THE UNIVERSITY OF MICHIGAN

INDUSTRY PROGRAM
OF THE
COLLEGE OF ENGINEERING

Industry Program Abstracts

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INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

INDUSTRY PROGRAM ABSTRACTS

Tenth Compilation

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INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

ABSTRACT OF THESIS

A SAMPLING SURVEY STUDY OF ARTERIAL BLOOD PRESSURE IN NASSAU, NEW PROVIDENCE, BAHAMAS, FOR DESCRIPTION OF LEVELS OF BLOOD PRESSURE IN A POPULATION IN RELATIONSHIP TO AGE, SEX, RACE AND OTHER FACTORS

Benjamin C. Johnson

IP-375 Dated July, 1959

This survey study of arterial blood pressures in the Bahamas, was made because it had been suggested that people in this area demonstrated high blood pressure levels. This fact implied the operation of possible environmental or genetic factors. These people reportedly represented somewhat of a geographic and genetic isolate; and it was known that the water supply was high in salt.

It was desired to study the distribution of blood pressure levels in the population, subclassified by age, sex and race, in order to compare these levels with results of other population studies. To accomplish this, the plan of study involved implementation of a probability sampling scheme for selection of persons for study. This method made possible the extension of the data to describe the entire population from which the sample was drawn, subject to the calculated sampling error.

Findings of the study were:

1) A definite race difference was seen with the Negro exceeding the white race for both mean systolic and diastolic pressures at all ages beyond adolescence.

2) A definite sex difference within race was noted.

3) Trends were observed toward increasing blood pressures with increasing heaviness of body build and increasing arm girth, both factors considered separately.

4) Comparison with other population studies showed that in regard to progression of systolic and diastolic blood pressure with age for a given race and sex, the Negro and white races were not greatly different from their racial counterparts studied elsewhere in the world. This finding suggests that if a specific environmental factor is involved in etiology, it is not operative in this location to any greater extent than in other areas studied.

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INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

ABSTRACT OF PAPER

EXPERIMENTAL INVESTIGATION OF A HIGH ENERGY DENSITY, HIGH PRESSURE ARC PLASMA

Edward A. Martin

IP-376 Dated August, 1959

In this paper the underwater spark is utilized to study the fundamental parameters of a plasma at 30,000 °K and 10,000 atmos pressure. The 25 kv spark is obtained by underwater discharge of capacitors having a stored energy of 1800 joules, the inertia of the water providing the confinement necessary to develop high pressures. Phenomena relating to the initiating wire (exploded wire) are discussed. Kerr cell photographs show that spherical structures are formed around both electrodes under certain conditions. A possible explanation is postulated. A detailed energy balance and particle balance are carried out.

The results show that the plasma has great capability to store energy in dissociation, excitation, and ionization without a corresponding increase in temperature. The plasma is 30% ionized and the total particle density is about 2×10^{27} per cubic meter. At this density the plasma radiates a blackbody spectrum. Pressures are obtained by calculation based on the rate of spark channel expansion and the shock properties of water. The plasma is found to have an internal pressure of the same order of magnitude as the external pressure because of interparticle coulomb forces. Plasma conductivity calculated from equations of Gvosdover and Spitzer and Harm agree very well with the experimental value.

The study is basically experimental, with the emphasis in interpretation being placed on reliability of the conclusions rather than on refined accuracy.

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INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

ABSTRACT OF THESIS

MEASUREMENT OF THE g-FACTOR ANOMALY OF FREE, HIGH ENERGY ELECTRONS

Arthur A. Schupp, Jr.

IP-377 Dated August, 1959

This paper is concerned with the measurement of the g-factor of free, high energy electrons using a double scattering experiment with a magnetic field perturbation between the scatterers. The theory of double scattering predicts that a beam of electrons, with their spins randomly oriented initially, will be partially polarized by single scattering from a target of high atomic number. The polarization will then precess in the magnetic field in the same manner as a classical magnetic moment vector. This measurement provides one of the few experimental checks on the present theory of quantum electrodynamics which predicts an infinite series of radiative correction terms to the Dirac value of 2 for the g-factor of the free electron.

