PROJECT WHIRLWIND

SUMMARY REPORT NO. 33
FIRST QUARTER 1953

Submitted to the

OFFICE OF NAVAL RESEARCH
Under Contract N5ori60
Project NR 048-097

DIGITAL COMPUTER LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge 39, Massachusetts

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FOREWORD

Project Whirlwind

Project Whirlwind at the Massachusetts Institute of Technology Digital Computer Laboratory is sponsored by the Office of Naval Research under Contract N5ori60. The objectives of the Project are the development of an electronic digital computer of large capacity and very high speed, and its application to problems in mathematics, science, engineering, simulation, and control.

The Whirlwind Computers

The Whirlwind computer is of the high-speed electronic digital type, in which quantities are represented as discrete numbers, and complex problems are solved by the repeated use of fundamental arithmetic and logical (i.e., control or selection) operations. Computations are executed by fractional-microsecond pulses in electronic circuits, of which the principal ones are (1) the flip-flop, a circuit containing two vacuum tubes so connected that one tube or the other is conducting, but not both; (2) the gate or coincidence circuit; (3) the electrostatic storage tube, which uses an electron beam for storing digits as positive or negative charges on a storage surface.

Whirlwind I (WWI) may be regarded as a prototype from which other computers will be evolved. It is being used both for a study of circuit techniques and for the study of digital computer applications and problems.

Whirlwind I uses numbers of 16 binary digits (equivalent to about 5 decimal digits). This length was selected to limit the machine to a practical size, but it permits the computation of many simulation problems. Calculations requiring greater number length are handled by the use of multiple-length numbers. Rapid-access electrostatic storage initially had a capacity of 4096 binary digits, sufficient for some actual problems and for preliminary investigations in most fields of interest. This capacity is being gradually increased toward the design figure of 32,768 digits. Present speed of the computer is 20,000 single-address operations per second, equivalent to about 6000 multiplications per second. This speed is higher than general scientific computation demands at the present state of the art, but is needed for control and simulation studies.

Reports

Quarterly reports are issued to maintain a supply of up-to-date information of the status of the Project. Detailed information on technical aspects of the Whirlwind program may be found in the R-, E-, and M-series reports and memorandums that are issued to cover the work as it progresses. Of these, the R-series are the most formal, the M-series the least. A list of the publications issued during the period covered by this Summary, together with instructions for obtaining copies of them, appears in the Appendix.

1. Quarterly Review and Abstract

During the first quarter of 1953, the computer was assigned to applications work for 672 hours; 88 percent of this time yielded useful results.

Of the 26 current problems before the Scientific and Engineering Calculations Group, all but 2 originated at MIT. Dealing with aspects of physics, chemistry, psychology, meteorology, mathematics, geophysics, and aeronautical, civil, chemical, electrical, and mechanical engineering, these 26 problems involve simultaneous algebraic equations, transcendental equations, ordinary and partial differential equations, integration, integro-differential equations, Monte Carlo techniques, and statistics.

The magnetic-drum system was installed and, with testing almost complete, is in part-time use for auxiliary storage. The magnetic-tape system has improved in operation as a result of weekly preventive maintenance and scheduled marginal checking.

To counteract gas release from stainless-steel ion-collector plates, storage tubes are now being made with plates of nickel fired at 90 C in pure hydrogen. Several tubes have also been constructed using a mica cross as a spacer between collector screen and storage surface; net worth of this modification has not yet been determined.

A comparison of 3 vacuum-tube types in 1952 and in this quarter shows a rise in failure rates attributable to intensive computer maintenance. In general, the most troublesome tube types are the 5670 (low plate current), the 6AK5 (change in characteristics), and the 12AY7 (active cathodes, resulting in high interface resistance and flicker noise). Vacuum-tube research has been concentrated on life tests of 3 tube types -- 6145, 5963, and 5687 -- and on measurements of the transient variation of cathode interface impedance with time.

Eight students are enrolled in the second-semester MIT subject 6.357, Digital Computer Applications Practice, a seminar and laboratory course. Seminars on Computing Machine Methods and evaluation of integrals on the product of two functions and an advanced seminar for WWI had 5 meetings each. A 2-week indoctrination program of 20 lectures was prepared for outside users of WWI and Scientific and Engineering Calculations Group personnel.

2. Mathematics, Coding, and Applications

2.1 INTRODUCTION

With the introduction of the new programming techniques and the procedures for assigning computer time to outside users, both of which were described in Summary Report 31, Sections 4.1 and 4.2, all problems being solved by, or in cooperation with, the Scientific and Engineering Computation (S&EC) Group were reassessed. Each programmer was required to submit a description of his problem (form DL-518) and a request for the amount of machine time needed (form DL-527). A group of staff members studied the applications, interviewed the applicants, and attempted to screen the problems. Those problems that were accepted for solution on WWI were assigned identifying numbers chronologically beginning at #100. Section 2.2 contains reports, arranged in numerical order, describing the work on those problems that have made use of computer time allotted to the S&EC Group during the last quarter.

Some of the problems described in this report have been discussed in previous summary reports under their earlier problem numbers, none of which exceeded #95. These old numbers are included in Table 2-1 to permit reference to previous reports.

Of the 26 problems actively being attacked, 24 originated within MIT, the others having been suggested by the Retina Foundation (114) and the Educational Testing Service (112).

Of the MIT-originated problems, the 7 marked with asterisks in Table 2-1 represent work being performed by members of the MIT Project on Machine Methods of Computation, another phase of the work under contract N5ori60, which is reported more extensively in a separate report ("Machine Methods of Computation and Numerical Analysis," Quarterly Progress Report No. 7, Project DIC 6915, MIT, 15 March 1953).

The variety of the problems being solved on the Whirlwind I computer is shown by the tabulation of problems arranged in Table 2-1 according to their fields of application.

The mathematical problems and procedures represented by the various current problems are tabulated separately in Table 2-2, since different problems in the same field frequently involve different mathematical methods, while problems in different fields sometimes are solved by identical methods.

A more flexible and more effective system for getting programs into WWI and for getting their solutions out was described in Summary Report 32, Section 4.1. This system is referred to as the Comprehensive System of Service Routines (CS).

The system provides for conversion, by WWI, from Flexowriter-coded perforated tapes to tapes in pure binary-coded form. Among the many provisions included in the CS, the following two are referred to frequently in the text. Consequently, brief descriptions of them are repeated here for the reader's convenience.

(1) Floating Address

A floating-address system enables a programmer to write his instructions so that they refer to the words of his program rather than to the location of those words in storage. The assignment of final storage locations is made by the computer as part of the conversion.

Field	Description	Number New	Number Old	Source
Aeronautical Engineering	Transient aerodynamic heating of a flat plate	115		MIT
Chemical Engineering	Fractional distillation of a volatile mixture	*130		MIT
Chemistry	Optical properties of thin metal films	101	21	MIT
Civil Engineering	Analysis of reinforced concrete walls	*113	50	MIT
Electrical Engineering	Operation of a three plant hydro-thermal electric generating system	104	54	MIT
Geology and Geophysics	Geophysical data analysis	106	63	MIT
	Interpretation of earth-surface resistivity measurements	*123		MIT
Instrumentation Lab	Direct interpretation of mathematical equations	108	57	MIT
	System of non-linear differential equations	109	57	MIT
	Fourier analysis and autocorrelation calculation	111	57	MIT
Mathematics	Educational testing studies: Lawley's method of factor analysis	112		Outside
	Spherical wave propagation	*119	42	MIT
	Analytical differentiation	125		MIT
	Deflection of thin elastic shells	*127		MIT
Mechanical Engineering	Turbine design (Aerothermopressor)	120	95	MIT
Meteorology	Radar cloud-analysis	103	93	MIT
Physics	Scattering of electrons from gases	*102	80	MIT
	Design of optical instruments	114	56	Outside
	Neutron-proton interaction	*124		MIT
	Non-linear meson theory	133		MIT
Psychology	Quantized group communication and learning	118	41	MIT
Servomechanisms Lab	Fourier transform and autocorrelation calculations	107	87	MIT
	Solution of the convolution integral equation	116	46	MIT
	Subroutines for the numerically controlled milling machine	132		
Miscellaneous	Comprehensive system of service routines	100	40	MIT
	Speech output: counting and assembly	117		MIT

Table 2-1. Current Problems Arranged According to Field of Application

Mathematical Problem	Procedure	Problem No.
1. Simultaneous algebraic equations		
Fifteen linear equations	Relaxation procedure	113
System of 16 non-linear equations	Iteration	120
System of 18 non-linear equations	Iteration	130
Matrix equation	Iteration involving Hotelling's method for solving the eigenvalue problem	112
2. Transcendental equation	Iteration	101
3. Ordinary differential equations		
Eight simultaneous non-linear differential equations	4th order Runge-Kutta	109
Solution of Schrodinger's equation in one dimension	Iterated Runge-Kutta	124
Two simultaneous non-linear second order	Series substitution	127
Second order non-linear	4th order Runge-Kutta	133
4. Partial differential equations		
Solution of the Mie equations	Evaluation of analytic solution involving spherical Bessel and Hankel functions	103
Calculus of variations; evaluation of the Euler expression	Three-point Lagrange derivative formulas	104
Parabolic (heat flow equation)	Four-point difference procedure	115
Non-linear hyperbolic	Difference equations written along the characteristics and solved simultaneously by iteration	119
(see also #113)		
5. Integration		
Calculation of Fourier transform and autocorrelation functions	Simpson's rule	107
Fourier analysis and autocorrelation	Trapezoidal integration	111
Inversion of the convolution integral	Iteration using Simpson's rule integration	116
Integral evaluation	Simpson's rule	123
6. Integro-differential equations		
Coupled second-order	Iterated Heun method	102
7. Monte Carlo technique	Random numbers generated by a recursive formula due to Wijngaarden	118
8. Statistics	Prediction by Linear operators	106

Table 2-2. Current Problems Arranged According to the Mathematics Involved

(2) Number Systems and Programmed Arithmetic

(m,n) numbers shall mean numbers which are of the form $z = x \cdot 2^y$ where x is an m-binary-digit number and y is an n-binary-digit number. For example, (24,6) signifies a two-register floating-point system dealing with numbers of 24 significant binary digits (roughly 7 decimal digits) with magnitudes between 2^{63} and 2^{-64}.

Arithmetic involving these (m,n) numbers is carried out by means of (m,n) interpretive subroutines. These subroutines enable the programmer to write coded programs using (m,n) numbers as easily as, or even more easily than, he might write programs in the single-length fixed-point (15,0) number system which is built into Whirlwind I.

2.2 PROBLEMS BEING SOLVED

Problem #100. Comprehensive System of Service Routines

The comprehensive system of service routines described in Summary Report 32 has been in several stages of operation during the past quarter.

The comprehensive system requires a large amount of auxiliary low-speed storage for two reasons:

(1) The programs involved are long and cannot fit simultaneously into high-speed storage.

(2) Conversion of words involving floating addresses must take place in at least two stages -- one to assign the floating addresses and one to finish conversion of instructions containing floating addresses which were unassigned when initially read from tape. The present comprehensive system procedure first stores in auxiliary storage a partially-converted program containing unassigned floating addresses, then reads this program back into the computer and completes the conversion.

