Digital Computer Laboratory
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

SUBJECT: BIWEEKLY REPORT, MAY 2, 1954

To: Jay W. Forrester

From: Scientific and Engineering Computation Group

1. MATHEMATICS, CODING AND APPLICATIONS

1.1 Introduction

During the period covered by this report 338 coded programs were run on the time allocated to the Scientific and Engineering Computation (S&EC) Group. These programs represent part of the work that has been carried on in 42 of the problems that have been accepted by the S&EC Group. Progress on 26 of these problems is given below in terms of programming hours, minutes of computer time, and progress reports as submitted by the programmers in question.

This past biweekly period was marked by a significant increase in the number of programs that have passed from a testing stage to actual production runs. In particular the revised Comprehensive System (CS II) has been operating successfully. Memoranda describing various aspects of the revised system will be made available as soon as possible. One such memorandum (M-2741), intended primarily for computer operators, has already been distributed. Summaries of the new input program, block recording (on magnetic tape) program, and modifications for the post-mortem program are included under problem #100.

Progress reports appear below for the first time for eight new problems. Problem #162 (for Dr. F. J. Eppling of the Laboratory for Nuclear Science) is carrying out a phase shift analysis of the elastic scattering of protons by O^{16}. Problem #169 represents a study by E.C.Hoy of the DCL Staff of the utilization of a general-purpose digital computer in switching-circuit design. In problem #182, a 30th order matrix is being inverted for Dr. S. C. Abrahams of the MIT Laboratory for Insulation Research. Of the other new problems, #174 and 175 are being done with the Solid State and Molecular Theory Group, #178 with the Instrumentation Laboratory, #179 with the Aerelastic Laboratory, and #180 with students in the Electrical Engineering Department.

1.2 Programs and Computer Operation

The following summary is included as a guide for interpreting the abbreviations used below. A more detailed description of the terms involved can be found in M-2497.

a. The upper case letter following the problem number has the following significance:
   A implies the problem is NOT for academic credit, is UNsponsored.
   B implies the problem is for academic credit, is UNsponsored.
   C implies the problem is NOT for academic credit, IS sponsored.
   D implies the problem is for academic credit, IS sponsored.

The absence of a letter indicates that it is an internal S&EC problem.

b. DIC denotes the Division of Industrial Cooperation.
   DCL denotes the Digital Computer Laboratory.
   CMMC denotes the Committee on Machine Methods of Computation.
   DDL denotes the Division of Defense Laboratories.

100. Comprehensive System of Service Routines, developed by the S&EC Group at the Digital Computer Laboratory for the input conversion of suitably prepared punched paper tapes. When so requested, these routines automatically provide a program with suitable programmed arithmetic, cycle-counting, and output facilities.
   :DCL Staff: Arden, 40 hours; Best, 66 hours; Combelic, 61 hours; Demurjian, 17.25 hours; Denman, 34 hours; Helwig, 70 hours; Kopley, 6 hours; Porter, 2 hours; Siegel, 58 hours; WWI, 1254 minutes

The S&EC system of utility tapes has been successfully operating during the past biweekly period.

A memorandum, M-2741, describing the new Comprehensive System (CS II) primarily for computer operators, is now available.

Similar memoranda directed to tape room personnel and to programmers will be issued shortly.

Further additions to the system are planned but these will be tested independently of the present working system.
                                                                    Staff

A new input program has been recorded on group 11 of the auxiliary drum.

The following kinds of paper tape can be read in automatically on the photoelectric tape reader (PETR):

   1. CS II Flexo tapes (identified by an initial fc or a fence)

   2. CS II Binary tapes (identified by an initial fb)

3. Post-mortem request tapes (identified by an initial fp)

4. Summer session tapes (identified by an initial fs)

5. 556 tapes (identified by any legal initial character which is not an f or a fence)

The additional programs required for the read in of the various kinds of tapes are stored on magnetic tape unit 0 and brought into CM by the input program.

Several other modes of operation can be obtained by inserting information into the right insertion register and pressing the upper activate button. Among these are:

1. automatic read in of paper tapes on the mechanical reader;

2. recording a stop character on unit 3;

3. examining a selected register on the magnetic drums;

4. select a given utility program from unit 0 and read it into CM. (These include the scope calibration program, a drum checking program, a magnetic tape checking program, and a PETR test program);

5. obtaining a scope post-mortem;

6. manual post-mortem requests.

Automatic logging is provided in the case of paper tape read in. For S&EC tapes (whose titles contain dashes) this will take place on the scope and the direct punch. For all other tapes (whose titles contain m or p) this will take place on the direct typewriter.

A memorandum describing the detailed operation of the input program will be issued shortly.

                                                                    Helwig

A utility program, 100-12-9017, is in use by S&EC staff members for doing the following jobs:

1. recording blocks (i.e., parts of the CS II programs, etc.) on MT unit 0 in such a form that they can be located and read in by the input program. This involves searching for the correct position on magnetic tape to begin recording, reading in and optimizing one or more 556 paper tapes, and finally recording the equivalent of the paper tapes on the magnetic tape as a block with a minimum of control words.

2. re-recording blocks on MT unit 0, which differs from recording only in that it replaces a block previously recorded by a new block which can, of course, be no larger than the original block.

3. optimizing 556 tapes, which consists of reading in one or more 556 tapes and punching out their equivalent as a single 556 tape which

contains no unnecessary words to be stored.

This program will read in most tapes that the input program will read in.
The exceptions are: (1) the title may contain at most 20 Flexo characters,
(2) no more than 14 different drum groups may be addressed, (3) no 556
ditto blocks may occur, (4) at no time during the read in of a tape may
the words stored form more than 459 groups of consecutive registers.

The program is being modified to remove restrictions (3) and (4)
and to permit punching out 556 ditto blocks and to make some minor improve-
ments in the way the manual intervention registers are used to control
the pperation of the program.

