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MATHEMATICS PANEL
QUARTERLY PROGRESS REPORT
FOR THE PERIOD ENDING APRIL 30, 1950

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MATHEMATICS PANEL

QUARTERLY PROGRESS REPORT

for the Period Ending April 30, 1950

A. S. Householder, Chief

Date Issued: JUN 12 1950

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TABLE OF CONTENTS

SUMMARY 4

SPECIAL PROBLEMS AND PROJECTS 7

- Tetrad Analysis (Yeast Genetics) 7
- Diffusion of Isotopes in Multicompartment Systems 7
- General Numerical Methods 7
- Effect of Radiation on Rate of Mitosis in Grasshopper Embryo 8
- Basic Studies in the Monte Carlo Method 8
- A Design Problem for the MTR 8
- Approximate Calculation of the Neutron Flux in a Thick Shield Containing Some Heavy Elements 9
- Teaching 9
- Criticality Computations 9
- Chromotography 9
- K-Capture and Beta-Decay, Correction for Size of the Nucleus 11
- Determination of a Potential Distribution 11
- Relationship of Dose and Time for 3rd and 4th Cell Divisions in Paramecia 11
- Calculation of Media Effective Doses of Ultraviolet Light on Grasshopper Embryos at Various Wave-Lengths 12
- Determination of the Neutron Flux in the ORNL Pile 12
- Photoreactivation Effect on Paramecia 12
- A Determination of the Proportion of Mice Carrying a Lethal Gene 13
- Age in H_2O - D_2O Mixtures 14
- Fermi Functions 14
- A Diffusion Solution for the Cylindrical Ducting Problem of Infinite Geometry 14
- A Machine Solution for the Fundamental Transport Equation in One Dimension 14
- Analysis of Data on Ducting Experiments on the MIT Cyclotron 15
- A Diffusion Solution for a Black Thermal Neutron Pipe Duct Containing a Pure Scattering Material 15
- A Machine Solution for the Flux in a Finite Three Dimensional Medium with a Cylindrical Duct and an Isotropic Source 15
- Monte Carlo Estimate of Ages and Collision Distribution in Tissue for 10 Mev Source Neutrons 16
- Interpolation on Computed Values of Internal Conversion Coefficients (K-Shell) 16
- Kinetics of the Homogeneous Reactor 16

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SUMMARY

New, full-time members of the Mathematics Panel are Miss Kathryn Pflueger and Miss Rooney Currey, while Professor G. E. Albert, of the Department of Mathematics, University of Tennessee, has joined the Panel as a consultant on a part-time basis. In addition, Mr. David Whitcombe is working with the Panel on loan from NEPA.

An informal agreement has been made with Argonne for the construction there of an IAS electronic digital computer for Oak Ridge. This reversal of a previous recommendation for the purchase of a machine from the Raytheon Corporation came about because of continued progress in the development of the Williams tube memory circuit, and the advent of an efficient electronic computer group at ANL. This group is now engaged in the construction of a machine for Argonne, and expects to continue as a permanent research and development group. The report issued November 14, 1949, by the joint NEPA-ORNL committee had made it clear that the IAS machine would be superior in speed, in electronic simplicity, and in simplicity of operation, giving preference at the time to the Raytheon machine only because of the then unsatisfactory state of development of the Williams tube memory and the lack of facilities for constructing the machine at Oak Ridge.

While the completion of the IAS machine is eighteen to twenty-four months off, automatic computing facilities in Oak Ridge have been greatly enlarged by the arrival of the IBM Card Programmed Computer at Y-12 and the completion of a linear-equation solver at NEPA. This latter will take a system of order as high as three hundred, and solves by a Gauss-Seidel iteration, accumulating eight-digit products and rounding off the sum to four digits. A readjustment of one unknown takes two seconds, independently of the size of the system.

While at first sight a machine to solve linear algebraic equations might appear to be of extremely limited use, this is in fact not the case. For numerical solution, differential and integral equations are replaced by an approximating algebraic system of difference equations. Moreover, even nonlinear systems, when solved by methods of successive approximation, generally require the successive solution of approximating linear systems. Hence, the machine should turn out to be extremely useful.