The initial comprehensive system used punched paper tape as auxiliary storage to fulfill the requirements implied by 1 and 2. The system was found to operate successfully, but the computer time required for conversion was excessive, since a considerable amount of time was required for punching out the partially converted program, reading it back, and punching out the program in final binary form.

In the current version of the comprehensive system, two magnetic-tape units are used as auxiliary storage. The various component programs which make up the comprehensive system are recorded on magnetic tape semi-permanently at the beginning of each computation session and are subsequently available automatically and rapidly from magnetic tape. During each conversion, the partially-converted program is stored on the second magnetic-tape unit. The program is then punched in binary form on paper tape which can be read directly into the computer at any time.

Computer time required for conversion will eventually be further reduced by suitably recording the final binary tapes on a third magnetic-tape unit and punching tapes from this recording on the auxiliary magnetic-tape-to-Flexowriter device after all conversions have been completed.

Programming experience at the Digital Computer Laboratory has indicated that floating addresses provide an extremely convenient method for the writing and modification of programs. Naturally, the location of programming mistakes is quite difficult unless rather elaborate post-mortem and mistake-diagnosis routines are available which print out information converted from binary back into approximately the same form in which it went in. Such programs require a large amount of storage (both high-speed and low-speed) and a large amount of work, but present little difficulty of principle. The newly available drum will facilitate the preparation of these much-needed programs which are not easy to produce using magnetic tape alone.

At the present time, interim post-mortem programs are available to permit the printing of specified ranges of storage in specified forms (interpreted instructions, generalized decimal numbers, octal numbers, decimal integers, decimal fractions, and ordinary instructions). The actual numerical addresses assigned to the floating-address symbols are tabulated on the numeroscope during the conversion process, and this photographed tabulation is used as an interim aid in mistake location.

Future changes in the comprehensive system will be concerned with the integration of the magnetic drum into the system. Methods of automatically executing programs stored on the drum by means of interpretive subroutines contained in high-speed storage are under consideration. Emphasis will be on efficient use of the drum in facilitating the various phases of the comprehensive system itself and on making the drum available to casual programmers as if it were part of the internal memory. This latter feature will be accomplished by including drum registers in the floating-address system and providing in the comprehensive system automatic, efficient programmed block-transfers as needed between drum and electrostatic storage without any thought required by the user.

Problem #101. Optical Properties of Thin Metal Films

Problem #101 is part of a project sponsored by ONR through the MIT Department of Chemistry to investigate the use of digital computers in evaluating optical properties of thin metal films from measured reflection and transmission coefficients of visible and infrared radiation. During the third quarter of 1952, results were obtained with WWI for gold blacks (gold films with very low reflection, analogous to carbon blacks) with radiation in the 100μ-460μ region. These results have now been interpreted and were used to estimate the "optical" conductivity and relaxation time of electrons in the blacks, as well as the state of sintering of the blacks.

With the introduction of the comprehensive system of service routines, it was decided to convert the main program into this system. This main program computes the reflection and transmission coefficients as functions of these properties of the films: index of refraction, absorption coefficient, and thickness (as well as of the index of refraction of the transparent backing on which the metal film is deposited and of the wavelength of the incident radiation). The main program occurs as a block in all applications, and since its position in the WWI computer naturally varies with the application in which it is used, the floating-address feature of the comprehensive system(CS) is extremely useful.

The main program has been tested and found successful in its CS form. A good deal was learned about the most efficient way of running a large number of samples and wavelengths by leaving the main program in storage and reading parameters in successively for various samples and wavelengths. The CS conversion of a large set of groups of parameters on one tape at first presented some unforeseen problems, which were easily overcome once located (a minor change in the CS routine will prevent the recurrence of the difficulty). The new version of the main program has been used to check multivaluedness of the reflection and transmission functions; it is known that there are at least two sets of optical constants that yield the same reflection and transmission. One of these sets is physically meaningless. In order to evaluate the optical constants from reflection and transmission by successive approximations, it is necessary to make sure that the approximations converge toward the physically meaningful set of constants. This has been accomplished to our satisfaction.

This exploration having been completed, a method for automatic successive approximations by WWI has been programmed and will be tested on the machine during the second quarter of 1953. A new feature is incorporated into this program--namely, the computation of reflection for the case of radiation incident on the backing as well as on the metal film itself. This is important for the examination of the two surfaces of the metal film, one being exposed to air, the other in contact with the backing. The program has been devised in such a way as to allow the machine to determine automatically which case is under consideration and to label the results accordingly.

Problem #102. Scattering of Electrons from Gases

The program for the solution of the original Morse-Allis equations[1, 2] has been rewritten by J. L. Uretsky of the MIT Physics Department and is now working. This program is to be the foundation for the more complicated approximations already described.[2]

The first attempt at a higher-accuracy solution (designated phase II of the project in reference 2) will be an effort to evaluate an assumption that the target atom is adiabatically perturbed by the incident electron. To this end we assume that the ground state of the target atom (as perturbed) is given by

$$\phi = \mu + c(r_i)\psi \qquad (1)$$

where $c(r_i)$ describes the perturbing effect of the incident electron, μ is the ground state atomic wave function, and ψ is the wave function of an excited state selected on the basis of physical reasoning. For helium, this excited state has been selected as the (1S, 2P)1P state. $c(r_i)$ is found from a first order perturbation calculation of the equation

$$\left[H_o + \frac{2}{r_i}\right]\phi = E_o\phi$$

where $H_o\,\mu = E_o\mu$, and E_o is the ground state energy of the atom.

Following the method of Morse and Allis[1], we can derive the scattering equations using ϕ as the atomic wave function instead of μ. We may denote the Morse-Allis equations by

$$\left[L_\lambda + V\right]R_\lambda = ER_\lambda \qquad (2)$$

where L_λ is a second order linear operator, V is the unperturbed potential (of the form $f(r)e^{-ar}$), and Ξ is an integral ("exchange") operator. Then the new equation for R' is of the form

$$\left[L_\lambda + V + V'\right]R'_\lambda = (E + E')\,R'_\lambda. \qquad (3)$$

Because of the inherent difficulty of programming the solution of such a complicated equation, it would be desirable to find an order-of-magnitude solution for this equation. We notice that

$$V'(r) \xrightarrow[r\to\infty]{} \frac{-a}{r^4}$$

which is just the expression for the potential of a polarized dipole. For small r, say $r < 1/a$, V' is a small correction to V. Noting that

(1) the Exchange terms become small for $r > 1/a$, and

(2) E' is always a small correction to E,

we can achieve our order-of-magnitude calculation of R as follows.

We assume that the atom is a sphere of radius

$$\rho = \frac{1}{a}$$

For $r < \rho$, R_λ is a solution of equation 2.
For $r > \rho$, R_λ is a solution of the equation

$$\left[L_\lambda - \frac{a}{r^4}\right]R_\lambda \equiv \left[\frac{d^2}{dr^2} - \frac{\lambda(\lambda+1)}{r^2} - \frac{a}{r^4} + k^2\right]R_\lambda = 0 \qquad (4)$$

The requirement that the logarithmic derivative of R_λ be continuous sets the boundary condition (at $r = \rho$) for equation 4. The logarithmic derivative of R_λ at any value of r may readily be found from an existing program.

Since a numerical solution of equation 4 may be hand-calculated without too much labor, we may use such a solution as an indication of whether or not to proceed with an exact Whirlwind solution of equation 3.

Problem #103. Transmission Cross Section of Absorbing Spheres; Spherical Bessel and Hankel Functions

The computation of the transmission cross-section of absorbing spheres was initiated by a contract between the Cambridge Research Center of the USAF and the MIT Meteorology Department for an instrument to measure drop size distribution in clouds in the atmosphere.

The transmission cross-section is expressed by

$$Q_T = \frac{\Sigma\ (2n+1)\ \left[\,|a_n^r + b_n^r|\,\right]}{x^2}$$

where x is the dimensionless parameter of radius divided by wavelength, with a range of $+1 \leq x \leq +17.50$ in intervals of +0.75. a_n^r and b_n^r are the primary relations involving spherical Bessel and spherical Hankel functions. The solution of the Mie equations for the transmission cross-section is summarized in Stratton's Electromagnetic Theory.

The basic numerical procedure used is the computation of values of the spherical Bessel functions $j_n(x)$ and $j_{-n}(x)$ repeated until the absolute value of the product $j_n(x)j_{-n}(x)$ is approximately equal to zero. The number of repetitions is somewhat less than 2x. Computations of the values of a_n^r and b_n^r (real parts only) are repeated the same number of times as $j_n(x)$.

Complete results have been obtained for these conditions. The data computed on Whirlwind I will be included in an article being prepared for publication in one of the professional journals, probably the Journal of the Optical Society of America. Present plans call for completion of the manuscript by summer, and the relevant portions will be made available to the Digital Computer Laboratory as a final report.

Problem #104. Hydro-Thermal Power System; Calculus of Variations

The programs for improving the mode of operation of a three-plant hydro-thermal electric generating system have been rewritten by Dr. R. J. Cypser of the MIT Electrical Engineering Department using the new magnetic-tape equipment and the floating-address system.

The new magnetic-tape instructions and the delayed print-out via magnetic tape have resulted in a reduction of computer time needed for each iteration by about a factor of three, have facilitated programming, and have reduced the amount of storage needed for control of the magnetic-tape units. The floating-address system has also greatly simplified the programming.

In order to save the time of rewinding a tape holding floating-point (24, 6) results, a program has been completed which will read backwards from magnetic-tape unit #0 (containing the binary results), unscramble the digits, convert to Flexo-characters, and record these on tape unit #3 using the delayed-print subroutine.

To aid in troubleshooting these programs, which use blocks of (24, 6) numbers, a program has been assembled using the delayed-print subroutine to print blocks of (24, 6) numbers via magnetic tape.

Four iterations have been obtained using the new programs. Penalty functions included to prevent system operation beyond operating limitations have proven to be troublesome by retarding convergence. Methods for alleviating this situation are being considered.

Problem #106. MIT Seismic Project

During the past quarter the Geophysical Analysis Group at MIT has directed its activities to the development of a sequence of programs which can be used to advance and verify the theoretical research activities of the Group. As a result, existing programs were rewritten with the view of making them more efficient and more general. In all, seven programs were written to carry out the predictions described in Summary Report 32. The most recent program permits the analysis of all permutations of four seismogram traces at one time. The program utilizes drum storage and records its results either directly on the numeroscope or on magnetic tape for later printing. In addition to the prediction programs, several other programs were written including variance programs, averaging programs, and statistical frequency programs.

The purpose of writing this sequence of programs is the determination of the optimum linear operator with respect to the estimation of the underground structure of the earth by means of the arrivals of reflected energy. The variables which come under consideration may be subdivided into geologic variables, instrumentational variables, and operational variables. The geologic variables include effects due to underground structure and physical constants of the earth. Instrumentational variables include effects due to frequency range, response of the seismic instruments used, and the geophone layout Operational variables include such mathematical variables as the spacing between data points, the prediction and the lag distances, the number and ordering of the seismogram traces, and the number of terms used in the linear operator considered. These variables influence the accuracy with which reflections can be determined. It is thus necessary to investigate the effects of all these variables and to optimize those under our control. The programs which have been written make it possible to hold all variables constant except any chosen one and to investigate the effects of this variable on the linear operator. Thus it is possible to develop numerical criteria for goodness of reflection discrimination and also to develop the most efficient succession of experimentation for use of these programs.