                                                                Best

The following corrections and additions to the CS II post-mortem
system either have been made or are being tested:

1. elimination of an automatic stop character after tape post-
mortem requests;

2. inclusion of ten carriage returns before any title;

3. printing a title before the automatic PA PM instead of after
on fp tape requests (excluding CS I PA PM);

4. inclusion of an identification mode;

5. correction of an inactivity alarm which occurred on all
Manual Intervention Register requests for a CS I PA PM after the first
fp tape request.

                                                                Arden

The CS II conversion post-mortem, which provides information about
certain kinds of errors detected during the conversion process, has been
revised, and the latest version recorded on Magnetic Tape unit 0 as part
of the CS II conversion program. The program apparently operates correctly.

                                                                Siegel

An error in the output adaptation section of the CS II conversion
program was detected and corrected. A great many tests have now been run
successfully on the output adaptation.

                                                                Demurjian, Porter

101 C. Optical Properties of Thin Metal Films on transparent backings
         are determined and printed out automatically by this program;
         the input data consist of the observed reflection and trans-
         mission coefficients, the index of the backing, the wavelength,
         and the sample thickness. The program calculates by means of
         an iterative procedure and prints out the index of refraction
         and the absorption coefficient of the film, the rate of var-
         iation of these constants with reflection and transmission,
         and the film's conductivity and dielectric constant.

:for Professor L. Harris, Chemistry Department, Dr. A.L.Loeb
:by Dr. A. L. Loeb(DIC); Richmond, 45 hours
:DCL: WWI, 74 minutes

An "approximate program" had been developed to compute optical
constants of thin films from reflection and transmission data. This
program neglects the backing and assumes that the film thickness is
much less than the wavelength of the radiation. Its results are used
in the "principal (accurate) program" as first estimates, from which
the principal program then calculates accurate values. In the visible
wavelength region the approximation is not very good, but the first
estimate does not need to be. In the infrared, where the first estimate
has to be very good, the approximation is excellent. Therefore, this
combined approximation plus iteration program has proven very satisfactory
in both the visible and the infrared regions.

This program is now being "cleaned up", i.e., manual modifications,
etc. are being incorporated into the program and new printouts are being
made. Columns and headings are lined up properly, and a provision for
interrupting the iteration procedure after a preassigned number of iter-
ations has been perfected. Thus the program and tape will be more amenable
to general use when the original programmer is not present.

Large quantities of data obtained in the Chemistry Department on
gold films are now being run on WWI. Twelve wavelengths in the region
between 4400 and 6600 Å are under consideration. Since the density of
gold films is not accurately known, four different densities are assumed,
and the results compared.

106 C. MIT Seismic Project is concerned with the development of methods
            for locating deep reflections from underground strata in
            seismic prospecting. The basic method is one of prediction
            by means of an optimum linear operator.
         :for Professor P.M.Hurley, Geology and Geophysics; Professor
         G. Wadsworth, Mathematics Department
         :by E.A.Robinson (Res. Assoc.); Briscoe, 36 hours; Simpson, 20
         hours; Walsh, 25 hours;
         :DCL: WWI, 215 minutes

The majority of computed results during the last biweekly period
have consisted of spectral and correlation estimates - a continuation of
a project to categorize the non-stationary properties of seismograms.
The other two projects mentioned in the last biweekly have suffered delays
and computations have not progressed.

In the meantime the group has been training certain of its newer
members in the use of the programs associated with problem 106 so they
will be prepared to carry on experiments during the summer months.

113 C. <u>A Stress Analysis of an L-shaped Homogeneous Planar Structure</u>
              is being made for the case of a concentrated static load.
              The structure is approximated by a framework of bars which
              will deform in the same manner as the prototype. This frame-
              work is then analyzed using the principles of virtual work
              and Southwell relaxation techniques. Boundary conditions have
              been specified for the edge of the framework so that the
              deformations of the model will conform to the actual defor-
              mations of the structure.
              :for Professor J.S.Archer, Department of Civil and Sanitary Eng.
              :by S. Sydney (Res. Assist.CMMC), 20 hours
              :DCL: WWI, 121 minutes

          Supplementary programs have been written to obtain data from
previous calculations in a more usable form for plotting desired graphs.
Intermediate Whirlwind results and final bar forces are obtained in the
form of a 556 tape,facilitating subsequent calculations for stress
intensities in the prototype plate. Two sets of results have been obtain-
ed with this program.

119 C. <u>Spherical Wave Propagation</u> produced by the sudden release of a
              spherical distribution of compressed air in the atmosphere
              is being studied by numerical means. This involves replacing
              a set of non-linear hyperbolic partial differential equations
              in 2 independent and 2 dependent variables by a set of difference
              equations written along characteristics. An iterative procedure
              is used to solve these equations.
              :for Professor C. C. Lin, Mathematics Department
              :by A. Ralston (CMMC), 5 hours
              :DCL: WWI, 31 minutes

          The numerical difficulties mentioned in the past few biweeklies
have proved more serious than originally thought. Near the shock a
large percentage error in one very small quantity subsequently causes a
large error in magnitude in other quantities. Due to these difficulties
a good deal of reformulation of the problem will have to be done before
further numerical results can be obtained.

126 C. <u>A Data Reduction Program</u> for use in the Servomechanisms Laboratory
              is being developed in separate stages to be combined at a
              later date. The first stage is concerned with devising a
              program to fit polynomials to arbitrary empirical functions
              using a least squared error criterion. The procedure makes
              use of Legendre polynomials and matrix multiplication.
              :for J.E.Ward, Servomechanisms Laboratory, DIC 7138 AF33(616)2038
              :by D.T.Ross(DIC); Turyn, 65 hours; Hamilton, 10 hours
              :DCL: WWI, 22 minutes

          Part 2 of the main program is operating correctly. The main
program has been tried once unsuccessfully. Further tests are continuing.

          A scope routine for printing out both single length and (24,6)
numbers is being written for inclusion in the main program.

131. The Training of New Personnel, Tours and Demonstrations are
among those activities included in this problem. Generally
speaking, any approved staff problem relating to training
and/or demonstrations is considered to be in this category.
:DCL Staff: Demurjian, 10.5 hours; Kopley, 2 hours; WWI, 72
minutes

During this biweekly period computer time was used for demonstration
purposes and for the filming of a television movie as described below.