If the g-factor were exactly 2, the polarization vector would precess once for every cyclotron revolution and the beam would remain transversely polarized independent of the time the beam spends in the magnetic field. Since the g-factor is slightly greater than 2, the polarization vector will precess slightly faster than the orbital precession of the electrons and after about 200 revolutions the beam will be longitudinally polarized. After another 200 revolutions the beam will be transversely polarized opposite to the initial direction. In this manner, the counting rate ratio after second scattering will vary with the time the beam spends in the magnetic field. This time is increased by trapping the electrons in the field for over 100 cycles of the counting rate ratio variations. The frequency of the variations will be the difference frequency, the spin precession frequency minus the orbital or cyclotron frequency.

It was found that, the g-factor anomaly is in excellent agreement with the current predictions of quantum electrodynamics.

The principal sources of error are the determination of the effective magnetic field, the measurement of the difference frequency, and the evaluation of the stray electric fields within the system.

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ABSTRACT OF THESIS

THE STABILITY OF A STRATIFIED FLOW

William Paul Graebel

IP-378 Dated August, 1959

This paper is concerned with the stability of the flow of two stratified fluids of equal viscosity but different densities. The flow is entirely motivated by gravity and its velocity distribution is anti-symmetric, with the lighter fluid flowing in a direction opposite to that of the heavier fluid, and with a point of inflection of the velocity profile at the interface. The flow takes place between two parallel planes, inclined at an angle θ with the horizontal.

It is believed that this study will help explain many phenomena which occur in nature and in industry such as the intrusion of salt water into river estuaries, intrusion of a cold front into warmer air, generation of waves by a turbulent wind, and the type of flow encountered by the chemical engineer in extraction columns.

For the case of vertical inclination it is shown that the flow is unstable at all values of the Reynolds number. The stabilizing effect of surface tension is also shown, although it can never induce complete stability. The celerity of the disturbances anticipated is small, and the displacement of the interface can be large.

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ABSTRACT OF THESIS

LIMIT OF SUPERSATURATION OF NITROGEN VAPOR EXPANDING IN A NOZZLE

Gennaro Louis Goglia

IP-379 Dated August, 1959

An experimental investigation was conducted to determine the limit line of supersaturation of superheated nitrogen vapor as it expanded in a supersonic nozzle. An aluminum, two dimensional source-flow, adjustable throat type of nozzle of one-inch-width was used in these tests.

The nitrogen used in the tests was stored in a tank which was surrounded by a bath of liquid nitrogen. The thermal capacity of the tank and that of the bath of liquid nitrogen surrounding the storage tank permitted the generation of the nitrogen vapor. While equilbrium conditions were being attained in the storage tank, liquid nitrogen was forced through the line connecting the tank with the nozzle-diffuser assembly. By this procedure it was possible to maintain the temperature conditions at the nozzle inlet as close to the saturation conditions as was possible.

The experimental results indicated that the condensation of the nitrogen was gradual and that there was no evidence of a condensation shock. It was evident that the flow up to the onset of condensation was isentropic and that the stagnation pressures along the nozzle axis as measured were almost those predicted for isentropic conditions. It was also observed that once the collapse of the supersaturated state occurred the flow process appeared to parallel the saturated expansion. A mass spectrometer analysis of the nitrogen used indicated the presence of approximately five percent oxygen content. The results of this study appeared to favor the acceptability of the Stever-Rathbun theory.

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ABSTRACT OF THESIS

GAS CHROMATOGRAPHY AS A RECOVERY PROCESS

Robin James Robinson

IP-380 Dated August, 1959

In this paper a study was conducted to determine the important variables in the design of a chromatographic column for use in recovery processes. Correlations are presented giving the effects of temperature and column length on retention volume, and the effects of flow rate, sample size, and column length on band width for systems of isobutane and normal butane.

It is believed that this process fills a need left by such well-known methods as infra-red analysis, mass spectroscopy, distillation, etc. The speed by which an analysis can be performed is one of the primary assets. Other features include the requirement of only a very small amount of sample to be tested, purity of separation attained, ease of detection of the separated components, and the low cost per analysis.

Resolution in a separation, the gap between two successive peaks, is defined in terms of retention volume and band width. The data show that retention volume is directly proportional to column length over the range considered. Retention volume is theoretically related to temperature.

The effects of flow rate, sample size, and column length on band width are also presented. In agreement with theory, band width is proportional to the square root of the column length. This fact is used to incorporate data taken on columns of varying lengths into a single correlation of band width and flow rate.

It is felt that the general agreement of the results with the theoretical model makes it possible for the results obtained on the systems studied, normal and isobutane, to be extended to other systems with a minimum of experimental work.