Problem #107. (a) Autocorrelation and (b) Fourier Transform, Evaluate Integrals

This problem is concerned with the calculation of the frequency spectrum of a given function by calculating first the autocorrelation function of the given function and then the Fourier transform of this autocorrelation function. During the present quarter, the programs for calculating the Fourier transform and the autocorrelation function, both using Simpson's rule in the evaluation of the integral, were corrected and checked. Special mistake-diagnosis routines were written for both programs in order to locate programming errors which could not be found by any other means.

The following three programs are now available: (1) autocorrelation with rectangle integration to be used when more than 600 data are available; (2) autocorrelation with Simpson's rule integration. All of these programs were revised to make use of delayed output via magnetic tape. This revision reduced the operating time by approximately 60 percent. The programs have been written in a general form and are beginning to be used by other projects. A report will be issued shortly by the MIT Servomechanisms Laboratory describing the programs in detail and listing all potential uses for the programs with complete instructions for modifications and preparation of data.

Problem #108. An Interpretive Program

A preliminary version of a conversion program capable of accepting and solving mathematical equations directly (from a paper tape produced by typing the equations explicitly) has been written and tested by Dr. J. H. Laning, Jr., of the MIT Instrumentation Laboratory. Although the present 1024-word storage capacity severely limits the complexity of problems that can be handled, the program can evaluate algebraic and/or numerical quantities involving parentheses, positive or negative numerical exponents, and ordinary addition, subtraction, multiplication, and division. A program is prepared as a sequence of typed equations in each of which the left-hand member is a single letter and the right-hand member is a function of previously defined algebraic or numerical quantities to which the variable is equated. Equations may at present be numbered from 1 to 10 and may be interspersed with print instructions or transfer-of-control instructions which select the next equations to be solved.

To overcome storage limitations and also to provide a wider variety of operations, the program is currently being rewritten to use magnetic-drum storage. The second bank of electrostatic storage will, of course, improve matters when it becomes available. In the final version, it is expected that the program will automatically evaluate various standard transcendental functions, and will provide a simple, direct manner of programming a fairly general class of problems

Problem #109. Fighter Gunsight Calibration, 8^{th} Order Differential Equation

The system of interest occurs as a set of eight simultaneous non-linear differential equations. The solution is being carried out by M. H. Hellman of the MIT Instrumentation Laboratory. Most of the time spent on this problem during the last quarterly period was devoted to locating errors in the solution obtained. All of the errors have been found, and nearly all of them were in the physical data rather than in the program. It is possible to make such a definite statement about the absence of errors because of the existence of solutions to this phase of the problem by the Card Programmed Calculator and the Rockefeller Differential Analyzer. In this particular case, solutions of roughly the same accuracy took 30 to 40 times longer to obtain on either of the other machines than on Whirlwind I.

The operations are carried out in floating-point (24, 6) arithmetic, and a 4^{th} order Runge-Kutta method of solution is used. The Runge-Kutta part of the program is written in quite general form and will be converted to a general subroutine for the solution of other ordinary differential equations.

It is tentatively planned to solve the same problem using (39, 6) instead of (24, 6) arithmetic for purposes of error-analysis. Otherwise, plans for the future are somewhat indefinite but include two possibilities: (1) the solution from time to time of closely related problems of practical interest and (2) an investigation of the possibilities of programming for Whirlwind I a larger portion of the overall problem of which the present problem is only a part.

Problem #111. Fourier Analysis - Autocorrelation Problem

This problem is being carried out by Dr. E. J. Frey of the MIT Instrumentation Laboratory. A function is given in the form of a table of its values at uniformly spaced values of its argument. The purpose of this problem is (1) to obtain the first and second Fourier coefficients of the function; (2) to subtract the first and second harmonics so obtained from the function; (3) to graph the reduced function; and (4) to autocorrelate the reduced function (i.e., find the value of the autocorrelation function for a number of values of the argument).

Each value of the function appears in the table as a four-place decimal fraction. Most of the computation involves the summing of products, so it is convenient on Whirlwind I to use three registers to represent a number. The decimal point is considered fixed, and the first register represents the integral part of the number and the other two registers the fractional part. By obtaining 30-digit products with the mh instruction and summing these, combining any integral overflow into the first register, errors due to round-off are almost entirely eliminated.

So far, the first part and five-sixths of parts 2 and 3 of the problem have been completed. It is expected that the remainder of the problem will be done within the next month.

Problem #112. Lawley's Method of Factor Analysis; Characteristic Vectors (Modified)

This problem has arisen from an attempt to apply Lawley's method of factor analysis to a 33 x 33 correlation matrix, R, obtained in "Studies of Speed Factors in Tests and Criteria at Annapolis," a study being carried out by the Educational Testing Service of Princeton, N. J., under contract with the Office of Naval Research. The Whirlwind computer is to solve the matrix equation

$$JF = FS^{-2}(R - S^2).$$

Here J is an unknown diagonal matrix, S^2 is a diagonal matrix whose elements are given by

$$S_i^2 = 1 - \sum_{r=1}^{m} f_{ri}^2,$$

where f_{ri} is an element of the m-by-33 matrix F, and m is the rank of R. This equation is to be solved for values of m from 4 to 9. The elements of J are the eigenvalues of the matrix $S^{-2}(R - S^2)$, and the rows of F are the corresponding eigenvectors or latent vectors.

The method of solution which has been programmed is to assume the initial values of f_{ri} and then to calculate the matrix $S^{-2}(R - S^2)$. An Hotelling solution is used to obtain the latent vectors of this matrix, yielding a new F matrix which is used to start a new cycle of calculations.

All errors in the program have presumably been found and eliminated. Two successive iterations have been run on the original first approximations, and the results found to agree (within rounding errors attributable to the double conversion involved) with the results of two separate iterations when the results of the first iteration were punched into tape and then used in place of the original first approximation.

Attempts to use a loop of magnetic tape -- so as to avoid computer idleness for several seconds during each iteration while the tape is returned to its starting point -- were dropped because of mechanical difficulties involved.

It was discovered that the present program will not yield an adequate number of significant digits in the results when there are 9 columns in the matrix of results (m = 9). If the approximate magnitude of the results to be obtained were known in advance, it would be easy to revise the program to obtain the desired accuracy. Lacking such advance knowledge, and since we do not have enough storage available to revise the program so as to obtain the desired accuracy without excessive waste of computer time, we are proceeding with the case where m = 4. The present program provides adequate accuracy for this case; and the results obtained when m = 4 should provide enough information about the magnitudes to be expected so that the case when m = 5 can be run with improved and more-than-adequate accuracy. Then the results for m = 6, 7, 8, and 9 will be obtained in succession.

Problem #113. Shear Wall Analogy, Simultaneous Linear Equations

A program has been used that solves the indeterminate lattice analogy structure for a system of statically consistent bar forces that also satisfy the strain requirements of the framework (see Summary Report 31). These bar forces are only an intermediate step in the analysis of the reinforced concrete wall. From these values, shear and normal stresses are computed at all sections of the framework. At the point of maximum stress in the framework, cracking is assumed to occur in the plate prototype. Analytically, cracking is interpreted in the framework as a reduction of the area of the bars in the overstressed region.

Previously, hand calculations were made after the Whirlwind program had solved the framework for a set of statically consistent forces. From these calculations only one point on the load-deflection curve could be obtained. After this calculation, a new set of bar area constants was prepared, and the program was performed again, using reduced-area values for the overstressed bars. The new results were used to calculate another point on the load-deflection curve.

A revised program is being prepared that will calculate a complete load-deflection curve in one Whirlwind I performance. Hand calculations are being eliminated from intermediate parts of the solution, and the analysis of the shear walls will be handled more efficiently.

This problem is being carried on by S. Sydney for the Structure Dynamics Division of the MIT Department of Civil and Sanitary Engineering.

Problem #114. Design of Optical Instruments

A brief description of this problem appears in Summary Report 32. In the present report it seems appropriate to place this particular problem, the design of ophthalmic instruments, in its proper relation to other optical design problems.

Computations of optical systems using the standard seven aberration theory do not always yield optimal instruments, even when fifth order terms are included. In the not uncommon cases involving non-spherical surfaces, prisms, etc., the standard theories are not applicable. Furthermore, the problem of design cost is important. Unless a relatively standardized method of computation is adopted, the time- and money-saving advantages of even a very high-speed digital computer are lost.

Therefore, the method of ray-tracing is a good choice for use on a digital computer, and this method is now being used. A ray-tracing program can be generalized to cover almost any case. The data of a particular system, and the initial coordinates and tangents of any number of rays, either skew or meridional, are then handled by the generalized program as a series of parameters.

In the ray-tracing method, aberration terms are considered as the differences of two or more rays. The calculations must be exact enough to determine high-order aberrations. The calculations made so far on Whirlwind indicate that this requirement is being met.

Study of the results of small variations of the first approximation to the desired optical system are quite helpful in indicating the direction and magnitude of major modifications to the initial system. Studies are being made to determine the optimum intervals of variation of different parameters such as lens radius, thickness, and separation. Very small variations may be considered as differentials; in this case the differential formulae of Cruikshank and McAuley may prove useful.

So far, evaluation of the results obtained from ray-tracing (about 300 rays up to this time) has been done under ONR sponsorship by Dr. F. Wachendorf of the Retina Foundation, at the Massachusetts Eye and Ear Infirmary, who first proposed the problem for the Whirlwind I computer. As experience is gained, it is planned to have the machine carry out some of the more important evaluation.

Problem #115. Transient Aerodynamic Heating of a Flat Plate; Linear Partial Differential Equation

In the rapid acceleration of an air vehicle to very high speed, the friction of the air at the surface generates a large amount of heat which flows into the structure of the vehicle and temporarily causes large temperature differences to occur. Large thermal stresses may be associated with these temperature differences and may constitute a serious structural design problem. Knowledge of the transient temperature distribution is therefore important.

In the present work, carried out as part of a doctoral thesis by G. Isakson of the Aero-Elastic and Structures Lab at MIT, two simple cases were considered. The first was that of convective heat transfer into one side of a flat plate which is insulated on its other side. This was intended to simulate the covering of an aircraft. The plate was assumed to be initially at uniform temperature, and the environment temperature was assumed to be initially at the temperature of the plate, to increase linearly with time during a finite interval, and then to remain constant. The period of linear increase, called the gradient time, was intended to represent the period of acceleration of the aircraft. Solutions were obtained by a finite difference numerical method, the second derivative of the temperature with respect to the space coordinate being expressed in terms of three ordinates. The computation was programmed to proceed until the temperature differential across the surfaces of the plate had reached a maximum and then to stop and print out the temperature distribution. Results were obtained for forty cases covering a wide range of values of a non-dimensional heating parameter and of the gradient time expressed in non-dimensional form. These results indicated that a rather large gradient time is required to effect a substantial reduction in the maximum temperature differential across the surfaces of the plate, particularly at very low or very high values of the heating parameter.