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The joint meeting of the American Mathematical Society and of the Biometric Society [see last Quarterly report[1]] was held according to schedule in Oak Ridge April 21 and 22, with one hundred fifty people in attendance. Besides thirty-six contributed papers, the invited speakers and their topics were:

Dr. J. Z. Hearon, University of Chicago,
"The Thermodynamics and Steady-state Kinetics of Some Biological systems."

Dr. Anatol Rapoport, University of Chicago,
"Probabilistic Theory of Neural Nets."

Dr. C. W. Sheppard, Oak Ridge National Laboratory,
"Mathematical Basis of the Interpretation of Isotope Experiments."

Professor Alfred Brauer, University of North Carolina,
"Criteria for the Irreducibility of Algebraic Equations."

Professor W. V. Parker, Alabama Polytechnic Institute,
"Characteristic Roots and Field of Values of a Matrix."

A social period followed the evening session on Friday with refreshments provided by CCCD, and on Saturday afternoon there was a bus tour of the Area.

At a joint meeting of the Institute of Mathematical Statistics and the Biometric Society, held at the University of North Carolina, March 17 and 18, papers were given by

A. S. Householder, on "Tetrad Analysis in Yeast,"

Jack Moshman, on "An Investigation of the Hemotological Effects of Chronic Low-Level Ionizing Radiation."

In addition, A. S. Householder spoke on varying mathematical topics at the University of Georgia (three lectures); Duke University; Catholic University of America; Columbia University Graduate Students' Statistical Society; University of Alabama; Abilene, Texas, for the Texas Section of the Mathematical Association of America; the Southwest Louisiana Institute; Louisiana State University (two lectures); and the University of Kentucky for the Kentucky Section of the Mathematical Association of America.

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(1) Householder, A. S., *Mathematics Panel Quarterly Progress Report for the Period Ending January 31, 1950*, ORNL 634 (Mar. 10, 1950).

Visitors during the quarter included Professor J. W. Tukey, Princeton University, as consultant in biometrics; Mr. Herman Kahn, Rand Corporation, to consult on some Monte Carlo problems; Dr. J. A. Rafferty, School of Aviation Medicine, Randolph Field; and Dr. Seymour Sherman, Institute for Advanced Study. While here, Professor Tukey spoke at the Biology Seminar and the Physics Seminar, and Dr. Sherman spoke at the University of Tennessee Mathematics Colloquium.

SPECIAL PROBLEMS AND PROJECTS

PROBLEM (continuation): Tetrad Analysis (Yeast Genetics)

PARTICIPATING MEMBERS OF PANEL: A. S. Householder, M. L. Nelson

STATUS: The techniques so far developed yield information as to the frequency of occurrence of exchange between the centromere and a given locus. However, for the construction of chromosome maps special assumptions must be introduced relating interference between neighboring segments. A paper by A. R. G. Owen, "The Theory of Genetical Recombination. I. Long—Chromosome Arms," *P.R.S.B.* 136 (1949) 67-94, seems to provide a suitable approach. However, the curvefitting computations required are rather heavy and these have not yet been formalized.

This problem was discussed at the Chapel Hill meeting of the Biometric Society (see above).

PROBLEM (continuation): Diffusion of Isotopes in Multicompartment Systems

PARTICIPATING MEMBER OF PANEL: A. S. Householder

STATUS: This problem was discussed by Dr. Sheppard before the Oak Ridge meeting of the Biometric Society (see above). A paper entitled, "The Mathematical Basis of the Interpretation of Tracer Experiments in Closed Steady State Systems" has been completed and will be offered for publication.

PROBLEM: General Numerical Methods

ORIGIN: Mathematics Panel

PARTICIPATING MEMBERS OF PANEL: All

BACKGROUND AND STATUS: The Card Programmed Computer, the Fairchild linear-equation solver, and the prospective general purpose electronic computer (see above), while providing facilities for computations on a scale exceeding any previously undertaken, bring with them also the need for a re-orientation. Standard numerical methods must be reviewed and new ones devised and adapted to the new facilities. First, attention goes quite naturally to operations with matrices, including the computation of eigenvalues and eigenvectors, not only because of the Fairchild equation-solver, but also because this is basic to a large class of numerical methods. Interpolation methods and other polynomial approximations, methods of solving differential and integral equations, and iterative methods for solving non-linear systems come next.