On April 26, twenty members of the Society of Women Engineers
were given computer and Flexowriter demonstrations and a tour of Whirlwind
installations after a lecture on computers by J.D.Porter.

On April 27, nine CBS-TV employees spent the day filming the
computer for a TV film on MIT research projects to be shown on a program
called "The Search". A series of such films describing major research
projects throughout the country will begin in the fall.

On April 28, fourteen students from Harvard University were
given a demonstration on and a tour of Whirlwind after a lecture on
digital computers by C. W. Adams.

132 C. Subroutines for the Numerically Controlled Milling Machine are
being revised and tested. The set of subroutines facilitates
programming of the computations involved in the preparation
of numerical data used to control the milling machine. The
subroutines involve routine numerical and logical operations.
:for J.O.McDonough, Servomechanisms Lab., DIC 6873
:by J.H.Runyon (E.E. Res Assist), 25 hours
:DCL: WWI, 12 minutes

A revised routine for Lagrangian interpolation which takes
advantage of extra buffer provisions in CS II was written and success-
fully tested. Testing of a program for preparing tape for Series 16
airfoil templates was begun. Errors which caused the first run to be
unsuccessful have been found and corrected.

140. Summer Session System consists of a conversion program, an
interpretive routine, and mistake diagnostic routines stored
in WWI. A special mnemonic instruction code has been developed
for use with this system, thus simulating a computer with char-
acteristics quite different from those of WWI. This Summer
Session (SS) computer was developed for the use of students
participating in the MIT 1953 summer session course on Digital
Computers and Their Applications. The SS computer was used
by the E. E. Department courses 6.535 and 6.25 and is avail-
able to programmers with suitable problems.
:DCL Staff: Siegel, 3 hours; WWI, 52 minutes

The SS computer is being used by Mr. R. C. Mills in connection
with Problem #180. Several SS programs have been run successfully. In
the course of this work, a mistake in the pat instruction was detected.

The mistake was corrected by changing one instruction in the SS PA.

The SS computer is ready for recording on magnetic tape unit 0 as a part of CS II. It will be recorded as soon as sufficient space on the tape unit becomes available.

142 D. <u>A Study of Shock Waves</u> has been undertaken in two dimensional solids subjected to impulsive loads. The analysis approximates the solid by two dimensional grid with concentrated masses at nodal points. The response of this system is computed from a finite difference approximation to the differential equations of motion of this system.
:for Professor C.N.Norris, Department of Civil and Sanitary Eng.
:by S. Sydney (Res. Assist. CMMC), 30 hours
:DCL: WWI, 36 minutes

Shear and stress intensities are being calculated from displacement values of the spring mass system simulating the behavior of an extended body under shock loading. The program written for these calculations has been tested and is being incorporated into the main program.

147 C. <u>Energy Bands in Crystals</u> are being studied by finding solutions of the corresponding second order linear differential equation satisfying boundary conditions at the origin. The solutions are found approximately by using the Gauss-Jackson formula for forward integration. The solutions and their first derivatives are to be combined in a sum, the weighting factors being functions of an independent parameter.
:for Professor J.C.Slater, Physics Department, DIC 6853
:by D.J. Howarth (DIC), 40 hours
:DCL: WWI, 78 minutes

Final testing of the routine to compute and solve the secular equations which represent the last stage of this problem has been completed and production work on this routine is now under way.

155 B. <u>Synoptic Climatology</u>. A multiple regression formula is used to predict temperatures from pressure distributions described by Tschebycheff polynomials. The matrix of scalar products which is used in the calculation of the coefficients of the multiple-regression system is being calculated on WWI.
:for Professor T.F.Malone, Meteorology Department
:by R. Miller(DIC), 25 hours
:DCL Staff: Porter, 5 hours; WWI, 115 minutes

Specification of the surface pressure pattern by means of fourteen numbers (standardized coefficients of orthogonal polynomials) has been completed for the month of January 1948-1952 for a grid the size of the eastern half of the United States.

A program for obtaining the regression coefficients in a least squares solution for an arbitrary dependent variable with a given set of independent variables has been completed.

Crossproducts necessary for determining the predictability of pressure 24 hours in advance for 91 points within a grid covering the major portion of the North American continent are in the process of being computed.

162 C. **Determination of Phase Shifts from Experimental Cross-Sections.**
A phase shift analysis is being made of the elastic scattering of protons by O^{16}. From a partial wave expansion of the differential cross-section those phase shifts required to provide a fit to a number of experimental angular distributions will be determined.
:for Dr. F.J.Eppling, Laboratory for Nuclear Science,DIC 6420
:by E. Campbell(DIC), 24 hours
:DCL: WWI, 9 minutes

This problem is concerned with the analysis of a nuclear scattering experiment, the elastic scattering of protons by O^{16}, over a range of bombarding energies from about .5 Mev to 4.6 Mev. Cross-sections were measured at eight scattering angles from $168.0°$ to $90.4°$(in the center of the mass system). From the experiment a series of eight curves is obtained in which the absolute differential cross-section, $d\sigma/d\omega$, is plotted as a function of the bombarding energy of the incident protons at each of the eight scattering angles. From these curves it is then possible to obtain $d\sigma/d\omega$ as a function of scattering angle at any given bombarding energy.