The second case to be considered was that of a wide-flanged I-beam with the outer faces of the flanges subjected to convective heat transfer and all other surfaces insulated. This case was intended to simulate the structure of a wing. The same initial conditions and environment temperature variation were assumed as in the case of the plate, and solutions were obtained by a similar finite difference numerical method. The computation was programmed to proceed until the temperature differential between the middle of the web and the edge of the flange reached a maximum and then to stop and print out the temperature distribution. Results were obtained for 80 cases covering a wide range of values of a non-dimensional heating parameter and of the non-dimensional gradient time. Four values were chosen for an additional parameter representing the ratio of the flange thickness to the web thickness. This parameter was found to have a substantial effect on the maximum temperature differential in the beam.

Problem #116. Torpedo Impulse Response; Convolution

This problem being carried out by Robert Kramer of the MIT Servomechanisms Laboratory, seeks to solve the convolution integral equation for the system impulse response when given the input to and the output from a physical system. During this quarterly period the major programming effort was concentrated upon streamlining the program running. Heretofore, it was necessary to handle separately four tapes to run the program -- the direct basic conversion program, the program tape, the system impulse response tape, and the input function tape. Under present operation, the program tape is assembled with the data tapes, and all the operator need do is place the one tape in the reader and press the read-in button. In addition to the streamlining of the tape handling, the output has been converted to the delayed printer including automatic runback. This streamlined program has been fully operative since 12 March.

Also during this period, some significant advances toward the termination of the system impulse response were made. First of all, a high-speed analog computer was used to determine an approximate system function which fitted the input-output pair within the accuracy of the analog computer. This function, when convolved on Whirlwind, resulted in a value of the area under the absolute value of the difference between measured and computed output which was 8 percent of the area under the absolute value of the measured output. The value of this ratio resulting from the use of the hydrodynamic equations and coefficients was 27 percent.

In addition, an estimate of the effect of the small bandwidth of the output measuring devices indicated that the essence of the effect was a simple delay of one time unit.

For the future, the high-speed analog computer will be tried as a means of estimating corrections to the impulse response. Also being considered for use are the Fourier transform program described under Problem #107 to determine both the system impulse response from input-output data and the impulse response correction for input-error pairs.

Problem #117. Speech Output; Counting and Assembly

This problem was undertaken as a spare-time hobby by Rollin P. Mayer of the Digital Computer Laboratory staff. Because of the interesting ideas involved, we have included the following report by Mr. Mayer.

A real-time computer must often give information to people. This is now done almost exclusively through visual channels. The supplemental use of speech output would use human senses more efficiently than sight alone, would allow the human to be concentrating on a particular visual channel and still receive other important messages, would allow the use of existing inter-communication and telephone circuits for communicating results to distant people, and would not require the human to learn a code of bell and buzzer signals.

Under many conditions it will be practical to design, build, adjust, and maintain audio generating equipment for allowing a simple programmed instruction to call for any of a number of speech sounds, full words, or complete sentences. For other conditions such an expense will not be justified. If enough memory is available, if the computer is fast enough, and if the number of speech messages is small enough to prevent a noticeable reduction in computation speed, then an ordinary audio amplifier is sufficient if a program is available for causing a given flip-flop of the computer to contain a time-sequence of binary states which, when presented to the ear, sounds like speech. Such a program might be particularly desirable for use by individuals who have only periodic access to a high-speed general-purpose computer and who do not feel justified in requesting the installation of special audio equipment to suit their individual needs.

Such programs have been tested, and the resultant speech is barely intelligible. Some new techniques for improving the quality have been envisioned, but have not yet been programmed or tested. Further investigations have temporarily been suspended until more time becomes available.

Problem #118. Quantized Group Communication and Learning; Non-Markovian Stochastic Process

Communication experiments have been performed on groups of five people in which some of the channels of communication have been closed. Each person is given some initial information, and the group task is to distribute this information throughout the group subject to the restrictions on the channels they may use. In addition, in one of the experiments the subjects were constrained to send messages simultaneously; such an event is termed an "act." At each act each person sends exactly one message. The subjects were motivated to complete each trial in the minimum number of possible acts. As the group repeats this process with new information on each trial, they become more skilled in their performance, the degree depending on the particular imposed communication network.

The Group Networks Laboratory at MIT has developed a mathematical model designed to account for the group learning in terms of simple assumptions about the learning of individuals. It has not been possible with these assumptions to obtain an analytic expression for the distributions of acts to complete the task as a function of trials. Without these distributions, it is impossible to determine the adequacy of the model to account for the experimental data, so they are to be determined by simulating the communication process on WWI using a Monte Carlo method.

The first act of the first trial is chosen completely at random within the limits of the imposed network. Thereafter, the probability that a message is sent through a given open channel is determined as a function of the previous acts in the trial, the trial number, and whether the previous trial was complete in a minimum number of acts or not. The specific value of the act is determined using random numbers generated in the computer (see below). When a trial is completed, the number of acts required is recorded. After 25 trials (one run) the process is repeated. At least 500 runs will be made for each network, and several networks of experimental interest will be studied.

The method for generating random numbers, due to A. van Wijngaarden (Amsterdam), employs the recursive relation

$$u_n = u_{n-1} + u_{n-k}$$

modulo a given number m. This relation has been programmed for $m = 2^{19} - 1$ and k=7, and a test of 123,000 of the 19 digit binary numbers so generated indicated that they are uniformly distributed between 0 and 1.

Problem #119. Spherical Wave Propagation

A preliminary investigation of methods for integrating numerically the hyperbolic partial differential equations governing the propagation of spherical waves made last year is described briefly as problem #42 in Summary Report 29.

The study of the problem has been continued this year by P. Fox and A. Ralston under the supervision of Professor C. C. Lin of the MIT Mathematics Department. They have used double-precision arithmetic in the hope of being able to study phenomena where the pressure and velocity variations become much larger than those so far treated. In particular, the region near the center of the sphere where the equations become singular has been investigated analytically, and a method for finding the solution in this neighborhood has been worked out, tested, and set up in subroutine form.

The problem, which treats waves propagating outwords from the center of the sphere, involves an ever-increasing number of points in the time-distance plane, and so provision must be made for intermediate storage of results on magnetic tape. Use is made for this purpose of available magnetic-tape subroutines for block reading and recording.

In general the computations involved in the problem have been written and pretested as subroutines, and currently a control program coordinating all the pieces of the computation is under test. When it becomes operative, a variety of initial conditions for the problem may be tested easily and results obtained for several cases. Of particular interest also is the possible development of a spherical shock wave and the behavior of the solution in the neighborhood of the shock. The program so far written for the problem should be satisfactory at least to within small distances of the development of the shock wave.

Problem #120. Thermodynamic and Dynamic Effects of Water Injection into Gas Streams of High Temperature and High Velocity

This problem is connected with the development of a potential gas-turbine component called the "aerothermopressor." The aerothermopressor is a device in which the stagnation pressure of a hot, high-velocity gas stream is increased by the evaporation of liquid water injected into the gas stream at the aerothermopressor inlet. Further description of this device may be found in Summary Report 32, Fourth Quarter, 1952.

The analytical aspect of this development program is concerned with a mathematical analysis of a one-dimensional aerothermopressor defined by nine parameters: (1) entrance Mach number, (2) entrance stagnation pressure, (3) entrance stagnation temperature, (4) water-injection rate, (5) initial droplet diameter, (6) initial droplet temperature, (7) initial droplet velocity, (8) wall friction, and (9) duct cross-sectional area. For each physically tenable set of these parameters, the state at each cross-section of the one-dimensional aerothermopressor is fully defined and may be calculated from a simultaneous solution of the following equations or resulting equations:

1) Energy equation
2) Momentum equation
3) Continuity equation
4) Newton's Second Law of Motion
5) Definition of droplet heat transfer coefficient
6) Definition of droplet mass transfer coefficient
7) Cross-sectional area variation

These are the seven fundamental constraints necessary to establish the state at each cross-section, though it should be understood that an actual solution involves manifold complications such as variations in droplet Reynolds number, Schmidt number, viscosity and thermal conductivity of the gas phase, introduction of the Gibbs relations for mixtures, etc.

The analytical computations being carried out on Whirlwind I are divided into two phases, discussed separately below:

Phase I: PROCESS ANALYSIS - If it is assumed that the droplet temperature is constant and that the ratio of final liquid velocity to gas velocity is unity, the continuity, momentum, and energy equations may be solved algebraically for the final state if two parameters representing the wall shear and normal pressure forces are introduced. The process is then defined by seven parameters,

1) Initial Mach No.
2) Initial Stagnation Temperature
3) Injection Rate
4) Initial Droplet Velocity

} Initial Parameters

5) Fraction of liquid evaporated
6) Area variation parameter
7) Wall friction parameter

} Independent Variables

A (15, 0) program treating this analysis has been successfully run. This program occupied nearly full capacity of electrostatic storage and contained a sub-program for finding non-integer roots of fractions for arbitrary values of both base and exponent. The computer has treated 504 combinations of the seven parameters listed above, each combination requiring about 68 seconds computation time, the root processes requiring about 60% of this time.

Though in digital computer parlance 9-1/2 hours approaches the infinite, it is estimated that the time required to produce this information by a desk calculator would easily be greater by a factor of about 100.

Phase II: DROPLET ANALYSIS - This treatment of the one-dimensional aerothermopressor involves a step-by-step integration of the differential equations resulting from the seven constraints discussed above together with the associated equations prescribing the variations of drag coefficient, heat and mass transfer Nusselt numbers, gas phase viscosity, thermal conductivity, etc.

A first draft of a (15, 0) program for executing this stepwise integration with the fraction of liquid evaporated as the running variable has been completed and includes means for detecting and treating a saddle-point type of singularity which may arise for certain combinations of the nine initial parameters. This program occupies some 400 registers in excess of electrostatic storage, necessitating use of the auxiliary magnetic drum in the final draft of the program.

The aerothermopressor development program is being carried out at MIT under sponsorship of the Office of Naval Research and under the guidance of Professor Ascher H. Shapiro. The analytical work discussed above is being done by Bruce D. Gavril as part of a Sc. D. thesis for the MIT Department of Mechnical Engineering.

Problem #123. Earth Resistivity Interpretation: Integration of Empirical Functions

A potentially powerful technique for the study of structure and composition of the earth beneath its surface is the measurement of electrical potential distribution about a current-electrode on the surface. A unique quantitative interpretation of this information cannot be attempted, however, until some simplifying assumption is made as to the manner of conductivity variation The simplest non-trivial case would be an isotropic medium whose conductivity varied only with depth, in a continuous or discontinuous manner. Assuming this condition, we must find some function of the potential distribution which is particularly sensitive to the variations we wish to study, and analyze this function.

A function that has these desired properties is designated as $k(\lambda)$, called Slichter's kernel, and is given by

$$k(\lambda) = \lambda \int_0^\infty r\phi(r) J_0(\lambda r) dr$$

where r is the radial distance from the current source, and $\phi(r)$ is the measured potential.

This problem is, initially, to write a program which for a given value of λ generates the proper Bessel function, selects the proper value of $r\phi(r)$ from a table (or generates it from a previously determined polynomial approximation), and integrates, using, say, Simpson's Rule; and then goes on to another value of λ.

The second phase of the problem will be to find and program an analytical scheme for $k(\lambda)$. Much time and effort has been spent in the last twenty years on this problem, with little real success. A new technique, using a linear programming approach is being considered, and the basic program for this technique is nearly complete.

This work has been undertaken by Mr. Keeva Vozoff of the MIT Geophysics Department.