Accordingly a systematic review of numerical methods is under way. A seminar has been started for members of the Panel, meeting twice a week to begin with. A series of "Notes on Numerical Methods" are being prepared for circulation within the Panel.

PROBLEM: Effect of Radiation on Rate of Mitosis in Grasshopper Embryo

ORIGIN: Dr. Mary Esther Gaulden, Biology Division

PARTICIPATING MEMBERS OF PANEL: A. S. Householder, Jack Moshman, Jerome Fishel

BACKGROUND: Embryos were irradiated in air as a control, and in atmospheres of N_2, O_2, and CO_2 and thereafter mitotic spindles were counted at regular intervals. The purpose of the test was to determine the statistical significance of the observed difference between mitotic frequencies in the control and the test embryos. The analysis was complicated by the nature of the variation in time of the absolute counts.

The method adopted was one proposed by J. W. Tukey. As the experiment was performed, a control and a test embryo were run simultaneously and paired counts were thus obtained. Tukey's suggestion was to pass parallel regression lines, with time as independent variable, through the differences of the square roots of the absolute counts, and to determine whether the common slope differed significantly from zero.

STATUS: Problem completed.

PROBLEM: Basic Studies in the Monte Carlo Method

PARTICIPATING MEMBER OF PANEL: G. E. Albert

BACKGROUND AND STATUS: Any application of the Monte Carlo method raises questions as to the relative effectiveness of possible sampling schemes and how to make a statistical evaluation of the results. This study, which is just beginning, is undertaken in the hope of getting some answers to such questions.

PROBLEM: A Design Problem for the MTR

ORIGIN: N. F. Lansing, Reactor Technology Division

PARTICIPATING MEMBER OF PANEL: E. A. Forbes

BACKGROUND AND STATUS: A computation was performed to assist in determining the location of flux-sensitive control detectors.

PROBLEM: Approximate Calculation of the Neutron Flux in a Thick Shield Containing Some Heavy Elements

ORIGIN: Dr. F. H. Murray, Reactor Technology Division

PARTICIPATING MEMBERS OF PANEL: Carl Perhacs, Rooney Currey

BACKGROUND AND STATUS: Computations were made to assist Dr. Murray in judging the possibilities of his method. Further computations are anticipated.

PROBLEM: Teaching

ORIGIN: School of Reactor Technology

PARTICIPATING MEMBER OF PANEL: M. L. Nelson

BACKGROUND AND STATUS: A course in mathematics is necessary in the School of Reactor Technology. During the months of March and April it was held one hour daily. Since then it has been held twice weekly, one hour meetings. The course consisted of a review of selected topics in the calculus ranging from the concepts of function and derivative to boundary value problems. Emphasis has been placed on the associated physical concepts. The design has been prepared for the course, given by Mr. Edlund, in reactor theory.

PROBLEM: Criticality Computations

ORIGIN: M. C. Edlund, Reactor Technology Division

PARTICIPATING MEMBERS OF PANEL: V. M. Gordon, E. A. Forbes, K. A. Pflueger

BACKGROUND AND STATUS: Two group, two region criticality computations were made.

PROBLEM: Chromatography

ORIGIN: Dr. G. E. Boyd, Chemistry Division

PARTICIPATING MEMBERS OF PANEL: R. R. Coveyou, V. M. Gordon, M. L. Nelson

REFERENCE: A random walk whose equation is hyperbolic, *Mathematics Panel Quarterly Progress Report,* Jan. 31, 1950, ORNL 634, pp. 14-15.

BACKGROUND: A fluid in which is concentrated a certain substance flows through a tube of constant cross-section. Inside the tube is a porous material which absorbs the concentrate.

x = distance along tube measured from end at which fluid source is located

c = concentration of substance in fluid

g = concentration of substance in absorber

t = time

v = flow velocity (constant)

The economy is assumed to be governed by

$$\partial g/\partial t = k(g_e - g) \qquad (\partial c/\partial t) + v\,(\partial c/\partial x) = k/f\,(g - g_e)$$

$g_e = Kc$ = "equilibrium" value of g.