For a reaction such as the one above the theoretical expression for $d\sigma/d\omega$ is given as follows:

$$\frac{d\sigma}{d\omega} = \lambda^2 \left| -\frac{\eta}{2} \csc^2 \frac{\theta}{2} e^{i\eta \ln \eta \csc^2 \frac{\theta}{2}} + \sum_{\ell=0}^{\infty} (\ell+1) P_\ell\, e^{i(\alpha_\ell + \delta_\ell^+)} \sin \delta_\ell^+ \right.$$

$$+ \sum_{\ell=1}^{\infty} \ell\, P_\ell\, e^{i(\alpha_\ell + \delta_\ell^-)} \sin \delta_\ell^- \bigg|^2$$

$$+ \lambda^2 \sin^2 \theta \left| \sum_{\ell=1}^{\infty} P_\ell'\, e^{i\alpha_\ell} \left\{ e^{i\delta_\ell^-} \sin \delta_\ell^- - e^{i\delta_\ell^+} \sin \delta_\ell^+ \right\} \right|^2$$

where:

$$\lambda = \frac{\hbar}{\mu v},$$

$$\eta = \frac{zZe^2}{\hbar v},$$

θ = the scattering angle in the center of mass system,

P_ℓ (cos θ) = Legendre polynomial of order ℓ,

P_ℓ' (cos θ) = $\dfrac{d}{d(\cos \theta)} P_\ell$(cos θ) , and

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$$\left. + \sum_{\ell=1}^{\infty} \ell P_\ell e^{i(\alpha_\ell + \delta_\ell^-)} \sin \delta_\ell^- \right|^2$$

$$+ \lambda^2 \sin^2 \theta \left| \sum_{\ell=1}^{\infty} P_\ell' e^{i\alpha_\ell} \left\{ e^{i\delta_\ell^-} \sin \delta_\ell^- - e^{i\delta_\ell^+} \sin \delta_\ell^+ \right\} \right|^2$$

where: $\lambda = \frac{\hbar}{\mu v}$,

$\eta = \frac{zZ\epsilon^2}{\hbar v}$,

θ = the scattering angle in the center of mass system,

P_ℓ (cos θ) = Legendre polynomial of order ℓ,

P_ℓ' (cos θ) = $\frac{d}{d(\cos\theta)}$ P_ℓ(cos θ)   , and

$$\alpha_\ell = 2 \sum_{x=1}^{\ell} \tan^{-1} \frac{\eta}{x} \; ; \; \text{and} \; \alpha_0 = 0.$$

$$\delta_\ell^\pm = \beta_\ell^\pm - \phi_\ell \quad \text{where} \quad \beta_\ell^\pm \text{ is the resonant phase shift and } \phi_\ell$$

is usually called the potential scattering phase shift or "hard sphere" phase shift. $\delta_\ell^\pm$ is the non-coulomb phase shift of the partial wave of orbital angular ℓ and total angular momentum $J = \ell \pm 1/2$; and where

k = $1/\chi$
η = the reduced mass of the system,
v = the velocity of relative motion,
z,Z = the atomic numbers of the colliding particles,
ε = the electronic charge
$\hbar$ = Plank's constant divided by 2π, and
$\ell\hbar$ = the orbital angular momentum of the incident protons.

Using this expression for $d\sigma/d\omega$ it is desired to extract the δ_ℓ's from $\ell = 0$ through $\ell = 3$, i.e., the S-wave, the P-wave, the D-wave, and the F-wave phase shifts, explicitly from the experimental angular distributions and to determine their limits compatible with experimental errors, which are estimated to be about 1% to 2% over most of the energy range covered by the experiment. If possible, it is desired to establish the minimum number and type of phase shifts required to fit any given angular distribution. The criterion of fit being used is to find the phase shifts which make the sum of the squares of the percentage errors in the cross-section a minimum.

From these phase shifts it will be possible to determine the properties of the excited states of F^{17} within the region of excitation energies which the experiment covers and in addition, to determine, within the limits of the experimental errors, whether or not a number of more subtle factors, such as the ground state of F^{17}, a low-lying bound state, and possible effects of core excitation, are influencing the scattering.

A preliminary program has been planned to obtain plots of the sum of the squares of the percentage errors in the cross-section as a function of each phase shift over a range of $-180°$ to $+180°$. This is being done in order to study the behavior of the minimums. So far, one tape has been run which gives the error as a function of δ_0, the S-wave phase shift.

166 C. <u>Construction and Testing of a Delta Wing Flutter Model</u> is being effected by replacing the actual wing by a structurally equivalent lattice network. An iterative procedure involving the evaluation of a matrix equation has been evolved for determining the bending and torsional stiffnesses of the component members of the network.
:for M. M. Chen (DIC)
:by S. Gravitz(Res.Assist. Aero. Eng.), 55 hours
:DCL Staff: Porter, 6 hours; WWI, 180 minutes

Approximately half of the first iteration cycle is now in working order. On the basis of the preliminary results, the first trial stiffnesses were found to yield influence coefficients which matched, on the average, to well within 100% of the given influence coefficients. The second half of the first cycle is completed and is in the process of being tested. Testing of this phase of the program has been uneven because of various machine and programming difficulties.

The relatively minor modifications to the program to insure automatic iteration are being evolved.

167 D. <u>Transient Effects In Distillation</u> are being calculated by solving sets of simultaneous non-linear ordinary differential equations using numerical integration methods. Several of the most important types are being explored and results of specific cases will be correlated.
: for Professor E. R. Gilliland, Chemical Engineering Department
: by J.F.O'Donnell(Res.Assist.CMMC), 80 hours; Polk, 40 hours; Smith, 40 hours; Myers, 40 hours
: DCL Staff: Porter, .5 hour; WWI, 553 minutes

About half the machine time used by this problem was devoted to the study of transients in continuous distillations. Some time was spent eliminating difficulties in convergence of the steady-state solution. With the program and the transient program running successfully, a large portion of the data for the thesis of the authors was obtained during this period. Also a program was written and operated successfully for calculating the change in reflux ratio necessary to maintain constant product composition after a step change in feed composition.

                                                          Polk and Smith

About one-third of the machine time was devoted to the problem of take-off in batch distillation. It was spent getting valuable exploratory results. This will be continued.

A program is being written to calculate the same type of results as the present program for the limiting case of no-holdup. This should be tested in the near future.

                                                          O'Donnell

The remaining machine time was spent trouble-shooting the program for tune-up in batch distillation. Several programming and coding errors were eliminated. CS II has been used and some difficulties have developed using the output sections. It is hoped that this program will be operated successfully soon.