Problem #124. Deuteron Binding Energy and Wave Functions

The initial phase of the present problem was described in Summary Reports 29 and 30. A potential is assumed for the neutron-proton interaction of the form

$$V(x) = -A \frac{e^{-x} - e^{-bx}}{x}$$

where A and b(b>1) are parameters which together determine the shape and depth of the potential, and x is the ratio of the inter-particle separation to a range parameter which is to be determined.

The computational part of the problem is being carried out on the Whirlwind computer by D. Combelic of the MIT Physics Department. The differential equation to be solved is

$$\frac{d^2u}{dx^2} = \left(F - A\frac{e^{-x} - e^{-bx}}{x}\right) u,$$

where u is the probability particle density, and F, the eigenvalue satisfying the boundary conditions that u vanish at $x = 0$ and $x = \infty$, is proportional to the binding energy of the deuteron.

Any combination of A and b which leads to a bound-state solution is studied further. The additional calculations involve then setting $F = 0$ and calculating two further quantities--the effective range and the Fermi scattering length. When these calculations have been completed for all the "good" combinations of A and b, an analysis of the results in light of the known experimental quantities will determine those values of A and b which best describe the actual interaction potential.

Problem #125. Analytical Differentiation

This problem consists of the investigation and illustration of the manipulation by WWI of functional relations in their analytical form. This is a departure from the usual method of representing a function by a table of data. The common functions can be expressed in a code to the computer program much in the same way a function is expressed in algebraic notation. This approach is related to the future use of compilation routines for the processing of standard types of programming problems. Thus it would be possible, using compilation methods, to prepare coded information describing in analytical form the problem to be solved and the functions involved, from which the actual program to be run would be automatically formed by the computer from a library of subroutines.

To illustrate one method of coding such information, a program has been written to perform analytical differentiation. The program is designed to read from tape an analytic function in a coded form and, following the rules of differential calculus, derive the analytical forms of the derivatives. For the purpose of the problem, we restrict ourselves to all functions of one variable which can be formed of finite combinations of rational, trigonometric, logarithmic, and exponential operations.

The program was tested, and it performed correctly for rational functions. This testing used 2 hours and 40 minutes of the 8 hours of computer time allotted to the problem. The program was then enlarged and rewritten to include the direct trigonometric functions and the exponential and logarithmic forms. At this point, the length of the program required use of the auxiliary magnetic drum. This enlarged program is to be tested with a variety of functions. It is expected that the projected program will be completed and tested within the allotted time. This problem is to be used by John Nolan in partial fulfillment of the requirements for the S. M. degree in Mathematics at MIT.

Problem #127. Finite Bending of Circular Ring Plate due to Edge Moments; Two Coupled Second Order Non-Linear Differential Equations

This problem concerns the solution of two simultaneous non-linear second order differential equations and arises from the study of the finite deflection of thin elastic shells. It has been formulated by Dr. Eric Reissner and programmed by N. J. Hicks, both of the MIT Mathematics Department.

The equations

$$f''(x) + \frac{1}{x} f'(x) - \frac{1}{x^2} f(x) = \mu \frac{g(x)f(x)}{x}$$

$$g''(x) + \frac{1}{x} g'(x) - \frac{1}{x^2} g(x) = -\frac{\mu}{2} \frac{f^2(x)}{x}$$

where μ is a given constant parameter, are to be solved subject to the boundary conditions

$$x = 1, \quad f'(1) + \nu f(1) = 1$$
$$g(1) = 0$$
$$x = \frac{b}{a} = \lambda < 1, \quad f'(\lambda) + \frac{\nu}{\lambda} f(\lambda) = 0$$
$$g(\lambda) = 0$$

It has been found that a Taylor Series solution of the form

$$f(x) = \sum_{n=0}^{\infty} a_n (x-1)^n$$
$$g(x) = \sum_{n=0}^{\infty} b_n (x-1)^n$$

is feasible provided the boundary conditions at $x = \lambda$ are replaced by additional initial value conditions at $x = 1$. To obtain these, a scheme of non-linear interpolation is used where f(x) and g(x) are expanded in powers of the parameter μ, i. e.

$$f(x) = \sum_{n=0}^{\infty} f_n(x) \mu^n$$

and similarly for g(x). These series are introduced into the original equations, and by equating coefficients of μ, values of $f_i(x)$ $(i = 0, 1, 2, 3, 4)$ and $g_j(x)$ $(j = 0, 1, 2, 3)$ are obtained. Using these values, an estimate for f(1) and g'(1) is obtained which then allows us to compute the coefficients a_n and b_n by means of a recurrence relation. Computation was carried through for $\mu = 1$, $\lambda = 0.1$ on a hand computer.

It is desired to solve the problem using Whirlwind I. To do this we break the problem into two parts: the interpolation and then the evaluation of the coefficients a_n and b_n. The interpolation has been programmed, and test runs have been completed. The program will now be used to obtain the additional initial values for various values of μ and λ. The final program will then be performed.

Problem #130. Six-Component Distillation, Variable Enthalpy and Equilibrium Data Simultaneous Non-Linear Equations

This problem, being carried out by J. O'Donnell of the MIT Chemical Engineering Department, is to find the theoretical number of plates or stages necessary to accomplish a specified separation of two key components by distillation of a volatile mixture. The general principle of solution of steady-state distillation problems is the following fact. When the concentration of the liquid on a given plate of a distillation tower is known, the concentration on an adjacent plate may be found by the application of material balances, enthalpy balances, and equilibrium relationships. How complicated the problem is depends on the number of components, the type of separation desired, and the form of the equilibrium and enthalpy data. In the past (S&EC Problem #83), programs have been written to demonstrate the solution of 3- and 4-component problems, assuming constant molal-overflow and constant relative volatility. These are forms of the data that make iteration unnecessary in going from plate to plate because only one of the simultaneous equations is non-linear.

In this problem the enthalpies of the liquid and vapor are taken as functions of temperature, pressure, and molecular weight (following the method of Scheibel and Jenny). The equilibrium constant for each component, K, is taken as a function of temperature and pressure (MIT data). Going from plate to plate thus necessitates the solution of simultaneous equations of which two for each component are non-linear. This must be done by iteration.

In this solution the data are expressed in tabular form. A set of concentrations for the bottom and top products are chosen which satisfy a material balance on the tower. Using the concentration of the bottom product of the tower, plates will be calculated toward the top until the concentrations pass the concentration of the feed. Then, using the concentration of the top product, this will be repeated, calculating from the top down to the feed point. At that point the sum of the number of plates in the bottom and top sections equals the number of plates in the tower.

Because the proper concentrations of all components in the two products will not be known initially, several complete solutions must be made in order to match the concentrations of all the components at the feed plate within the desired accuracy.

The demonstration of the utility of the machine method in this type of calculation should be of considerable interest to the petroleum and chemical industries.

The complete program, including two basic subroutines, has been written utilizing the (15, 15) number system. An old (15, 15) typewriter output routine has been rewritten for the new programmed-arithmetic routines, and is operating satisfactorily. Some mistakes have been found in the two basic subroutines for equilibrium and enthalpy data calculation and have been corrected. When these routines are satisfactory, the main program will be tested.

Problem #132. Revision, Extension, and Testing of Subroutine Library Used in Programs for Obtaining Data for the Numerically Controlled Milling Machine; Routine Numerical and Logical Operations

In the past, Whirlwind I has been used, along with punched-card and hand computations, to calculate the instructions needed to direct the Numerically Controlled Milling Machine (NCMM) at the MIT Servomechanisms Laboratory in preparing a specified piece. The object of the present problem is to develop and test a set of library subroutines for computations associated with this work.

The larger the proportion of the necessary computations that can be put in library form, the less writing and trouble-shooting is required for a program for a particular job. At present, some routines for the most common operations, such as preparation of NCMM tape, which were written before the Comprehensive System was developed, are being revised.

Problem #133. Non-Linear Meson Equation

A radial equation for the external meson field of a spherically symmetric source (obtained from non-linear meson theory) has a wandering singularity of such a kind that there exists an upper bound for the field of a source of given radius. This upper bound cannot be exceeded by increasing the source strength, but only by increasing the radius. Since the field determines the nuclear forces, the relation between this upper bound and the source radius is of physical interest, and is being investigated numerically by D. Finkelstein of the Laboratory of Nuclear Science and Engineering at MIT.

For each value of the source radius X, the desired upper bound obeys essentially the equation

$$-y'' + y + 2y^3/x^2 = 0 \quad \text{for } x > X \quad (y = y(x);\ y(\infty) = 0)$$

and has a singularity at X. This equation is being solved by the method of Runge-Kutta for various values of the asymptotic field at large x. The known behavior of the solution near X is used to extrapolate to the singularity.

The program will be checked by solving the equation

$$-y'' + y + 2y^2 = 0$$

with the same boundary conditions by the Runge-Kutta method and comparing the result with the explicit solution.

References

1. Morse and Allis, Phys. Rev. 44, 269 (1933).
2. "Machine Methods of Computation and Numerical Analysis," Quarterly Progress Report No. 5, p. 10 and ff.

3. Operation of Whirlwind I

3.1 SYSTEMS ENGINEERING

During the period 1 January through 31 March 1953, a total of 672 hours of computer time was assigned to the Applications groups, of which 88 percent yielded useful results. (Corresponding figures for the month of December 1952, not reported in the preceding report, were 272 hours and 91 percent.)

Considerable amounts of time have been devoted to modification work on the computer during recent months in order to improve system reliability by eliminating minor weaknesses in circuitry. As an example, all grid-circuit clamp crystals are being shunted by resistors to prevent loss of grid bias due to leakage current through the relatively high back impedance of the crystals.

Another aim of these changes has been to improve the stability of the system with respect to pulse amplitude by both increasing the amplitude of drive and increasing circuit tolerance to large variations in drive. It was originally intended that the pulse circuits of Whirlwind would operate with normally-off tubes driven up to approximately zero bias during conduction. However, experience has shown that much better stability is obtained by using rather large positive grid drive instead, provided rather simple changes are made to the gate-tube circuitry. These changes consist mainly of inserting small limiter resistors in the control grids and raising plate supply voltage, the result being much improved tolerance to overdriving.

During the past year several cases of blown fuses have been traced to phenolic breakdowns between turret lugs. So far, these breakdowns have been between lugs with a potential difference of 250 volts; dirt deposits on the phenolic surface were the suspected cause. The rate of breakdown increased slowly from one every few months to one or two per month. The cause has been traced to migration of silver from the silver-plated lugs through the phenolic boards. This process is aggravated by high humidity.

All new construction is now using tin-dipped lugs which are not subject to the migration phenomenon. The air-conditioning system has been modified during January to obtain low humidity in the computer room, and this seems to have reduced the breakdown problem. If, however, these steps eventually prove inadequate, it may be necessary to slot the phenolic boards between turret lugs operating at 250 volts or more.

3.2 INPUT-OUTPUT SYSTEM

The operating terminal facilities of the WWI computer are still essentially the same as described in the last summary report, except that the auxiliary magnetic-drum system has been delivered and installed. The new photoelectric paper-tape readers have not arrived yet; delivery is now expected in April. Small changes and improvements have been made in all parts of the system, and considerable effort is being applied to the problem of enlarging the system to provide more extensive terminal facilities.