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ABSTRACT OF THESIS

AN EXPERIMENTAL STUDY OF STRESSES IN THE END BLOCKS OF POST-TENSIONED PRESTRESSED CONCRETE BEAMS

Ti Huang

IP-381 Dated September, 1959

The purpose of this study was to determine the distribution of stresses inside the end blocks of post-tensioned prestressed concrete beams. It is known that in these regions, due to the presence of both longitudinal and vertical external forces, the concentration of the end forces at the exterior end, and the change of section at the interior end, the state of stress is truly three-dimensional. Various methods had been proposed and used for the analysis and design of end blocks. Almost all treated the problem as two-dimensional; and most forces in the vertical direction were neglected.

In this study, a model beam with the end blocks of different lengths was tested. The strains at various interior and exterior points were measured by SR-4 strain gages. The same end blocks were analyzed two-dimensionally by means of numerical procedures. Distribution of stresses in the lateral direction was then established by comparing the analytical and experimental results.

From the investigation, the following conclusions were drawn: (1) End blocks with length-depth ratio much greater than unity are not advisable to use. (2) For I, T or box-shaped beams, a critical tension zone exists near the interior end. (3) The lateral distribution of σ_x at the interior end is in the shape of a parabola, with the minimum value at the plane of symmetry. (4) Although, several of the vertical forces may be neglected, the reaction from the end support and the vertical shear at the interior end must be considered. (5) The use of long horizontal tapers into the web (webs) of the beam may be both economical and efficient.

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ABSTRACT OF THESIS

A STUDY OF THE IRRADIATION METHOD IN THE MEASUREMENT OF MOLECULAR WEIGHT DISTRIBUTION IN POLYSTYRENE

William W. Graessley

IP-382 Dated September, 1959

The purpose of this paper was to study the radiation crosslinking-solubility characteristics of polystyrene; to determine whether properties of the molecular weight or size distribution of a polymeric system can be measured experimentally from its subsequent crosslinking-solubility behavior.

A series of samples of polystyrene was irradiated in vacuum by Cobalt-60 gamma radiation for various total doses, and the resulting solubility for each dosage was determined by solvent extraction of the partially gelled solid films. From existing theories of random crosslinking and chain scission, equations were developed, relating the measurable properties of gel curves (solubility as a function of radiation dose) to the initial molecular weight distribution of the sample.

Two conclusions can be drawn from the results: 1) for polystyrene, the basic assumptions of statistically random crosslinking and chain scission are well met in the range of chain lengths covered, and 2) the resulting gel structures are stable and reproducible enough to allow accurate computation of the distribution parameters desired.

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ABSTRACT OF THESIS

THE EFFECT OF CENTRIFUGAL FORCE ON THE DECONTAMINATION FACTOR IN THE EVAPORATION OF RADIOACTIVE SOLUTIONS

Gerald H. Golden

IP-383 Dated September, 1959

This paper investigated the mechanism of decontamination of the vapor produced in a centrifugal evaporator for concentrating radioactive solutions. In the evaporator the feed solution, consisting of five liters of an aqueous solution of strontium-89, flowed down the inner wall of a vertical rotating aluminum drum which was heated by means of electrical resistance heaters in an air jacket surrounding the drum.

The vapor from the centrifugal evaporator was passed into a condenser, and the resulting condensate was passed through the counting system which consisted of a thin-walled Geiger tube surrounded by a cationic ion exchange resin bed. A total of 31 runs were made upon the final modification of the centrifugal evaporator to measure the decontamination factor under various operating conditions. It was found that for each of three vaporization rates, the decontamination factor increased in an approximately exponential manner with increasing evaporator speed.

It was postulated that by increasing the speed of rotation of the evaporator considerably, a point would be reached at which bubble formation in the liquid would cease, and there would be no entrainment of droplets by the vapor. It was not found possible to attain the necessary speed to reach this point with the evaporator employed in the present study.

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ABSTRACT OF PAPER

THE SYNTHESIS OF LINEAR FILTERS WITH REAL OR IMAGINARY TRANSFER FUNCTIONS

Elmer G. Gilbert
Joseph Otterman

IP-384 Dated September, 1959

This paper deals with the synthesis of real or imaginary transfer functions, i.e., with the synthesis of filters with even (symmetric) or odd (antisymmetric) impulse responses. Realization is only possible within a time lag T, and requires a delay element filter with a finite memory of 2T.

The approximation problem has been solved in both the frequency domain and in the time domain. Two sets of orthogonal approximating functions, one based on Legendre polynomials in the time domain and the other on Fourier series in the time domain, are used to form a minimum integral-square-error approximation.