                                                          Myers

168 D. <u>Indicial Downwash behind a Two-Dimensional Wing</u>. In the analysis
        of the response of an airplane to a sharp-edge gust, and
        particularly in the calculation of stresses in the horizontal
        tail, it is important to know the downwash at the tail caused
        by the lift response of the wing to the gust. In the present
        solution for the downwash behind a two-dimensional wing, some-
        thing more than the "indicial downwash" is sought. This is
        effected by allowing the gust front itself to have an arbitrary
        horizontal velocity which, combined with the velocity of the
        airplane, U, results in the wing's penetrating the gust front
        at a velocity V.
        :for Professor H. Ashley, Aero. Eng. Dept., DIC 6727
        :by N.P.Hobbs (Res. Ass. Aero. Eng.), 40 hours
        :DCL Staff: Porter, 1 hour; WWI, 92 minutes

The quantity $C_{II}(A,X^*)$ has been calculated for A+1 X^* for four
values of X^*. Physically, this means that the downwash is now known at
four points in the wake for infinite immersion rate of the wing ($V = \infty$)
and for times such that the leading edge of the vortex sheet has not
reached the observation point. It remains to calculate $C_{II}(A,X^*)$ for
A+1 X^* and to integrate $C_{II}(A,X^*)$ to obtain the downwash for immersion
rates other than infinity.

169 B. <u>Utilizing a General-Purpose Digital Computer in Switching-Circuit
        Designing</u> to find the most economical physical realization of
        a prescribed switching function. The procedure chosen is one
        that will yield a minimum sum-of-products form of any given
        transmission function within certain limits (i.e., no more
        than 15 variables or 29 terms at present).
        :for Professor D.A.Huffman, Electrical Engineering Department
        :by E.C.Hoy (Res. Assist. E.E.), 66 hours
        :DCL: WWI, 44 minutes

A minimum sum-of-products form is obtained by applying the
following rules of Boolean algebra to the function:

1. $XY + XY' = X$

2. $X + X'Y = X+Y$

3. $X + XY = X$

4. $XY + YZ + ZX' = XY + ZY'$

All but the last of the above rules have been programmed and
tested successfully. The last has been programmed but is in the process
of being checked. An output routine has been successfully programmed that
types out the solution in standard equation form on the delayed printer.
About ninety percent of the programming has been completed. After the
last rule is checked out, only a few timing runs need be made to finish
the problem as far as Whirlwind I is involved. The results will be
analyzed and incorporated into an S.M. thesis for the Electrical Engineer-
ing Department.

171 C. <u>Improved Power Spectrum Estimates</u> are to be obtained by inves-
          tigating modifications to existing techniques for the numerical
          calculation of Fourier cosine transforms to minimize the effects
          of truncation and to supply a confidence curve, based upon the
          interval variations of the calculations, which will help to
          evaluate the significance of the resulting spectrum estimate.
          The object is to obtain a method which will give significantly
          better power spectrum estimates than can be obtained using
          existing techniques.
          :for J.E.Ward, Project Engineer, Servomechanisms Laboratory
          :by D.T.Ross(DIC), 80 hours; Hamilton, 20 hours
          :DCL: WWI, 163 minutes

        Six functions with known spectra have been run with the Improved
Fourier Transform program which uses weighting functions. Most of these
results will be incorporated directly in an S.M.thesis report for the
Electrical Engineering Department. Two of the runs give the spectral
windows for the process, which completely describe the properties of the
methods used. Examination of these results shows that considerable
information can be gained from the manner in which the successive spectra
differ. Dense packing of frequencies can be discovered by growth of
sections of the spectra, for example. A new idea for improving frequency
resolution through the use of an appropriately chosen "bump" function
will be briefly tested, although a complete study of this procedure will
not be possible before the thesis date.

172.B. <u>Overlap Integrals of Molecular and Crystal Physics</u>. Two-center
          overlap integrals are to be evaluated between various Slater
          atomic orbitals, which are of the form: (power of r) x (exp -ar)
          x (spherical harmonic). By use of prolate spheroidal
          coordinates, formulas in terms of simple functions can be
          derived for these integrals but are unsatisfactory because
          they are of formidable complexity and have false singularities.
          The integrals are evaluated by recasting the expressions in
          terms of spherical Bessel functions of imaginary argument,
          which can be generated by a high-speed computer.
          :for Professor J.C.Slater, Physics Department
          :by F.J.Corbató (Res. Asst., CMMC), 80 hours
          :DCL: WWI, 198 minutes

        The testing of the auxiliary subroutines is now in its final
stages. In particular, the master-control and one of the sub-control
routines have been tested. Test results have been obtained for two other
sub-control routines and have yet to be evaluated. The fourth sub-control
program is written and typed but untested. Finally the curve fitting
method was refined and useful fittings of physical data have been achieved.

173. **MIT Course 6.537 Spring Term 1954.** Twelve students have enrolled in the Electrical Engineering course 6.537, entitled Digital Computer Applications Practice, being given by Professor C. W. Adams. The purpose of the course is to study the advanced preparation of coded programs for automatic, electronic digital computers, in particular, for Whirlwind I. This study will include techniques for handling storage and terminal equipment, detecting errors and mistakes in programs, the control of scale factors, and the use of subroutines. Each student will program, prepare on punched tape, and execute on Whirlwind, one problem of his own choosing, making use of the CS II computer.

:DCL Staff: Combelic, 7 hours; Demurjian, 2.5 hours; WWI, 55 minutes

#173-100. The problem being programmed is the simultaneous solution of a set of linear algebraic equations by the Crout method. The upper bound on the order of the coefficient matrix is determined only by the capacity of the high speed storage. The solution is carried out in floating point arithmetic. The bulk of the program, however, is in WWI code, interpretive instructions being used only to form the inner products.

To date, the program has been tested twice on the computer. Each test resulted in the discovery of a logical programming error. These errors have been corrected and preparations have been made for a third trial run on the same fourth-order matrix with known solution.

