rather than against atmospheric conditions in the solution of the complex problems of air pollution. The various ways in which meteorology may be used advantageously are set forth in detail, and their scope is suggested by the list of main section headings given below:

Atmospheric Influences on Dispersion and Their Measurement  
Natural Cleansing Processes in the Atmosphere  
Meteorological Influences on Chemical Reactions in the  
Atmosphere  
Topography in Relation to Air Flow and Atmospheric Diffusion  
The Effective Stack Height  
The Behavior of Smoke Plumes  
Plant Location  
Plant Design and Layout  
Plant Operation

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ABSTRACT OF THESIS

THERMODYNAMIC PROPERTIES OF CARBON TETRAFLUORIDE

Nallan C. S. Chari

IP-430 Dated April, 1960

In this paper experimental data on the vapor pressure, saturated liquid density, critical properties and calculated heat capacity at zero pressure for carbon tetrafluoride were correlated in the form of equations, which represented the data with satisfactory precision. These equations, along with the other equations available in the literature were then used in the formulas developed for calculating the thermodynamic properties of the saturated liquid and vapor, and of the superheated vapor.

The thermodynamic properties of the saturated vapor and liquid are presented in two sections. The first section, entitled the Saturation Temperature Table presents the saturation pressure, specific volume of gas, specific volume of liquid, density of gas, density of liquid, enthalpy of liquid, latent heat of vaporization, enthalpy of gas, entropy of liquid and entropy of gas at saturation conditions corresponding to each temperature in the range of  $-270^{\circ}\text{F}$  to the critical temperature. The second section, entitled the Saturation Pressure Table presents the same thermodynamic properties as listed above, but this time in the given range of pressures from 0.2 psia to the critical pressure. The saturation temperature is presented in this table in place of saturation pressure of the first section.

The thermodynamic properties of the superheated vapor are reported as values of volume, enthalpy and entropy up to about  $300^{\circ}\text{F}$  superheat conditions at tabular pressures from 0.2 psia to the critical pressure. Above the critical pressure and up to a pressure of 5000 psia, these properties are presented up to  $700^{\circ}\text{F}$ .

These properties are assumed to cover the range of conditions where carbon tetrafluoride is normally expected to be used as a refrigerant.

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ABSTRACT OF THESIS

SOME ASPECTS OF THERMAL NEUTRON DETECTORS

George R. Dalton

IP-431 Dated May, 1960

When a thermal neutron absorber is used to measure a thermal neutron density, the extent to which the detector disturbs the neutron density must be considered. This paper has derived an analytical expression which relates the neutron population which exists when a detector is present to the population when a detector is not present. The effect on this expression of such quantities as detector composition, detector geometry, composition of the surrounding medium, and many others may then be investigated.

In deriving the expression relating the steady state detector absorption and the unperturbed neutron population there are no restrictive assumptions. In adapting the problem for a numerical solution the number of assumptions has been kept as small as possible while still allowing the problem to be handled on a large digital computer. There are two general restrictive assumptions which are made throughout this paper. First, the neutron energy spectrum in and around the detector is assumed to be independent of position and to be the same energy spectrum that exists when the detector is not present. Second, it is assumed that the detector is located in a large homogeneous medium. Further the detector is assumed to be several mean free paths from any boundaries of the medium.

There are several features, investigated for the first time, which were built into the analytical relationship between the detector activation and the unperturbed neutron density.

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ABSTRACT OF PAPER

A STUDY OF ENGINE-COOLING CONTROL  
FOR ARMY VEHICLES

F. L. Schwartz

W. T. Crothers

IP-432 Dated May, 1960

This report presents a study of fan-cooling problems which involve Army Vehicles. The objective was to evaluate all possible form drives and air-flow controls for the purpose of obtaining optimum cooling under all environmental conditions. A study was made of hydraulic, mechanical, electrical, or other means of driving a cooling fan; and the efficiency, torque requirement, speed variation, size and weight, reliability, maintenance and availability of various drives were considered.

A general discussion is included on the method of cooling control using flow restrictions, drive control and fan control. Information relating to the design of controls is included for quick reference, giving sources of information indicating where complete design data can be located. It was found that with the diversity of air-cooled and water-cooled engines now in use and anticipated, no one cooling control system is feasible.

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