$c(x,t) = c_0 \qquad x = 0,\ 0 \leq t$

$g(x,t) = 0 \qquad xt = v,\ 0 \leq x$

By making the transformations

$y = (Kk/f)(x/v) \qquad z = k(t - x/v)$

$g(x,t) = Q(y,z) \qquad Kc(x,t) = C(y,z)$

the preceding system reduces to

$$(*) \qquad \partial c/\partial y = -C + Q \qquad C(0,z) = C_0 \equiv Kc_0$$

$$\partial Q/\partial z = C - Q \qquad Q(y,0) = 0$$

This system is noted in the reference in connection with another problem. The solution is given there or alternatively

$$(1/C_0)\ C(y,z) = 1 - \exp(-z) \int_0^y \exp(-s)\ I_0(2\sqrt{zs})\ ds$$

$$(1/C_0)\ Q(y,z) = \exp(-y) \int_0^z \exp(-s)\ I_0(2\sqrt{ys})\ ds$$

STATUS: A tabulation of the preceding functions has been started. The solution of system (*) in which the boundary values are $C(0,z) = f(z)$ and $Q(y,0) = g(y)$ has been obtained. The latter is of interest for the case in which a "clear" fluid washes the original substance from the absorbing material.

PROBLEM: K-Capture and Beta-Decay, Correction for Size of the Nucleus

ORIGIN: Dr. D. K. Holmes and Dr. M. E. Rose, Physics Division

PARTICIPATING MEMBERS OF PANEL: E. A. Forbes, K. A. Pflueger

STATUS: 85% complete for cases presently under consideration.

PROBLEM: Determination of a Potential Distribution

ORIGIN: Dr. W. M. Good, R. W. Lamphere, Physics Division

PARTICIPATING MEMBERS OF PANEL: M. L. Nelson, R. R. Coveyou, C. Perhacs

BACKGROUND AND STATUS: Mr. Lamphere wants to know the potential distribution in an acceleration tube for two cases, one in which the distribution has axial symmetry, and the other in which the distribution has no symmetry. The ultimate purpose is to determine electron trajectories through both the fields.

The potential distribution of the symmetrical case was determined by the Liebmann net method, and the calculation of an electron trajectory through this field is now in progress. The NEPA machine is being considered for the calculations of the asymmetric case.

PROBLEM: Relationship of Dose and Time for 3rd and 4th Cell Divisions in Paramecia

ORIGIN: Dr. R. F. Kimball, Biology Division

PARTICIPATING MEMBERS OF PANEL: J. Moshman, V. M. Gordon

BACKGROUND: It was observed that an inverse relationship existed between the time necessary for third and fourth cell divisions in paramecia after irradiation. A family of equations of the form $y_i = a_i x_i^b$ was derived, one for each level of dosage, which expressed time for the fourth division for the i-th dose (y_i) as a function of the time for the third division at that dosage (x_i). There was a common exponent for the family. Another series of curves were fitted permitting both coefficient and exponent to vary with dose. It was noted that the coefficients monotonically increased and the exponents similarly decreased with dose. Significance was observed for each equation.

STATUS: Completed.

PROBLEM: Calculation of Media Effective Doses of Ultraviolet Light on Grasshopper Embryos at Various Wave-Lengths

ORIGIN: Dr. J. G. Carlson, Biology Division

PARTICIPATING MEMBERS OF PANEL: J. Moshman, V. M. Gordon

BACKGROUND: A series of grasshopper embryos were irradiated at various dosages within seven different wave-lengths. By an iterative procedure a first degree curve was fitted to the logarithms of the doses and the probits corresponding to the percentage affected at the corresponding dose. Such lines were fitted for each wave-length, each under conditions of light and darkness. Median effective doses were derived for each case and differences noted for light and darkness. It was found that 2650 Å was the most efficient, *i.e.*, it affected half the embryos at a minimum dosage. Significant differences between light and darkness appeared at the higher wave-lengths.