3.21 Magnetic Tape

The magnetic-tape system now includes four magnetic-tape drive units. Two of the units are permanently connected to the computer; of the other two units, one may be connected to the computer and the other to an automatic print-out device or vice versa depending upon the position of a manually operated switch.

The tape system is working quite satisfactorily now. Most of the noise troubles were traced to faulty tubes which have now been replaced by a new ruggedized tube type. The troubles caused by mechanical difficulties have been virtually eliminated by periodic preventive maintenance. The tapes are cleaned once a week and are replaced if they show signs of wear. The drive mechanisms are checked for oil level, clutch adjustment, and general mechanical fitness. Some minor changes have been made in some of the circuits to permit better means of checking operating margins with voltage variations, and marginal checking of the magnetic-tape system is being worked into the regular marginal-checking schedule of the computer.

Steps are now being taken to provide more flexibility in the automatic print-out equipment. The printer uses a 6-digit code, and the code put on magnetic tape is being increased to 8 significant digits. The two extra digits will be used to select a printing or punching operation and, if punching is selected, to decide whether or not to punch a seventh hole for each character.

3.22 Magnetic Drums

The auxiliary magnetic-drum system, designed and built by the Engineering Research Associates of St. Paul, Minnesota, was delivered to the project in the middle of December. Fig. 3-1 shows the drum system in its three cabinets. The drum equipment was immediately installed in the Barta Building and testing was started. The testing has been continuous and of increasing complexity, until now the drum is being used part-time as auxiliary storage with very satisfactory results.

The principal trouble encountered in operation of the drum has been with the magnetic heads. The drum uses ferrite heads which have a much better response than the usual mu-metal, but this is the first drum built by ERA which uses the ferrite heads. Because of expansion of the plastic in which the ferrite head was imbedded within its mounting, operation of the drum was found to be very dependent upon temperature. The manufacturer is correcting this temperature-sensitivity by redesigning the head mounting. In the meantime, all of the heads have been readjusted by the manufacturer, and about a quarter of them have been replaced by a slightly improved model. The drum is now enclosed in an insulated housing, and the temperature is regulated (manually at present) to keep it at about 40 $\pm$3 C.

The operation of the drum is now very good, and all 12 groups of 16 heads are usable. Present work is toward a study of the various operating margins and a means of connecting the drum system into the computer marginal-checking system. Power for the drum system is being supplied from a separate motor-generator set, but, for simplicity of fusing and interlocking, computer power will be used when the connections are ready.

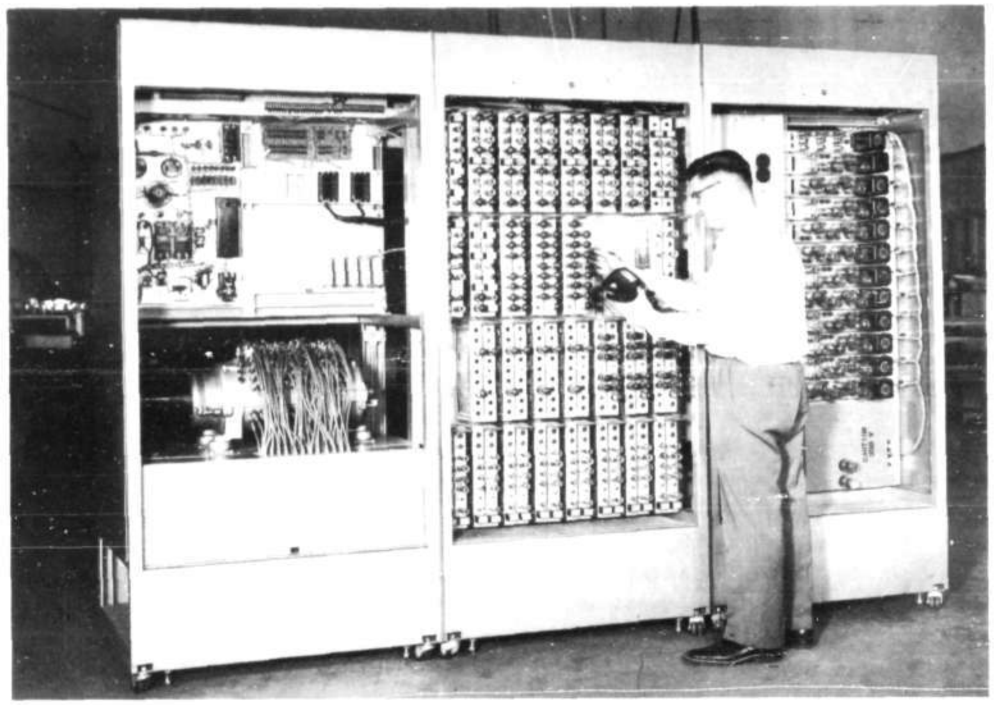


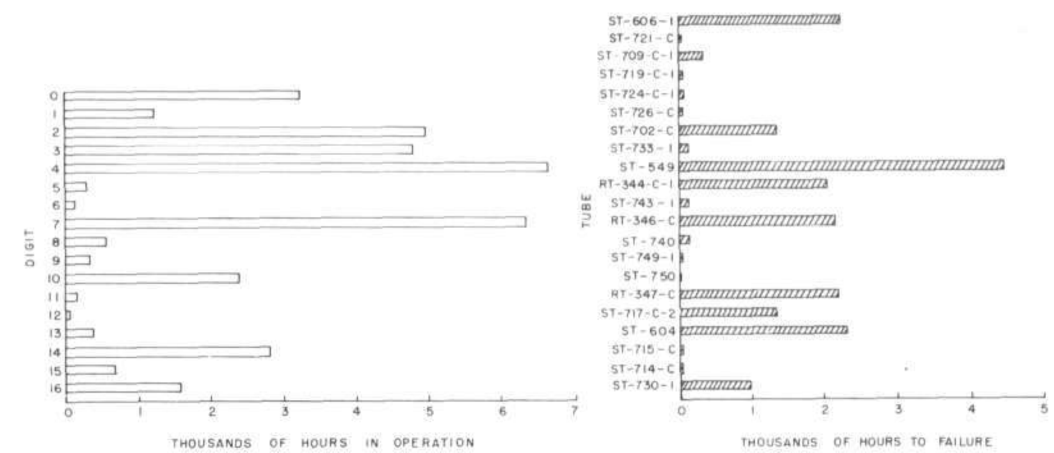
Fig. 3-1. Auxiliary magnetic-drum system.

3.3 ELECTROSTATIC STORAGE

Fig. 3-2 provides data on the life of all the storage tubes that operated in WWI during the first quarter of 1953. The left-hand bar graph shows the hours of operation to date of the 17 tubes in the computer at the end of the quarter. The right-hand graph shows the hours of operation at the time of failure for the 21 tubes that failed during the quarter.

Tube production by the Storage Tube Group during this quarter has been between 4 and 5 tubes per week. These storage tubes were used as replacements for the one operating bank of 17 tubes in the computer. Those tubes not needed for replacement purposes have been installed in the second bank, which will be put into service during the next quarter. Eight research tubes are included in the above production record. Most of the research tubes were constructed to study Philips type "L" cathodes.

The production rate is somewhat lower than had been anticipated, partly because of the need for further experimental investigation of the action of the ion-collector plate. The storage tubes made were all of the 700-series type containing an ion-collector plate. This ion-collector plate is necessary to eliminate the ion-deflection shift described in previous reports.



(a) TUBES IN SERVICE ON MARCH 31, 1953

(b) FAILURES, JANUARY 1, 1952 – MARCH 31, 1953

Fig. 3-2. Life of storage tubes in WWI.

Storage tubes are now being made with a mica-cross spacer. This spacer aids in maintaining a close and uniform spacing of about 0.004 inch between the storage surface and the collector screen.

3.31 Gas Release from Ion-Collector Plate

After a number of ion-collector tubes had been made, it was observed that in some tubes the holding-gun voltage required for stable storage experienced a sudden upward shift. This shift in some cases was severe enough to make the tubes unusable. An internal gas discharge accompanied this sudden shift in the required holding-gun voltage. In most cases this discharge was indicated by a burnout of resistors used for decoupling the voltage to several of the storage tube elements. However, in one case the discharge lasted long enough so that it could be observed taking place within the tube. During this discharge, currents to various electrodes were increased by a factor of 50 to 100 above normal.

Additional research work concerning this phenomenon disclosed that the most probable mechanism for these tubes becoming "gassy" was a release of gas from the ion-collector plate. This gas release was brought on by the continual bombardment of the ion-collector plate by relatively high-energy ions created within the tube. The large area of the ion-collector plates, coupled with the fact that they had not been vacuum fired before being assembled into storage tubes, caused them to release gas continually during normal tube operation. Finally, a point would be reached at which the electrostatic fields within the tube were great enough to initiate a breakdown.

Tubes now being constructed utilize ion-collector plates made of nickel instead of stainless steel, and these nickel plates are fired at 950 C in an atmosphere of pure hydrogen. In approximately 10 tubes constructed under these conditions, no evidence of internal breakdown has been observed.

3.32 Spacer between Collector Screen and Storage Surface

The importance of maintaining a uniform spacing between the collector screen and the storage surface was described in the last report. Several tubes were constructed during this period in which a piece of nickel 0.004 inch thick and 0.04 inch square was welded to the collector screen on the side next to the storage surface. This center post aided materially in keeping the spacing between the collector screen and the storage surface uniform in the presence of approximately 100 volts potential between these two elements. However, it did not eliminate regions of non-uniform spacing caused by buckling of the mica target itself

A different type of collector-to-surface spacer element now being employed is best described as being a mica cross. Fig. 3-3 shows one of these spacers. Starting initially with a circular piece of mica, of a thickness equal to the collector-to-surface spacing desired, four squares are punched out leaving bands 0.080 inch wide extending from the center to the edges in all four directions. In order to use this spacer, the spots normally lying on these mica cross-bars must either be considered unusable or the array of spots must be arranged so that none of them fall on these areas. The latter procedure has been adopted for WWI by simply expanding the area of spots along both horizontal and vertical center lines. Since the storage tube deflection voltages in WWI are derived from a set of binary weighted current sources, this change was relatively easy.

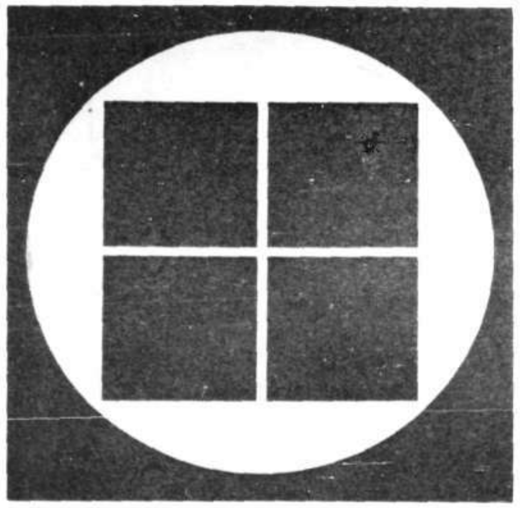


Fig. 3-3. Mica-cross spacer.

Tubes using this mica-cross spacer seem to exhibit a much better uniformity in spacing between the collector and the storage surface than has been obtained by other methods. However, it still does not inhibit severe cases of mica buckling. None of the tubes with this spacer has yet been installed in the computer. Hence, the net worth of this technique will not be known for several more months after considerable operating experience has been obtained.