<div align="right">Arbuckle</div>

#173-101. This problem is intended to evaluate the double integral

$$P_\mu(a) = \int_{-\infty}^{+\infty} \frac{e^{-\omega^2}}{\sqrt{\pi}} \left[\int_{-\infty}^{4+\alpha} \frac{e^{-x^2}}{\sqrt{\pi}} \, dx \right]^{\mu-1} d\omega$$

The analysis of the integral requires that the numerical evaluation of the error function be determined. Using an approximation derived by the Rand Corporation, tapes have been prepared to determine the precision to which this approximation is valid. It is desirable to obtain 8th place accuracy. So far, results show values good to 6 places. Initial evaluation of the double integral is being tried for values of $\mu = 2$ and a = 0. For these values, an analytic solution is readily obtainable and is used as a test for the numerical evaluation.

<div align="right">Brun</div>

#173-106. This problem is concerned with finding roots of a polynomial by Newton's method. The control portion of the routine seems to work successfully. However, the roots obtained are not exactly correct. At present, the program is in the process of being debugged and more runs are being made on the computer.

<div align="right">Jones</div>

#173-107. This problem is concerned with the solution of sets
of linear equations by the Gauss-Jordan reduction. The program is
intended to handle dependent as well as independent sets of equations.
The program has been coded for independent sets of equations, but has
not as yet given correct results. The routine for solving a dependent
set has been worked out but has not as yet been coded.

<div align="right">Kreide</div>

#173-110. An Arc Tangent Subroutine has been coded for CS as
partial credit for course 6.537. By applying Euler's Transformation to
the Taylor's Series Expansion about zero, the following expression was
obtained:

$$\text{Arc tan } x = \frac{x}{1+x^2}\left[V_o + y\Delta V_o + y^2\Delta^2 V_o + \ldots\right]$$

$$\text{where } y = \frac{x^2}{1+x^2}$$

$$\text{and } V_o = 1$$

$$\Delta V_o = 2/3$$

$$\Delta^n V_o = \frac{2 \cdot 4 \cdot 6 \ldots (2n)}{3 \cdot 5 \cdot 7 \ldots (2n+1)}$$

This method worked but did not prove as satisfactory as had
been hoped since about 14 terms are required for $x = 1$ to make the error
less than 10^{-5}. At present, investigation is being made of the Rand
Approximations of the Arc tangent.

<div align="right">Petrick</div>

174 C. <u>Tight Binding Calculations in Crystals</u>. The unperturbed wave
function for a crystal is approximated by a linear combination
of atomic functions. A Hamiltonian matrix is set up between
these functions. The eigenvalues of this matrix are the energy
levels of the electrons. The diagonalization of the Hamiltonian
will be done on WWI.
:for Professor J.C.Slater , Physics Department
:by G.Koster (DDL), 30 hours
:DCL: WWI, 157 minutes

During the past period it was decided that it was more efficient
for Whirlwind to calculate the matrix elements of the Hamiltonian matrix.
These matrix elements are simple polynomials of trigonometric functions.
This program has been written, tested, and is now being used to calculate
the energy levels of electrons in nickel.

175 C. <u>Impurity Levels in Crystals</u>. The calculation of impurity levels
in crystals involves the solution of difference equations
which are solved by a Green's function method. This involves
finding the inverse of matrices (H-E) where H is the unper-
turbed Hamiltonian and E is the energy of the impurity level.
The inversion will be done by Whirlwind I.
:for Professor J.C.Slater, Physics Department
:by G. Koster (DDL), 30 hours
:DCL: WWI, 97 minutes

A program has been written to calculate the inverse of H-E for a series of E values. This program has been tested and found to work. It will be applied to the calculation of impurity energy levels in a body centered cubic structure.

178 D.   Trajectory Study Against an Evading Target.assumes that the target
         evades by flying a circular course instead of the predicted
         linear one. With reference to a certain coordinate system,
         the distances between the missile and the target are computed
         for some initial guess at the independent variable time. The
         rate is observed and when the rate is sufficiently close to
         zero the corresponding value of R is considered the minimum
         passing distance.
         :for Professor H.G.Stever, Aeronautical Engineering Department
         :by C. Block(DIC), 20 hours
         :DCL: WWI, 151 minutes

     This is a trajectory study of a missile seeking an evading target. What is desired is the minimum-passing-distance of these two objects for a variety of missile velocities and target velocities and evasive courses. About 1400 runs have been made successfully. Another 600 runs have been computed by WWI but due to technical programmer's error they are not of much use. For each run the minimum-passing-distance, time, 3 parameters that define a run, and the number of iterations needed to compute the minimum-passing-distance are recorded on magnetic tape for delayed printing.

179 C.   Transient Temperature of a Box-Type Beam. The transient temperature
         response of a box beam due to a time varying heat flux input
         on one flange is calculated by an uncoupled finite difference
         procedure. Re-radiation and convection losses are neglected
         and the thermal properties of the structure are assumed constant.
         The results are to be compared with experimental test data.
         :for J.C.Loria and Professor J.W.Mar, Aeronautical Engineering
         DIC 6727
         :by L. A. Schmit Jr.(DIC),,50 hours
         :DCL: WWI, 134 minutes

     The problem is to calculate the transient temperature response in a box beam type structure due to a time varying heat flux input on one flange. Re-radiation and convection losses are neglected. Variation of the local thermal conductivity and specific heat of the structural material with temperature is neglected. Variation of the contact resistance at the web flange joint with temperature is neglected. The system does not satisfy the thin plate criteria and therefore cannot be treated as a unidirectional heat flow problem. The system is treated as two-dimensional (i.e., of unit length). The contact resistance of the web flange joint is thought to be between certain limits. Transient temperature response curves (temperature versus time) have been obtained experimentally for five representative points on the structure. The results of these calculations are intended to: 1.) show which value of the contact resistance parameter gives the best correlation with the experimental results; 2.) indicate whether the discrepancies arising from the simplifications made in this treatment can be tolerated.