STATUS: Completed.

PROBLEM: Determination of the Neutron Flux in the ORNL Pile

ORIGIN: Dr. D. K. Holmes, Physics Division

PARTICIPATING MEMBER OF PANEL: J. Moshman

BACKGROUND: Using an adaptation of the Monte Carlo technique, it is desired to determine the neutron flux at a number of representative points in the ORNL pile, making use of as few computational simplifications as possible. A tentative sampling plan has been devised which will stratify, or weight, the neutrons on the basis of the distance from the center of the uranium rod at their first collisions. It is hoped that such a stratification will be sufficiently realistic to decrease the variance of the final estimates and thus permit greater accuracy for a given number of neutron histories.

STATUS: A preliminary small sample to determine the approximate strata weights is awaiting an expression from the Physics Division for the inelastic scattering in the different media.

PROBLEM: Photoreactivation Effect on Paramecia

ORIGIN: Dr. R. F. Kimball, Biology Division

PARTICIPATING MEMBERS OF PANEL: J. Moshman, V. M. Gordon

BACKGROUND: It is now a well known phenomenon that the presence of light inhibits the effect of ultra-violet radiation on cell division. A number of

experiments were run and the mean time necessary for the paramecia to complete six divisions at various doses at two wave-lengths under conditions of light and darkness was recorded. In each case the standard error was computed also. A series of four lines was fitted to the logarithms of time and dose, one for each combination of light and wave-length.

STATUS: Calculations are proceeding to compute families of lines and to determine the significances of the various regression equation and coefficients.

PROBLEM: A Determination of the Proportion of Mice Carrying a Lethal Gene

ORIGIN: Dr. W. L. Russell, Biology Division

PARTICIPATING MEMBERS OF PANEL: A. S. Householder, J. Moshman

BACKGROUND: Male mice are submitted to a certain amount of radiation. In an unknown proportion, a mutation is induced which produces a lethal gene. It is desired to estimate this proportion.

If these male mice are mated, and the resulting females in the first generation are in turn bred, the litters of these females should show a 1:1 sex ratio when no lethal gene was produced. If the original male did carry a lethal gene after irradiation, the second generation will show a sex ratio of two females to each male.

A sequential procedure was derived to test the hypothesis of a 1/3 proportion of males (if there were a lethal present) against an alternate hypothesis that the proportion of males is 1/2. The method followed the outlines of the Wald Sequential Probability Ratio Test and has the virtue that one may expect to require about 50% of the litters compared to the "classical" procedure. If we permit the probability, β, of falsely calling a non-lethal mouse a lethal, and, α, the probability of incorrectly stating a lethal mouse is a non-lethal, the expected value of the proportion P of lethal is

$$E(P) = \frac{N_0 - \beta N}{N(1-\alpha-\beta)}$$

where N is the total number of mice tested and N_0 is the number classified as lethal.

The test proceeds by examining litters and comparing the observed number of males with a predetermined (based on α and β) pair of varying limits. If the number of males violates either limit, the test is concluded.

Expected values of litter sizes have been computed for various combinations of α and β.

STATUS: The sampling plan has been submitted to Dr. Russell.

PROBLEM (continuation): Age in H_2O - D_2O Mixtures

ORIGIN: L. C. Noderer, Reactor Technology Division

PARTICIPATING MEMBER OF PANEL: N. M. Dismuke

STATUS: Histories for mixtures containing 15%, 50% and 85% H_2O will be determined. In these three experiments, sufficient data will be retained to estimate the age for slightly different mixtures. To improve sampling, the spectrum was weighted with an approximation to the age to be calculated. Calculations are still in the boardwiring and testing stage.

PROBLEM: Fermi Functions

ORIGIN: Dr. P. R. Bell, Dr. M. E. Rose, Physics Division

PARTICIPATING MEMBERS OF PANEL: J. Fishel, N. M. Dismuke

STATUS: In progress.