A number of the approximating functions are plotted, both in the frequency domain and in the time domain. The described techniques are demonstrated in examples involving synthesis of low pass filters.

It appears that the approximating functions based on Fourier series have the following advantages over functions based on Legendre polynomials: 1) realization is simple in form, consisting of $(1 - e^{-j\omega 2T})$ and H_3 in cascade, and 2) at most, only one pole is required at $p = 0$.

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ABSTRACT OF THESIS

AN ANALYTICAL AND EXPERIMENTAL STUDY OF THE PRESTRESSED BOWSTRING ARCH

Movses J. Kaldjian

IP-385 Dated September, 1959

The purpose of this study was to analyze the prestressed bowstring arch, and to compare its structural behavior with the conventional nonprestressed type. The sort of interaction that exists between the arch rib and the tie girder makes the structure highly indeterminate. The increased use of prestressed concrete (though not restricted to it) in construction justifies such an investigation as potentially valuable to the structural engineer.

In Chapter II of the study, a general expression is derived from the strain energy of the structure for solving bowstring arches with extensible suspension rods. In Chapter III of the study, the membrane-analogy method of solving the bowstring arch was introduced.

In Chapter IV of the study, the laboratory investigation of the strains and displacements in several 49-inch-span aluminum models is described briefly, and the results obtained from these lists are compared with the analytical values.

Three general conclusions can be drawn from the study. (1) The good agreement obtained between the results of the analytical methods and the experimental work shows the accuracy of the theoretical analyses. (2) The membrane-analogy method yielded very satisfactory results; thus its use for preliminary design is especially recommended. (3) Design diagrams show that prestressing bowstring arch for dead-load bending moment is always beneficial for the arch rib and only beneficial for the tie girder when the slenderness ratio of the arch rib is small and the stiffness ratio of the tie girder to that of the arch is fairly large.

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ABSTRACT OF THESIS

AN INVESTIGATION INTO THE STABILITY OF A STEADY STATE VIBRATORY SYSTEM GOVERNED BY THE NONLINEAR DIFFERENTIAL EQUATION

$$m\ddot{x} + cx\dot{x} + ax = F_o \cos \nu t$$

Bernard Morrill

IP-386 Dated October, 1959

The purpose of this investigation was to determine the stability of a steady state vibratory system which has the characteristic of nonlinear damping as represented by the differential equation

$$m\ddot{x} + cx\dot{x} + ax = F_o \cos \nu t \qquad (1)$$

The importance of this investigation lies in the technique developed for analyzing a system with nonlinear damping; a technique which may also be applied to systems which are governed by nonlinear damping which is of a form other than that given by Equation (1).

Chapter I of this investigation develops a stability criterion which may be applied to any nonlinear system represented by a second order nonhomogeneous differential equation, providing such a system has a periodic solution.

Several assumed solutions for Equation (1) are developed in Chapter II, one of which is a solution containing a subharmonic of the one-half order. A comparison of the predicted instabilities with the points of instability as determined by an analogue computer is made in Chapter III.

It was demonstrated that unstable solutions may exist in the frequency range below resonance. Whether a solution is stable or unstable depends upon the initial conditions.

It may be concluded from the results of this investigation that the stability of the system defined by Equation (1) may be predicted over a wide range of amplitude and frequency inputs. The accuracy of the predictions are well within the range of accuracy of the engineering estimate of the values of the constants in Equation (1).

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ABSTRACT OF THESIS

AN INVESTIGATION OF CORNER EDDIES AND FREE-SURFACE INSTABILITY

Aris C. Spengos

IP-387 Dated October, 1959

This paper is concerned with an investigation of corner eddies and free-surface instability such as might be found in the flow of paper stock in a Fourdrinier paper machine. The phenomena investigated in this study are: (a) the formation of corner eddies immediately preceding an abrupt contraction in the flow area, (b) the instability of a free surface due to a downward acceleration, and (c) the instability of a free surface due to an abrupt change in boundary geometry. It has been observed that the occurrence of these phenomena adversely affect the quality of paper produced.

It is analytically demonstrated that the formation of corner eddies upstream from the discharge opening of the head box of a paper machine is partly the consequence of the rotationality of the upstream flow. The differential systems for two cases of two-dimensional flow, with appropriate boundary conditions for the flow in the head box, and their solutions are presented.