Tape 179-86-4,5 ran successfully in 23 minutes (4/14/54) and gave
transient temperature response curves at five points in the structure
corresponding to the location of thermocouples in the experimental set-up.
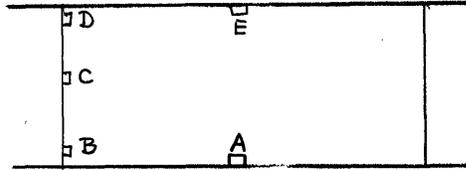
Figure 1

Schematic Cross Section of Box Beam Showing Location of Thermocouples

Comparison of the calculated and experimental transient temperature
response curves showed that: the calculated results for point A were as
much as 64°F higher(17% error) than the measured results; the calculated
results for point B were as much as 36°F lower(21% error) than the
measured results; and the calculated results for point C were as much
as 36°F lower (25% error) than the measured results.

At this point more reliable information on the thermal character-
istics of the structural material became available. This data indicated,
as did the results discussed above, that a higher value of the thermal
diffusivity should be used. Adjustment of the specific heat of the
exposed plate consistant with the new data was also made. Based on these
changes, which showed promise of an improved correlation, the 179-86-6
tape was prepared.

Tape 179-86-6 ran successfully in 25 minutes (4/23/54) and gave
transient temperature response curves at five points corresponding to
the location of thermocouples in the experimental set-up.

Comparison of the calculated and experimental transient temperature
response curves showed no appreciable improvement in correlation.

Two factors that help to explain this poor correlation are current-
ly being studied. The first is that the joint contact admittance between
the web and flange increases by as much as a factor of three with in-
creasing mean joint temperature. The detail of the web flange joint and
the use of steel screws in an aluminum structure can be shown to produce
large increases in the joint contact pressure with increasing mean joint
temperature.

The second factor previously neglected is that the exposed flange
should be considered as a thick plate with variable specific heat, rather
than as a thin plate with constant specific heat. In qualitative terms
the behavior might be thought of as a protective layer of high specific
heat being formed thus effectively protecting the inner surface to some
extent.

The point at which further use of the computer will be justified
depends upon the conclusions reached in re-examining the treatment used
in the light of the results to date.

180 B. <u>Crosscorrelation of Blast Furnace Input-Output Data.</u> It is
desired to evaluate a system function relating iron output
to coke input. This will be done by performing a cross-
correlation of the quantities and then evaluating the Fourier
transform of the crosscorrelation function.
:for Professor D.P.Campbell and C.A.Powel, Electrical Eng. Dept.
:by R. G. Mills,160 hours; H.J.Scholz,160 hours
:DCL: WWI, 261 minutes

In an effort to make an analytical study of process efficiency as
applied to production, the relatively continuous blast furnace process
was chosen as a vehicle. It is hoped that a transfer function, which will
relate coke consumed and pig iron produced, may be obtained for the
process.

The problem was conceived in an effort to extend the principles
of servomechanism analysis to the transformation of materials in an
industrial process. A number of conferences with specialists in blast
furnace operation has shown that little concrete theory and virtually no
exact operating techniques have been developed, and consequently, a
transfer function would be of utmost practical application. Much time
in the field has been spent to arrive at this result by other methods,
but no satisfactory conclusion has yet been reached. It is hoped that
this study will provide a new technique for production process analysis
and be of immediate assistance in analyzing the blast furnace operation.

The method used will be that suggested by Professor Y.W.Lee,
namely, the evaluation of the Fourier transform of the crosscorrelation
function relating input and output; these computations will be made
using 1.) nation-wide pig iron industry data covering a six-year period,
2.) data for a block of seven furnaces over the same period, and finally
3.) much more detailed data for a single furnace over a shorter period
of time.

During the past four-week period, preliminary runs, for the purpose
of trouble-shooting the several programs, have been completed, and the
cross-correlation functions for both national and seven-furnace input-output
data have been computed. Also partially complete is the computation of
the cross-correlation function for input and output of a single furnace;
the remaining portion of this computation has been programmed and will be
run in the immediate future.

The completed work represents an estimated 75% of the total
project. Yet to be completed are Fourier transforms of the cross-
correlation functions. This will be done using a CS program developed
by D.T.Ross of the Servomechanisms Laboratory and is expected to require
approximatley 90 minutes of computer time.

A minor item to be completed is the optimization of a Summer
Session sine-cosine subroutine.

Difficulties encountered have been largely programming error,
although a minor error in the Summer Session computer was discovered.

182 C. Crystal Structures. In solving a crystal structure, the
corrections to the atomic parameters are obtained by a
least squares method, as a set of n simultaneous linear
equations in n unknowns. n may be 30 or more. It is
required to solve this determinant.
:for Dr. S.C.Abrahams, Laboratory for Insulation Research
:DCL Staff: Arden, 6 hours; WWI, 72 minutes

This problem is a continuation of problem #105 to make use of
routines developed by Dr. A. Meckler under problem #134.

The inversion of the 30th order matrix associated with this
problem is proving difficult because of an eigenvalue spread of about
1000 : 1. However, it seems probable that at least a crude inverse will
be obtained.

1.3 Operating Statistics

1.31 Computer Time

The following indicates the distribution of WWI time allocated
to the S&EC Group.

Programs	68 hours, 46 minutes
Conversion	20 hours, 33 minutes
Magnetic Drum Test	40 minutes
Magnetic Tape Test	57 minutes
Scope Calibration	25 minutes
Demonstrations (#131)	1 hour , 12 minutes
Total Time Used	92 hours, 33 minutes
Total Time Assigned	99 hours, 07 minutes
Usable Time, Percentage	93.5%
Number of Programs	338

1.32 Program Time Distribution

The following table attempts to show how the WWI time expended
on S&EC programs was distributed with respect to machine runs that gave
meaningful results (productive computer time) and runs that gave unsatis-
factory results (lost computer time). Productive computer time is sub-
divided to indicate the time involved in actual computations as contrasted
with the time expended getting information out of WWI. Computer time lost
is subdivided to show the portion of time lost due to errors in the
programmer's formulation of his problem (logical errors); due to errors
in the programmer's use of the WWI code, CS Conventions, etc. (technical
errors); due to tape preparation errors; due to errors by the S&EC computer
operators in running the program; due to malfunctioning of terminal equip-
ment; and finally due to miscellaneous causes.