PROBLEM: A Diffusion Solution for the Cylindrical Ducting Problem of Infinite Geometry

ORIGIN: Dr. R. L. Echols, NEPA

PARTICIPATING MEMBER OF PANEL: D. W. Whitcombe

BACKGROUND: Although the trend in reactor design seems to be toward liquid metal coolants, air ducts are still of interest since air tubes are unavoidable in any design. The above solution is published as ORNL-668 and NEPA-1363-STR-24. The flux solution for an infinite cylindrical duct with a plane source of neutrons is found by two methods. The first solution is an iteration solution; the second uses the steepest descent approximation. Both methods solve the same diffusion equation and boundary conditions.

PROBLEM: A Machine Solution for the Fundamental Transport Equation in One Dimension

ORIGIN: Dr. A. S. Householder, Dr. R. L. Echols, and E. S. Bettis

PARTICIPATING MEMBER OF PANEL: D. W. Whitcombe

BACKGROUND: The equation

$$\phi(x) = \lambda \int_0^a \phi(y) E_1 |y-x| dy + S(x)$$

is written in the form of linear equations and set up for the Fairchild machine at NEPA. The solution measures x in mean free path units, $\lambda = .4961$, for body tissue, $a = 10$ units and the source, S, for (1) a collimated beam of neutrons and (2) for an isotropic source of neutrons.

The problem is also of interest when one considers standardizing foils in a flux field. In this case a will be about five mills or less in thickness.

PROBLEM: Analysis of Data on Ducting Experiments on the MIT Cyclotron

ORIGIN: Dr. C. Goodman, MIT, and Dr. R. L. Echols, NEPA

PARTICIPATING MEMBER OF PANEL: D. W. Whitcombe

BACKGROUND: As a master's thesis project at MIT, air ducts have been built into concrete blocks and their cyclotron is used as a neutron source. The data are being studied from two points of view: (1) to find how ORNL-668 handles the straight-through duct and how to modify this theory when a bend is present; (2) to find a means of obtaining a quick estimation of the exit flux.

PROBLEM: A Diffusion Solution for a Black Thermal Neutron Pipe Duct Containing a Pure Scattering Material

ORIGIN: Dr. N. M. Smith, ANP and Shielding Group

PARTICIPATING MEMBER OF PANEL: D. W. Whitcombe

BACKGROUND: Laplace's equation is solved for a cylindrical pipe with a plane source of thermal neutrons. The solution is found in terms of the extrapolated boundaries r_0 and z_0. These are then related to the actual boundaries r_1 and z_1 and the exit current has been found at $r = 0$ and $z = z_1$. A sample problem for the case of bismuth will be included.

PROBLEM: A Machine Solution for the Flux in a Finite Three Dimensional Medium with a Cylindrical Duct and an Isotropic Source

ORIGIN: Dr. A. S. Householder, Dr. R. L. Echols, and E. S. Bettis

PARTICIPATING MEMBER OF PANEL: D. W. Whitcombe

BACKGROUND: The problem will be solved using a straight-through duct containing a material of interest to the design group. Since the geometry is cylindrical, the solution is essentially two dimensional. The computations are to be performed on the Fairchild machine which can solve for the unknowns in 300 linear equations. Then 20 places in the axial direction and 15 in the radial direction (or vice-versa) may be used. It is felt that this will give a fair representation of the flux distribution.

PROBLEM: Monte Carlo Estimate of Ages and Collision Distribution in Tissue for 10 Mev Source Neutrons

ORIGIN: Dr. W. S. Snyder and Dr. J.Neufeld, Health Physics Division

PARTICIPATING MEMBERS OF PANEL: A. S. Householder, R. R. Coveyou, N. M. Dismuke, M. R. Arnette

BACKGROUND: See *Mathematics Panel Quarterly,* A. S. Householder, Dec., Jan., Feb., 1948-1949. ORNL-345, p. 11.

STATUS: Two thousand neutron histories are being obtained on the IBM equipment at Y-12. The neutrons have been followed through 16 collisions apiece, and about 1600 remain unabsorbed and with energy above one volt.