The analysis of the instability of a free surface when it is subjected to a downward acceleration larger than that of gravity is carried out for three-dimensional disturbances. Surface tension and depth of fluid have been taken into consideration, but the effects of the Coriolis acceleration and viscosity have been neglected. Data collected with the use of an experimental apparatus simulating flow conditions in a paper machine verify the trend predicted by the analysis.

The experimental investigation of the instability due to an abrupt change in the boundary geometry was carried out with the same experimental apparatus. The results indicate that the growth of the disturbances depends on the degree of change of the boundary geometry, and on Froude number.

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ABSTRACT OF PAPER

TRANSIENT PHENOMENA ASSOCIATED WITH THE PRESSURIZED-DISCHARGE OF A CRYOGENIC LIQUID FROM A CONTAINER

J. A. Clark
G. J. Van Wylen
S. K. Fenster

IP-388 Dated October, 1959

In this paper theoretical and experimental investigations are reported of the transient wall and fluid temperatures during the pressurized-discharge process of liquid nitrogen from a container. Also given is an analysis for predicting the quantity of pressurizing gas which may be expected to condense on the liquid interface during discharge.

Experimental measurements indicate that wall temperatures below the interface are influenced principally by the liquid temperature but that, with the passage of the interface, the wall temperature experiences a significant transient. A theoretical analysis of this transient confirms this behavior and with assumed values of the gas and liquid heat transfer coefficients, the theory and experimental results compare favorably.

The thermal response of the liquid in the region of the interface appears similar to that of a semi-infinite solid whose surface temperature is suddenly increased.

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ABSTRACT OF THESIS

ON OPERATORS RELATED TO NORMAL OPERATORS

Joseph G. Stampfli

IP-389 Dated October, 1959

The scientist of today is continually being confronted with the problem of solving the differential equations which arise in connnection with his research. This paper studies operator structure with the purpose of obtaining information of practical as well as theoretical importance in the solution of these differential equations. The equations of dynamics relating position, velocities, and accelerations give rise to systems of differential equations of the second order or higher. Electric circuit phenomena are described by currents and their time derivatives and thus lead to such equations. The study of problems involving continuous media, such as problems in fluid dynamics, elasticity, wave propagation, and heat conduction also require differential equations for their solution. In the recently developed field of servomechanisms or control systems, differential equations are indepensible.

Once a differential equation has been formulated to describe physical behavior, existing techniques may provide no way to find its solution nor even to approximate the solution. In an attempt to rectify this situation new approaches to the theory of differential equations are being developed.

If the differential equation is considered as representing an operator on a function space then the powerful theory of linear spaces may be utilized. It is such an approach that is considered here. A study is made of two classes of operators (on a Hilbert space) which have applications to differential equations.

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ABSTRACT OF THESIS

IRON SILICA SAND INTERFACE REACTIONS

George Austin Colligan

IP-390 Dated October, 1959

The purpose of this paper was to study the reactions that take place at the interface between iron and silica with varying atmospheres over the range of temperatures experienced in producing an iron-base cast alloy.

Mold-metal interface reaction has historically been a serious problem in the field of cast metals. This interface reaction between metal and mold material is the cause of surface-roughness dimensional inaccuracy, metal penetration and "fused sand." The solution to this problem has been approached as unique for each individual casting, mold material and alloy. Vacuum-melted iron and alloys of 1% and 9.85% manganese were used with quartz sand to determine the pertinent equilibria in this iron, silicon, oxygen, carbon system in the presence of a strong excess of silica.

The results of the equilibrium investigation have determined the location of the important univariant curves in the iron, silicon, oxygen, carbon system under the conditions of interest in cast metals practice. These results agree with the available published data at lower temperatures, and indicate that the activity of iron oxide in a silica saturated slag is one-fifth to one-sixth the equilibrium value in the absence of silica.

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ABSTRACT OF THESIS

AN ANALYSIS OF TRUSS DISPLACEMENTS

Donald Adam DaDeppo

IP-391 Dated October, 1959

This paper deals with the analysis of displacements in space trusses. The displacement problem is considered as a problem in geometry and is stated as follows: Given a compatible set of elongations of the truss members, find the displacements.

A vector method of solution, which is based on the assumption that the displacements are small, is presented. Solution for the displacements is obtained in a step-by-step fashion. For the most part, only three simultaneous linear equations must be solved in each step. Application of the method is demonstrated by examples, which, although simple are by no means trivial, and clearly demonstrate that the proposed method is practical in application.