These times are determined as percentages of the time listed
above in section 1.31 for programs. The times used in computing these
figures are extracted from the biweekly report forms submitted by the
various programmers who have used S&EC allocated WWI time.

1. Productive Computer Time
   Computation   57.5%
   Output   13.4%
2. Computer Time Lost Due to Programmers' Errors
   Technical   19.2%
   Logical   5.9%
3. Computer Time Lost Due to Other Difficulties
   Tape Preparation   2.8%
   Operator's Errors   0%
   Terminal Equipment Malfunction   0%
   Miscellaneous   1.2%

1.33 Tape Preparation (M. Mackey)

An attempt is being made to obtain some idea of the time expended in the preparation of tapes. During the past biweekly period a check was made on the tapes processed.

Due to the variations in procedures involved we have distinguished among original complete tapes and the following three types: typed modifications - changes of 11 or more registers which must be typed, converted, then attached to the main program or changes which must be made in the body of a Flexowriter tape; manual modifications - changes punched directly in 556 form and attached to a converted tape; combined tapes - which require duplication of two or more complete tapes.

The following information was compiled:

	Complete Tapes	Typed Mods	Manual Mods	Combined Tapes
No. of Tapes	148	50	32	16
No. of Registers	27901	3879	138	
Time Consumed	84hrs.8min.	33hrs.58min.	2hrs.25min.	7hrs.8min.

Thus, it may be seen that the average length of an original complete tape is 188.5 registers requiring 34.1 minutes to prepare. A typed modification averages 77.6 registers in length and requires 40.8 minutes to prepare while Manual Modifications average 4.3 registers and require 8.3 minutes for preparation

2. COMPUTER ENGINEERING

(S.H.Dodd)

Minor troubles have continued to interrupt computer operation during the past biweekly period. In many cases the malfunctions would have been quickly found had they occurred alone, but compounded by wiring errors and cold soldered joints, or being of an intermittent nature, they caused trouble incommensurate with their severity.

A parity check has been installed on the auxiliary-storage section of the buffer drum. It has revealed an unexpected number of bad transfers from groups 4-7, in the form of spurious "ones" being read into the in-out register. The source of these spurious pulses has not yet been determined.

2.1 WWI System Operation

2.11 Core Memory (A.J.Roberts, L.L.Holmes)

A considerable amount of time was lost during the past biweekly period as a result of sudden tube failures. An intermittent short in a buffer amplifier in clock-pulse control which provides synchronizing pulses for the in-out system resulted in a loss of approximately 12 hours. An open filament in a cathode follower in one of the in-out matrices caused intermittent program alarms. Several hours were spent locating the source of this trouble. As a result of these failures, considerable thought is being given to improving in-out trouble-shooting techniques. Additional checking facilities may be required to improve the situation.

Some time was lost because of core-memory parity alarms caused by tap shorts in tubes in the digit-plane drivers.

Loss of power to one of the racks was traced to an unsoldered connection on an Allied plug-in relay. An investigation of 200 of these relays was made. Eight relays were found to have unsoldered connections. All the relays of this type in the system will be checked on the next installation day.

2.12 Magnetic Tape (A. X. Perry)

Reliability of the delayed print-out has been excellent during the last biweekly period, much of it due to the marginal-checking facilities recently installed. Some instances of reported failures were caused by programming difficulties.

All panels necessary for operating Unit 2 as a delayed print-out have arrived and will be made ready to operate shortly. Unit 2 has been converted to make use of the triangular-hub type reels and is in operable condition. Some mechanical faults have been observed but are not of a serious nature. Efforts to correct these conditions are already in progress.

2.13 _Typewriter and Paper Tape_ (L.H.Norcott)

Two Flexos were given routine periodic inspection and overhaul,
and the last new Flexowriter was modified for use with Whirlwind during
the past two weeks.

Aluminum paper guides have been installed on the back of several
Flexos. These guides have been affixed with banana plugs so that they
can be easily removed to permit access to the tape cans.

2.2 _Terminal Equipment_   (R.H.Gould)

Circuits to provide computer control of the output-printer motor
will be installed soon. Operation will be similar to the control of the
photoelectric-reader motor. The proper _si_ address will turn on the motor
and insert a delay to let it attain full speed. The motor will remain on
for a short while after the printer has been deselected and then turn off.
This time will be determined from experience with the automatic control.
The operation of the manual switch on the printer will not be affected.

Modifications to in-out control to simplify the operation of
block control and the block orders will be postponed for a week because
of a heavy load of modifications in the rest of the computer. They should
be done in two weeks. Programs using these orders will not be affected.

2.21 _Magnetic Drums_   (H.L.Ziegler)

Parity check for groups 4-7 of the buffer drum has been in op-
eration for the past week and appears to be entirely satisfactory.

To lessen trouble-shooting difficulties when the fairly large
electronic head-switching system of the auxiliary drum is put into ser-
vice, a method has been worked out to permit changeover of one digit at
a time. An additional advantage is that the changeover initially requires
only one-half the full complement of Type 3 gate-writing amplifiers.
Because of this modified requirement, changeover of digits began 26 April
instead of being held up until about 1 June as originally thought necessary.

An erasing scheme that is simple, sparing of equipment, and easy
to use has been devised for the magnetic-drum systems. Preliminary tests
are encouraging.

3. ADMINISTRATION AND PERSONNEL

Staff Transfers
(J.C.Proctor)

Alexander Vanderburgh has transferred from a DIC staff member in 6345 to a DDL staff member.

New Non-Staff Personnel
(R.A.Osborne)

Jean Harris is a new secretary in the General Engineering Group.

Mary Heywood is a new member of the Drafting Department.

George Kebler is another new member in the Drafting Room.

Stanley Olsen has joined the Electronic Construction Ship.

John Pierce is an MIT student working part time in the Tube Testing Laboratory.

Francis Shaw is a new laboratory assistant in Group 6345.

Terminated Non-Staff

George Maynard

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