PROBLEM: Interpolation on Computed Values of Internal Conversion Coefficients (K-Shell)

ORIGIN: Dr. M. E. Rose, Physics Division

PARTICIPATING MEMBERS OF PANEL: R. R. Coveyou, E. A. Forbes

DISCUSSION: The values of the K-shell internal conversion coefficient (electric and magnetic) were calculated as functions of Z, E, and multipole order by the Harvard machine group, under the direction of M. E. Rose. Because of the complexity of this calculation, it was decided that these values should be machine calculated on a rather sparse grid in the Z-E plane. It would be highly desirable to have these values on a finer grid. The present project has this as its purpose.

STATUS: Preliminary calculations are in progress designed to produce adequate formulas from which the interpolated values may be safely calculated.

PROBLEM: Kinetics of the Homogeneous Reactor

ORIGIN: C. Graham and J. Stein, Reactor Technology Division

PARTICIPATING MEMBERS OF PANEL: M. L. Nelson, R. R. Coveyou, E. A. Forbes, J. H. Fishel, A. R. Currey, V. M. Gordon

DISUCSSION: The problem is the prediction of transient behavior of the homogeneous reactor under sudden reactivity perturbations. The model adopted is a system consisting of reactor plus heat exchanges plus connecting pipes. The assumptions made are the following:

(a) Reactivity changes are "felt" throughout the reactor without time lag.

(b) Reactivity is a linear function of the mean reactor temperature and the volume of gas within the reactor, both with negative coefficients.

(c) Gas generation is proportional to pile power.

(d) Gas removal is proportional to amount of gas present.

(e) Flow of working fluid is laminar throughout the system.

(f) The neutron flux is constant over the reactor volume.

(g) The working cycle of the system is ten seconds in length: eight in the reactor; two in the external circuit.

The equations that result from these assumptions are as follows:

(1)

$$\dot{P}(t) = K(t)P(t) + \sum_i \lambda_i A_i(t),$$

(2-7)

$$\dot{C}_i(t) + \lambda_i C_i(t) = \beta_i P(t),$$

(8-13)

$$A_i(t) - A_i(t-10)\, e^{-10\lambda_i} = C_i(t) - C_i(t-4)\, e^{-4\lambda_i} + C_i(t-6)\, e^{-6\lambda_i} - C_i(t-10)\, e^{-10\lambda_i},$$

(14)

$$\dot{\theta}(t) = SP(t),$$

(15)

$$T(t) - T(t-10)\, e^{-h/\rho c} = T_s(1-e^{-h/\rho c}) + \theta(t) - \theta(t-4) + e^{-h/\rho c}\,[\theta(t-6) - \theta(t-10)],$$

(16)

$$\dot{g}(t) + b\,[g(t) - g(0)] = d\,[P(t) - P(0)]\ ,$$

[redacted]

(17)

$$K(t) = K_0 + \delta K - \alpha\,[T(t) - T(0)] - \gamma\,[g(t) - g(0)],$$

with:

$P(t)$ = pile power.

$C_i(t)$ = energy stored in 6th group of delayed neutrons emitted in whole system.

$\Delta_i(t)$ = energy stored in 6th group of delayed neutrons emitted actually in reactor.

$T(t)$ = mean reactor temperatures.

$g(t)$ = volume of gas present in reactor.

(The other quantities may be regarded as defined by the equations.)

The boundary conditions are obtained from the assumption that the pile is operating at equilibrium at $t = 0$, at which time a certain excess reactivity is suddenly introduced.

For the first four seconds, the equations may be greatly simplified. In particular, the difference equations (8-13) and (15) are eliminated, and one then has a system of first order equations, each linear, but with non-linear coupling between them.

These equations are at present being integrated numerically for certain values of the relevant parameters. To do this, we compute the first six terms of a Taylor series for each function, determine roughly the region of validity of the resulting expansions, and evaluate for some subsequent time within this region of validity. This procedure is then repeated, with the expansion now taken about this new point. The reason for this procedure is that the functions and, even more, their derivatives vary widely in the time interval of interest. Hence, a procedure is desirable which gives the integration step of maximum practical length, and which furnishes some criterion for lengthening or shortening the integration step.

STATUS: Still in progress. Results will be detailed elsewhere.

[redacted]