In general, the labor required to calculate the displacement at every joint in a truss by the proposed method is about the same as that required to calculate the displacement at one joint in one direction by the classical methods.

A step-by-step solution is possible only because the displacements, considered as a whole, are governed by a special system of simultaneous equations. The equations are derived in a matrix formulation of the problem. Practical methods for inverting the matrix of coefficients are given. From the matrix formulation it is shown that the stress and displacement analysis problems are virtually identical.

Inherent errors in the displacements are considered in detail, and formulas for estimating these errors under different conditions are given. However, the example does not permit any general conclusions relative to the errors, which may be expected in a general case, but shows that a considerable amount of numerical work is required to obtain a close estimate of the inherent errors.

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ABSTRACT OF THESIS

THE USE OF STRONG SHOCK WAVES IN THE THERMAL DECOMPOSITION OF ETHANE AND ETHYLENE

Irving F. Miller

IP-392 Dated October, 1959

In this paper a chemical shock tube is utilized to measure the rate of thermal decomposition of ethane to form ethylene and hydrogen and the rate of thermal decomposition of ethylene to form acetylene and hydrogen at high temperatures. The reactant gas mixture is rapidly compressed and heated by the shock wave and then rapidly expanded and cooled by a rarefaction wave. In its simplest form, the shock tube consists of two chambers separated by a thin diaphragm. One section contains a driver gas at high pressure while the other contains the reactant gas at a low pressure. When the diaphragm is suddenly ruptured, the movement of the high pressure gas into the low pressure section causes a shock wave to propagate through the low pressure section. The mixture is quenched by a rarefaction wave reflected from the end of the high pressure section.

The temperature and pressure history in the shock tube is computed from the measured wave velocity, along with the initial conditions of the driver and reactant gases. If a reaction mechanism is postulated, a reaction rate constant can then be computed from the composition of the final mixture in the tube. When a first order mechanism is postulated, the computed rates obtained in this investigation at temperatures between about 2200°R and about 5000°R indicate a lower apparent energy of activation than previous data obtained at lower temperatures (less than 2000°R) in conventional reactors.

It was found that a significant percentage of acetylene can be made directly from ethane at the high temperatures achieved in a shock tube (4700°R and higher) and this reaction may have commercial possibilities. With the possibility of commercial applications in mind, a method for duplication of the conditions in the shock tube on a continuous basis was investigated theoretically. The system which was postulated was a convergent-divergent nozzle with a standing shock wave at the exit. The rate at which energy would have to be transferred through the wall of the nozzle to the high velocity gas stream is extremely and perhaps prohibitively high.

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ABSTRACT OF THESIS

THE COMBUSTION OF HEAVY FUEL OILS IN ATMOSPHERES OF REDUCED OXYGEN CONTENT AND ELEVATED TEMPERATURES

Frederick K. Boutwell

IP-393 Dated October, 1959

This paper is concerned with a study of the combustion characteristics of a heavy fuel oil using a vitiated air at high temperatures as an oxygen source. This subject is of concern to the widening of the application of gas turbines and the realization of improved thermal efficiencies in the production of power by utilizing the thermal energy of the exhaust gases and the use of these gases in combustion processes.

Tests were run on a specially designed combustion chamber utilizing a mixture of the products of combustion from a natural gas burner and air to simulate the exhaust gases from a gas turbine. A commercial burner with a horizontal rotating cup atomizer was used with number 6 fuel oil in the combustion test chamber throughout the tests. No effort was made to control the oxygen content independently of temperature.

The characteristics of combustion are presented in the form of a combustion limits curve, and tabulated results. The limits curve shows the rich and lean limits of combustion plotted against the vitiated air temperature. It is shown that the combustion process is affected adversely by the use of the vitiated mixture at elevated temperatures.

It is concluded that the use of gas turbine exhaust gases as a source of air for further combustion processes will require special consideration in the design of combustion chambers and burners due to the decrease of efficiency of combustion in the vitiated products from the turbine. These chambers will require a greater combustion volume, and greater than usual attention to the aerodynamic design parameters of the atomizer and chamber combination, to attain complete combustion.

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ABSTRACT OF PAPERS

NOTES ON MATHEMATICS FOR ENGINEERS

Prepared by the American Nuclear Society
University of Michigan Student Branch

IP-394 Dated October, 1959

This set of notes has been compiled by the American Nuclear Society, The University of Michigan Branch, to provide in one volume, a handy reference for a large number of the commonly-used mathematical formulae, with respect to notation, definition and normalization. Although these results were available in an excessive number of references it was found that because the notation or normalization varied, or the formulae were so spread out that they were difficult to find, their use was time-consuming.