4. Circuits and Components

4.1 VACUUM TUBES

4.11 Vacuum-Tube Life

During the first quarter of 1953 the WWI computer operated approximately 1700 hours. This has been a period in which extensive efforts have been made to put the computer into the best possible operating condition. In particular, Bank A of electrostatic storage has received considerable work preliminary to placing it back in operation. The extensive maintenance work has resulted in relatively high failure rates for vacuum tubes.

In order to keep the amount of data at a reasonable level, average failure rates for the three most numerous tube types in WWI have been calculated for the year 1952. These are compared below with the failure rates for these same types in the first quarter of 1953.

	FAILURE RATE, PERCENT PER 1000 HOURS	
Tube Type	1952	First Quarter 1953
7AD7	2.00	4.5
7AK7	0.26	0.7
6SN7GT	1.07	1.5

All these rates are up considerably, beyond the probable range of statistical fluctuations for the 7AD7's and 7AK7's. However, failure rates over the rest of the year will probably show a decrease as the period of intensive maintenance is completed.

It has been mentioned previously that SR1407 tubes are replacing the 7AD7 tubes in WWI as failures occur, and that SR1407 tubes are being used in new equipment. The SR1407 was a Sylvania developmental type which has now been superseded by the RTMA type 6145. During the past quarter all the remaining SR1407 tubes have been used, so that only 6145 tubes will be used for replacements and new equipment from now on. Appropriately, the failure rate of the SR1407 was calculated in February, from 765 tubes with ages up to 9000 hours. The failure rate was very nearly 1 percent per 1000 hours, and did not vary greatly for the different classes of service. About one-third or more of the 7AD7 sockets are filled by SR1407 tubes at this time, which means that the failure rate listed above for 7AD7's should be even greater than the 4.5 percent listed, probably as high as 7 percent or more. However, the rate listed in the table is consistent with previous rates, and hence it is valid for comparison purposes.

A fairly large number of failures is listed (Fig. 4-1) for the 5670, which is the premium version of the 2C51. Most of the failures are due to low plate current. However, the specifications as now written allow very little decrease in the plate current of new tubes before the rejection point is reached. It is expected that specifications and circuits will be reviewed in the near future to correct this situation. Similar reviews are scheduled for other tube types as well.

Type	Total in Service	Hours at Failure	Reason for failure, number failed: Change in Characteristics	Breakage	Shorts, Open and Leakage	Gases	Heater Failures
C16J	12	4000-5000	1				
		5000-6000	1				
		6000-7000	1				
C1J	18	15000-16000	1				
		16000-17000	1				
OC3/VR-105	15	17000-18000	2				
OD3/VR-150	24	7000-8000	1				
5670/2C51	58						
5670		1000-2000	1				
		4000-5000	1		1		
		6000-7000	1		1		
		7000-8000	1				
2C51		12000-13000	1				
2D21	58	14000-15000	1				
3D21A	4	17000-18000	1				
829B/3E29	209						
829B		1000-2000			1		
3E29		6000-7000	1				
		7000-8000	1				
		10000-11000	1				
		11000-12000	2				
		13000-14000				1	
		14000-15000	1				
		15000-16000	1	1			
5651	14	17000-18000	2				
5687	85	1000-2000			1		
5U4G	17	6000-7000	1			1	
		11000-12000	1			1	
5Y3GT	9	10000-11000	1				
		17000-18000	1				
6AG7	126	2000-3000			1		
		8000-9000			2		
		10000-11000	9		1		
6AK5/5654	204						
6AK5		0-1000	2				
		1000-2000	2		9		
		5000-6000			2		
		6000-7000			2		
		8000-9000			6		
		10000-11000	24		22		
5654		0-1000	1				
6AL5	249	0-1000	2				
		5000-6000			1		
		6000-7000	1				
		8000-9000	1				
		10000-11000	11				
6AS6	5	13000-14000	1				
6AS7G	134	0-1000	1				
		3000-4000			1		
		5000-6000	2		1		
		6000-7000	2		1		
		7000-8000	1				
		11000-12000	1				
		12000-13000			1	2	
		13000-14000			1		2
6L6G/GA	119	7000-8000	1				
6SL7GT	12	7000-8000	1				
		13000-14000	1				
6SN7GT	428	7000-8000	1				
		9000-10000	1				
		10000-11000	1				
		12000-13000	1		1		
		13000-14000	1				
		14000-15000			1		
		15000-16000	1		1		
		16000-17000	1		1		
6V6	1	4000-5000			1		
6X4	12	6000-7000				1	
6X5GT	7	9000-10000	1				
6Y6G	319	2000-3000				1	
		15000-16000			2		
		16000-17000			2		
		17000-18000	1				
715B	56	7000-8000	1				
		17000-18000	1				
6145/7AD7/SR-1407	2030						
SR-1407		0-1000			1		
		2000-3000			2		
		3000-4000	1				
		8000-9000			1		
		9000-10000			1		
7AD7		0-1000	1		8		
		1000-2000	1		2		
		2000-3000	1		1		
		4000-5000			4		
		5000-6000	2		2		
		6000-7000	7				
		7000-8000	8		1		
		8000-9000	4		4		
		9000-10000	11		4		
		10000-11000	8		3		
		11000-12000	1		2		
		12000-13000	8		6		
		13000-14000	2		2		
		14000-15000	4		3		
		15000-16000	7		10		
		16000-17000	9		17		
		17000-18000			1		
7AK7	1764	0-1000	2		1		
		1000-2000			2		
		2000-3000	2		1		
		3000-4000			2	1	
		11000-12000	1				
		14000-15000			2		
		15000-16000			2		
		16000-17000	2		4		
12AY7	39	1000-2000			2		
		2000-3000	1				

Fig. 4-1. Tube failures in WWI
January 1 to March 31, 1953

Considerable numbers of 6AK5 tubes continue to fail. Most of these failures are found on retest, as the tubes in the RF amplifiers for storage readout are changed to 5654's. This changeover is about 55 percent complete and should be finished during the next quarter. The 6AL5 failures are associated with a routine check of all tubes in the RFA's made at the time of the changeover.

The use of 12AY7 tubes in critical circuits used for magnetic-tape readout has caused considerable trouble. These tubes have active cathodes, at least in the tubes so far used. The active cathodes contribute to high interface resistance, which causes loss of gain. In addition, it has been shown by van der Ziel at the University of Minnesota (in a paper presented at the 1953 MIT Physical Electronics Conference) that interface resistance causes a great increase in the flicker noise of vacuum tubes; flicker noise is troublesome in low-level circuits. The active cathodes also sublime readily, which causes a film to be deposited on the micas. The film has a relatively low resistance, and random contacts to the film will cause large noise spikes to appear at the amplifier output. There is a premium version of the 12AY7 available, which has the RTMA number 6072. The 6072 has replaced the 12AY7 in the most critical circuits, and no trouble has been observed up to more than 1000 hours.

4.12 Vacuum-Tube Research

During this period vacuum-tube research has been concentrated on life tests of three tube types--6145, 5963, and 5687. In addition, work has been done in extension of the measurements of the transient variation of cathode interface impedance with time.

The 6145 life test has now run for 1700 hours. The first 700 hours were run in the pre-burning panels for this type; the last 1000 have been run in special life-test panels. These tubes have shown good operation when run normally-on, drawing cathode current. However, the performance when they are run cut-off leaves something to be desired. Under these conditions, barium deposits on the control grid. This deposit reduces the work function of the grid, which makes the control grid have a higher contact potential. In addition, grid emission may occur. A higher bias is required to cut off the tube, and the zero-bias plate current increases when the tubes are run cut-off. The grid emission may be as high as 20 microamps, which can be troublesome. No interface impedance has been found, however. The tubes so far run on life test are early production; additional tubes from later production runs will be put on life test in the near future.

The 5963 life test has shown these tubes to be subject to cathode interface impedance. Contrary to previous experience, the normally-on side develops more interface impedance than the cut-off side. This behavior is found when the tubes are run with 6.9 volts as well as 6.3 volts on the heaters, although the divergence is smaller with the higher voltage.

The 5687 life tests have been run in an effort to determine the optimum heater voltage for stability of the cut-off section. Some improvement has been found in stability at 12.0 volts on the heater as contrasted to 12.6 volts. Additional work in this area is needed.

The transient change in cathode interface impedance has been described previously, in particular in Summary Report 32, for the fourth quarter of 1952. Additional investigation of this phenomenon has been made, and the research has been reported at the MIT Physical Electronics Conference, held March 26, 27, and 28, 1953. The total capacitance of the interface impedance is particularly interesting, as it is approximately proportional to the inverse of the interface barrier layer thickness. This capacitance is quite constant for short pulse lengths with different cathode temperatures and cathode currents. However, as current continues to flow over a period of 1 second, the capacitance is decreased, indicating an increase in barrier thickness. The results so far obtained can be interpreted in terms of the results Nergaard[1] obtained for slugs of barium orthosilicate, which is the presumed material at the interface. He showed that a potential barrier develops at the positive terminal, corresponding to the junction of the interface compound and the cathode coating. The gradient induced in such a barrier by current flow would cause migration of barium ions out of the region of the barrier, which would tend to further increase the barrier thickness. This work will be continued as time allows.

References

1. Nergaard, L., RCA Rev. 13, 464 (1952).

4.2 COMPONENT REPLACEMENTS IN WWI

Fig. 4-2 lists the replacements of components other than tubes during the first quarter of 1953.

Component	Type	Total in Service	No. of Failures	Hours of Operation	Comments
Capacitors	Oil-filled 0.1 mfd 600 V d-c	96	1	5000-6000	Oil leak
	Mica 0.001 mfd 300 V ±5%	3470	1 1	7000-8000 14000-15000	Internally broken pigtail, intermittent open
Chokes	100 μh 125 ma	512	1	6000-7000	Open
Crystals	D-357 & 1N34A	8886			
	D-357		1 1	11000-12000 16000-17000	Low R_b Low R_b
	1N34A		4	4000-5000	3 high R_f; 1 low R_b
	D-358 & 1N38A	3171			
	D-358		2 1 23	0-1000 4000-5000 15000-16000	Low R_b Loose lead at + end Low R_b
	1N38A		3 1 3	2000-3000 7000-8000 15000-16000	Low R_b Low R_b Low R_b
Delay Lines	0.25 μsec	50	2 1	0-1000 1000-2000	Open Open
Relays	Cramer Type TEC Time Delay 10 amp 115 V a-c	1	1	17000-18000	Intermittent operation
Resistors	Wire-wound 5000 ohm 8 watt ±1%	643	2	7000-8000	Below tolerance
	Deposited Carbon 5000 ohm 1 watt ±1%	180	1	3000-4000	Above tolerance
	Wire-wound 1000 ohm 50 watt	36	1 1	1000-2000 6000-7000	Insulation
	Nobleloy 0.1 meg 1 watt	161	2	7000-8000	1 open 1 above tolerance
	Composition 220 ohm 1 watt ± 5%	890	1 2 2 1	0-1000 5000-6000 6000-7000 9000-10000	Burn-out Burn-out Burn-out Burn-out
Transformers	1:1 Pulse	1896	1 1 1 1	0-1000 2000-3000 7000-8000 15000-16000	Open secondary (intermittent) Open secondary Open secondary Open primary (intermittent)
	3:1 Pulse	3631	1	0-1000	Open primary (intermittent)
	5:1 Pulse	240	1	16000-17000	Open primary

Fig. 4-2. Component failures in WWI
January 1 to March 31, 1953

5. Academic Program

5.1 CATALOGUE SUBJECTS; SUMMER SESSION, 1953

Eight students are registered for the second-semester MIT subject 6.537, Digital Computer Applications Practice, which is being run as a seminar and laboratory course. Each student has selected a problem to program by himself for solution on the Whirlwind I computer. The problems chosen are a 2nd-order non-linear ordinary differential equation by Runge-Kutta method, simultaneous linear algebraic equations (arising in a wave equation) solved by a new (Crout) elimination procedure, simultaneous linear algebraic equations solved by a new (Craig) descent method, a mistake-diagnosis routine, a floating-address conversion program, heat balance in a chemical reactor (polymerization of tetrafluoroethylene), optimization of an assembly-line problem, and the game of NIM.