Short explanations are included, with some examples, to serve two purposes: first, to recall to the user some of the ideas which may have slipped his mind since his detailed study of the material; second, for those who have never studied the material, to make its use at least plausible, and to help in his study of references.

It is believed that a sufficient quantity of material is included to make necessary only infrequent use of other references, except for integral tables, etc. for elementary work; however, the user may find it desirable to add some pages of his own.

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INDUSTRY PROGRAM OF THE COLLEGE OF ENGINEERING

ABSTRACT OF THESIS

LIQUID AND GAS-PHASE MASS TRANSFER ON BUBBLE-CAP TRAYS

John Wesley Begley

IP-395 Dated October, 1959

A high percentage of the fractionation or absorption systems encountered by the design engineer may be grouped into narrow ranges of liquid viscosity and density. The great interest in these systems in the past has limited the investigations of mass transfer on bubble caps to the same narrow ranges of the liquid properties. However, it is not uncommon for the designer to be confronted with a separation problem where the liquid viscosity or density may be several-fold larger or smaller than the values used in studies reported to date. The purpose of this investigation of mass transfer on bubble-cap tray was to study the effects of liquid properties in the higher ranges not covered previously.

The equipment used in this investigation consisted of a 7 1/2 x 12-inch square tray equipped with 9, 1 1/2-inch diameter, bubble-caps located on a 2 1/2-inch rectangular spacing. The systems used in the study were purposely chosen so that the effects of the liquid properties upon the gas and liquid-phase resistances could be studied separately. The liquid-phase resistance was studied by absorbing carbon dioxide cyclohexanol. The bulk hydraulics of the two-phase system on the tray were studied in conjunction with the mass transfer studies. These data were then used in the interpretation of the mass transfer data by use of simple mathematical models developed previously.

Variations in liquid density, viscosity, and surface tension were not found to have a significant effect upon the bulk hydraulic characteristics; however, correlations are included to show the effects of the foregoing variables upon froth height, clear liquid height, and gas holdup.

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ABSTRACT OF PAPER

TRANSIENT PHENOMENA ASSOCIATED WITH THE PRESSURIZATION OF LIQUID NITROGEN BOILING AT CONSTANT HEAT FLUX

S. K. Fenster
G. J. Van Wylen
J. A. Clark

IP-396 Dated November, 1959

This investigation concerns liquid nitrogen which is boiling as a result of a constant heat flux through the walls of the containing vessel. When this boiling liquid is pressurized, boiling ceases because the fluid is now sub-cooled with respect to the new saturation temperature. A transient process then follows in which the liquid is heated and boiling initiated. Finally steady state boiling at the new saturation temperature is achieved. The purpose of this investigation was to study the transient phenomena following pressurization. The transient heat transfer coefficients in the liquid nitrogen have been calculated from experimental data and an analytical study made.

Because this study is relevant to the pressurization of the liquid oxygen tanks of missiles, the length to diameter ratio, wall thickness, and materials of the primary test cylinder were influenced by actual missile practice. The apparatus consisted of a cylinder three feet high and one foot in diameter which contained liquid nitrogen. The heat flux through the container walls could be regulated and measured. Temperature at various wall heights and throughout the liquid were measured, as a function of time, by use of thermocouples.

Results of heat transfer coefficients as a function of time are shown in graphical form. The variation in heat transfer coefficient, up until the time of first bubble formation, was shown to be influenced by the viscous deceleration of the initial turbulence due to boiling, and the free convection effects due to the wall-liquid temperature difference.

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ABSTRACT OF PAPER

THE MAGNETIC ANALOG WITH SPIRAL SEARCH COILS

A. D. Moore

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The solution of field problems is of ever-increasing interest. Such potential fields as current flow fields, electrostatic fields, heat flow fields, fluid flow fields, and magnetic fields, are analogous to each other. In theory, any one such field may be set up physically to serve as the analog in solving a problem in any other such field.

The most difficult field problems are those concerned with distributed sources, with solutions needed close to the source or even within it. The developments enabling the analog to solve such problems are presented herein. A 2-dimensional heat flow field, for example, may be set up in an infinite (or essentially infinite) uniform medium, the heat source being distributed over the cross-section of the heat-producing region. The magnetic analogy would be achieved by replacing the heat section by current in a solid conductor. Flux lines outside of the conductor could be determined, these being analogous to the heat isothermal lines. Thus, the outside heat field could be solved by analogy. But such a magnetic analog would not permit of inside flux exploration, and could not then solve the much more difficult internal part of the field.