A repetition of last summer's intensive two-week special program in Digital Computers and Their Applications will be offered at MIT from August 24 through September 4, 1953. A series of lectures on coding will progress from introductory material to advanced coding and mistake-location techniques. A concurrent series of lectures will cover briefly such related topics as numerical analysis, logical design, reliability, business applications, operational procedures, available computers, etc. In addition, there will be some twenty hours of programming practice and discussion in small groups, together with actual performance on the Whirlwind I computer, of three practice programs prepared by students working in small teams.

5.2 SEMINARS ON COMPUTING MACHINE METHODS

The seminars on Computing Machine Methods are arranged jointly by representatives of the MIT Committee on Machine Methods of Computation and the MIT Digital Computer Laboratory. Various speakers from other MIT activities and elsewhere, as well as members of the two sponsoring groups, participate in these weekly seminars, which are held in a lecture room at the Institute. The program during the past quarter was as follows.

Date	Subject	Speaker
February 17	Operations Research (Operations Research is the application of methodology of physical science to problems of management of large-scale operations -- industrial, governmental, or military. Machine computation has been used in many of these problems in the gathering of data and in the solution of the problem. Examples were given.)	Professor Philip M. Morse, MIT
February 24	The Nature of Programming (The advantage of the high-speed computing machine over the human computer lies not primarily in the complexity of the tasks which the computer can carry out-- for the computer is a much less complicated instrument	Professor Norbert Wiener, MIT

Date	Subject	Speaker
	than the human brain--but in the speed with which it can carry out its tasks. Thus computing machines must be used in a manner forbidding any human operations on the data while the machine is in action. That is, the programming of the machine must be done at high speed, and the machine becomes not only a numerical machine working with digits 1 and 0, but a logical machine working with affirmities and denials. This aspect of the machine has made it available for other programming processes than those of computation and makes it clear that it will lead to the automatic factory.)	
March 3	Two Digital Computers, A.C.E. and S.W.A.C. (The A.C.E. pilot-model computer at the National Physical Laboratory, England, was constructed to gain experience for the design of a more comprehensive machine. A brief description of the simple mode of operation, coding procedure, and performance were given. The S.W.A.C. at the Institute for Numerical Analysis in Los Angeles is a computer with logical operation more advanced than that of the pilot-model A.C.E. This machine was also described briefly and the logical systems compared.)	W.D. Worthy, Goodwin Fellow, St. John's College, Cambridge
March 10	The Monte Carlo Method for Non-Stochastic Problems (For some fifty years, model-sampling techniques have been used by statisticians to solve difficult probability distribution problems. Recently similar techniques have been employed by mathematical physicists to solve diffusion problems and other physical problems with a probabilistic mathematical model. It is natural to look into the question of whether sampling techniques can be extended into the field on computation problems which do not necessarily arise from applications of probability theory. This talk discussed the use of sampling for calculating the iterates of a linear operation. Only integrals and finite matrices were considered. Emphasis was placed on devices for reducing the sample size.)	Dr. J.H. Curtiss, Computation Laboratory, Harvard University

Date	Subject	Speaker
March 17	A Whirlwind Program for Reading a Class of Mathematical Equations (A program was described which permits Whirlwind to receive as its input a certain class of mathematical equations in a direct form. The equations are typed on a standard Flexowriter, using more or less conventional mathematical symbolism. The resulting punched paper tape is then fed to Whirlwind together with the conversion program that translates the tape into a standard Whirlwind program which is automatically executed.)	Dr. J.H. Laning, Jr., Instrumentation Laboratory, MIT

5.3 TRAINING PROGRAM FOR S&EC PERSONNEL

The following schedule covers the Scientific and Engineering Computation (S&EC) Group's two-week Training Program designed to give users of WWI a good start in the direction of programming their own problems. The Training Program is also used for the indoctrination of S&EC personnel.

1. Introductory Lecture
2. Simple Order Code
3. Several Exercises (Floating Addresses)
4. Scope (Curve), Exercises, and Visit with WWI
5. Control Switches, Pushbuttons and Alarms, Conversion
6. Remainder of Order Code, Binary Arithmetic, Octal Arithmetic
7. Temporary Storage, Preset Parameters, Relative Addresses, Control Elements
8. Flow Diagrams, Programming Techniques and Devices
9. 5-56 Tape, Input Program, Mistake Diagnosis, Post Mortems
10. Procedures (forms), Subroutines, Scale Factoring, Programming Examples (numerical analysis), and Techniques
11. Computer and Tape Room Operations and Forms
12. Review
13. Output: Flexo-type-punch, Delayed Printer, Scope, Examples (output conversion)
14. Programmed Arithmetic and Interpretive Subroutines
15. Floating Point and (m, n) Notation
16. Comprehensive System (PA): Cycle Control, Generalized Decimal No., Buffer Storage, Notation
17. Uses of Magnetic Tape
18. Comprehensive System (PA) continued
19. Basic Conversion and Comprehensive Conversion System Notation
20. Comprehensive System Pitfalls and CS Output

5.4 WWI ADVANCED SEMINARS

Five advanced seminars for WWI were held at MIT during the period February 13 - March 10. The seminars were open to all who were interested and were held for the purpose of discussing new developments in Whirlwind I hardware or techniques, hearing new suggestions, receiving reports from a committee on new suggestions, and discussing any questions or suggestions of general interest.

Date	Title	Speaker
February 13	Cautions in Using Basic Conversion Program or Comprehensive System of Service Routines	E. Kopley D. Combelic
February 20	Uses of Magnetic Tape	D. Combelic
February 27	Post Mortems and Mistake Diagnosis	F. Helwig
March 6	Magnetic Drum	
	(a) Auxiliary Storage	E. Kopley
	(b) Status (testing, reliability)	K. McVicar
	(c) Use of Magnetic Drum for Comprehensive System	F. Helwig
March 20	Other Computers	C. W. Adams

5.5 SEMINARS ON EVALUATION OF INTEGRALS OF THE PRODUCT OF TWO FUNCTIONS

A series of seminars open to all interested persons is being sponsored by the MIT Digital Computer Laboratory to discuss methods for the numerical evaluation of finite or infinite integrals of the product of two functions. These integrals include those arising from problems involving auto- and cross-correlations, convolutions, and transforms.

Although the initial impetus for these seminars arose from problems to be programmed for Whirlwind I, other allied problems as well as theoretical discussions are to be included according to the desires of those participating in the seminars.

Meetings held during the first quarter of 1953 are tabulated below.

Date	Subject	Speaker
February 12	Multiple Integrals Appearing in Problems Involving Stochastic Processes (These integrals and some techniques for their evaluation by means of analogue computation were discussed.)	Dr. E.J. Frey, Instrumentation Laboratory
February 12	Determination of Spectrum of Atmospheric Turbulence by Means of Correlation Techniques, Using an Airplane as a Probe (A cross-power analysis was used to determine the spectra of three stochastic inputs from the correlation matrix of the outputs.)	Mr. R. A. Summers, Instrumentation Laboratory
February 19	Numerical Techniques for Estimating the Impulse Response of a Linear System from Measured Input and Output Functions	
	1. Least Square Techniques. 2. An Iterative Procedure Due to Samuelson.	Mr. Edward Arthurs, Servomechanisms Laboratory
	3. Numerical Convolution Techniques. 4. Madwed Number Theories Approach. 5. Analogue Computer Techniques.	Mr. Robert Kramer, Servomechanisms Laboratory
February 26	Application of Linear Predictor Operators Non-Stationary Multiple Time Series with Numerical Applications	Mr. Enders A. Robinson, Director, Geophysical Analysis Group
March 24	Review of Tukey and Hamming's Paper on Measuring Noise Color	Professor George P. Wadsworth, Mathematics Department

6. Appendix

6.1 REPORTS AND PUBLICATIONS

Project Whirlwind technical reports and memorandums are routinely distributed to only a restricted group known to have a particular interest in the Project. Other people who need information on specific phases of the work may obtain copies of individual reports by making requests to Robert R. Rathbone, Digital Computer Laboratory, 68 Albany Street, Cambridge 39, Massachusetts. Reference should be made to code number DCL-6.1.

The following reports and memorandums were among those issued during the first quarter of 1953.

No.	Title	No. of Pages	Date	Author
SR-32	Summary Report No. 32, Fourth Quarter 1952	36		
R-219	Electronic Selection and Control of Read-Record Heads of Magnetic Tape Units (S.M. Thesis; Abstract in E-514)	51	12-15-52	J. A. O'Brien
E-515	The Technique for Evaporation of a Beryllium Mosaic	8	12-16-52	T. F. Clough
E-520	The WWI Auxiliary Magnetic Drum System	30	1-9-53	J. W. Forgie
E-521	The Low-Speed 2^6 Counter, Model II	7	1-29-53	H. Platt
E-523	Core Drivers--Model V and Model VI	4	2-10-53	H. W. Boyd
E-525	Normalized Flip-Flop Chart	14	2-17-53	H. W. Boyd
E-526	High-Speed (5965) Flip-Flop	3	2-24-53	H. W. Boyd
M-1812	The Philosophy of Statistical Filter Design	6	1-27-53	[illegible]. I. Wells
M-1828	Design and Tests of Electronic Circuits for Operating Safety Margins	3	1-27-53	J. W. Forrester
M-1909	WWI Experience with Dust and Blemishes on Magnetic Tape	3	3-13-53	J. W. Forgie

6.2 PROFESSIONAL SOCIETY PAPERS

At the AIEE Winter General Meeting held in New York in January, D.R. Brown presented a paper entitled "Magnetic Materials for High-speed Pulse Circuits." At the same meeting D.A. Buck and W.I. Frank spoke on "Non-destructive Sensing of Magnetic Cores."

N. L. Daggett and E. S. Rich presented a paper on "Diagnostic Programs and Marginal Checking in the Whirlwind I Computer" at the IRE 1953 Convention, March 24. The paper was summarized in the March 1953 issue of Proceedings of the IRE.

The January 1953 Physical Review carried an article entitled "A Theory of the Deviation from Close Packing in Hexagonal Metal Crystals" by J. B. Goodenough.

"Computer Reliability," by E. S. Rich and R. R. Rathbone, appeared in the February 1953 issue of Radio-Electronic Engineering.

The April Electronics contained an article by D.R. Brown, of this Laboratory, and E. Albers-Shoenberg, of General Ceramics, called "Ferrites for Digital Computers."