The magnetic analog described determines both parts of the field - inside and outside. That is, it leads to the complete solution. This is achieved by subdividing the total current among a number of increment currents carried in parallel rods. The successful development of the magnetic analog also hinged on the invention of a new form of search coil: the spiral search coil.

The magnetic analog at present is limited to 2-dimensional fields in the large uniform medium. Such problems do come along, and they are important. For example, in the gas bubble method of underground gas storage, difficult fluid flow problems arise. The magnetic analog may possibly apply to some of these problems.

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ABSTRACT OF THESIS

EFFECT OF ELECTROMAGNETIC FIELDS ON GRAVITATIONAL STABILITY OF A VISCOUS FLUID

Michael Bentwich

IP-398 Dated November, 1959

The effect of electromagnetic fields upon the stability of a conductive viscous fluid with a negative temperature gradient is investigated. The numerical relationship between the imposed electromagnetic field and the critical temperature-gradient has been found. In most cases considered, convection is inhibited by the electromagnetic field, but the effectiveness of the inhibition has been found to depend very markedly on the mode of convection.

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ABSTRACT OF PAPER

FREE CONVECTION HEAT TRANSFER AND FLUID FLOW IN CLOSED VESSELS WITH INTERNAL HEAT SOURCE

F. G. Hammitt
E. M. Brower
Paul T. Chu

IP-399 Dated November, 1959

This report summarizes the closed-cell internal heat source, free convection analytical and experimental research which has been conducted by the authors and co-workers over the past several years. Portions of this work have previously been reported in IP-259, 290, 314, and 340.

Experimental and analytical results are summarized as briefly as possible. Some phases of the work are still continuing and will be described in future reports.

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ABSTRACT OF THESIS

DIRECTIONAL CORRELATION OF GAMMA RAYS IN GERMANIUM 72 AND DYSPROSIUM 160

Robert George Arns

IP-400 Dated November, 1959

This paper is concerned with the gamma-gamma directional correlation experiment and its application in studying the decay of two radioactive nuclei. The directional correlation of successive gamma rays has been the principal tool of low-energy nuclear physics for determining the spins of excited states and the multipole order of the emitted radiation. The gamma-gamma directional correlation experiment consists in measuring the coincidence rate between successive gamma rays as a function of the angle between their directions of emission. A method is outlined which facilitates the interpretation of directional correlation data when one or both of the emitted gamma rays are not of pure multipole order.

Directional correlation measurements were made on five cascades involving the gamma rays in Ge^{72}, and six cascades involving the gamma rays in Dy^{160}. The results are discussed in terms of the unified model as interpreted by Davydov and Filippov. Evidence is cited to support the existence of rotational levels in all non-spherical nuclei. It is shown that these levels may be interpreted as arising from the rotation of a non-axial ellipsoid.

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ABSTRACT OF PAPER

CORRELATION OF BENDABILITY OF MATERIALS WITH THEIR TENSILE PROPERTIES

Joseph Datsko
Chin T. Yang

IP-401 Dated November, 1959

With the advent of high-temperature resistant materials in the sheet metal industry, it is becoming increasingly important to treat the subject of minimum or "critical" bend-radius analytically. A simple equation is presented that correlates the minimum bend-radius with the percentage reduction of area of the material. The theoretical derivation as well as experimental data are given in the paper, with very good agreement between the two. Consequently, it is possible to predict the minimum bend-radius for a specific material, provided that the percentage reduction of area, as determined by a standard tensile test is known. The relationship applies equally well to metals and non-metals.

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ABSTRACT OF PAPER

ANALYSIS OF POWER SPINNING OF CONES

B. Avitzur
C. T. Yang

IP-402 Dated November, 1959

In this paper the geometry of the cone, the roller, and the spinning operations are described mathematically. A shear type of deformation is postulated, based on experimental evidence. The displacement, velocity, strain rate, and stress fields are computed for "Mises Material," and hence with Mises stress-strain rate law. The power consumed in the operation is computed from the strain rate and stress fields. The expression for the power is in a form that can hardly be solved analytically. A numerical solution is therefore employed and results are presented in graphical forms, where the power and tangential force are plotted for a variety of the process variables. The numerical solution is compared with actual power and force measurement in experimental tests and the agreement is reasonably good.

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