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THE A-2 COMPILER SYSTEM
OPERATIONS MANUAL

15 November 1953
The A-2 Compiler System Operation Manual is a working paper intended to provide the reader (assumed to be a UNIVAC programmer) with all the information necessary to make use of the existing system. The descriptive material has been included only as necessary to introduce concepts or terminology peculiar to automatic programming or to the A-2 System.

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# TABLE OF CONTENTS

General Description .................................................. 1  
Elements of the A-2 Compiler System ................................ 3  
Rules for Subroutine Construction .................................. 5  
Permanent Constants .................................................. 8  
Rules for Generative Routines ....................................... 10  
Information Writing .................................................. 12  
Sample Problem ...................................................... 17  
Operating Instructions ............................................... 31  
A-2 Floating-decimal Subroutine Library ......................... 35  
Comments ............................................................ 50  
Glossary ............................................................... 52
GENERAL DESCRIPTION

The A-2 Compiler is a programming system for UNIVAC which produces, as its output, the complete coding necessary for the solution of a specific problem. If the problem has been correctly described to the compiler, the coding will be correct and checked (by UNIVAC) and the program tape may be immediately run without any further action.

The compiler must have available a library of subroutines. Since the A-2 Compiler was designed primarily for use in mathematical problem solving, the only library presently available is a two-word floating-decimal library containing the arithmetic, sin, cos, arctan, exponential and nth root routines. Several non-computational routines are also included as well as generalized routines for generating the data-handling subroutines. Experience gained in working with earlier compilers advised against the inclusion of specialized data-handling routines in the library.

The coding necessary for the solution of a specific problem is ordered by the programmer in a pseudo-code. This pseudo-code is called "information", and it is the information which tells the compiler how to proceed just as C-10 Code tells UNIVAC how to proceed. This pseudo-code is a new language which is easier to learn and much shorter and quicker to write. Logical errors are more easily found in information than in UNIVAC coding because of the smaller volume.

The A-2 Compiler produces a "program" which utilizes the memory as follows:

- 000 - 059  initial and special read instructions
- 060 - 170  data blocks (usually input)
- 180 - 230  working storage
240 - 779 compiled program (9 blocks per segment)
780 - 999 floating decimal arithmetic
900 - 939 common constants
940 - 999 data block (usually output)

The nine block section of compiled program is called a "segment".
Additional segments are read into this part of the memory if the compiled
program exceeds nine blocks. Control may be transferred forward or backward
from one segment to another as required by the problem.

Relatively simple changes in the compiler will make it applicable
for problems needing more data or working storage.

A compiled program may approach the best hand-tailored coding, and for
a large class of problems, the A-2 Compiler, with suitable libraries, will
cut programming and debugging time to a point where a slight inefficiency in
running time can be tolerated.
ELEMENTS OF THE A-2 COMPILER SYSTEM

1. COMPILER
The executive routine whose function is to coordinate the other elements of the programming system.

2. LIBRARY
An ordered set of subroutines and generative routines. Since the subroutines are stored in the library in relative form, they must be transformed before they can be used.

3. GENERATED LIBRARY
A set of subroutines prepared for a specific problem as ordered by the information. This library is built up from two sources.
   a) Coding produced from specifications in the information by generative routines which are in the library.
   b) New coding peculiar to this problem and of no value in other problems. This is merely copied from element 4 and built into a subroutine.

4. INFORMATION
An ordered set of instructions stated in a pseudo-code. These instructions fully describe a solution to the problem specified in a language which the compiler understands.

5. RECORD
A list in operation number order prepared by the compiler as an intermediate output, necessary in a later stage of compilation for control transfers and desirable for the programmer as a general check of the compilation or as a locator of specific sections of the final output program. There is an item in the record list for each operation which contains:
a) Call-word of subroutine used in operation;
b) Operation number;
c) Segment serial number;
d) Starting line number within segment.

6. **RUNNING PROGRAM**

The complete set of instructions in C-10 Code for solving the problem;
the final output of the compilation process.
RULES FOR SUBROUTINE CONSTRUCTION

The subroutine is the logical unit or building-block. It operates in a specific way on input data, arguments, to produce results. The compiler forces certain limitations on the form of subroutines.

The requirements for subroutines to be used with the A-2 Compiler are stated below. Those marked with an asterisk (*) are requirements peculiar to the two-word floating-decimal library.

1. Subroutines are written in relative coding starting in line 000 of the subroutine which contains the call-word. The call-word consists of four 3-digit fields.

   xxx lll f00 c0f

   xxx = The identification code (alphabetic) of the subroutine,
   lll = The number of lines in the subroutine, exclusive of the call-word and sentinel word (word of ignores) at the end.
   * f00 = A floating-decimal point subroutines.
   c0f = A sentinel which serves to identify the start of a subroutine.

2. Line 001 of the subroutine is the only entrance (exclusive of R U or generalized overflow reentries).

3. In referring to arguments, 1RG, 2PG, etc. are used instead of memory locations; i.e., B 1PG. The output of the subroutine, the results, are referred to by 1PS, 2PS, etc.

4. Normal exit from a subroutine is considered to occur when the line preceding the ending sentinel is the last line in the subroutine to be executed, or when control is transferred from any line in the subroutine to the ending sentinel. Under these conditions the next line to be executed will be the entrance line of the next compiled subroutine.
5. Any exit from the subroutine other than one of the type described above (4), is called a controlled exit and is written T 1CN or U 2CN, etc. A _skip must precede such instructions (i.e., 000000 Q 3CN).

6. References to other lines within the subroutine, require the use of an "!!" in the digit position (digit 3 or 9) preceding the 3-digit relative line number.

7. A set of the most used constants will be the memory in locations 900 - 999 when the problem is being run, and these may be referred to by fixed memory locations (see list of Permanent Constants). Constants not on this list must be included in the subroutine.

8. There are ten temporary storage locations in 890 - 899 which may be used by any subroutine.

9. The floating decimal arithmetic routines are fixed in the memory in locations 780 - 889. Any subroutine can use this section by placing A in 890, 891 and B in 892, 893, and by selecting the proper R U 0 instruction. A and B are floating-decimal operands with integers in even and exponents in odd-numbered locations.

   A + B = C       R 810 U 780
   A - B = C       R 810 U 828
   A x B = C       R 810 U 847
   A ÷ B = C       R 810 U 830

C is the result in 894, 895.

10. This section is also available to normalize numbers if the operand is placed in 894, 895, zero in RL and R 810 U 808. The result will be placed in 894, 895.
11. All subroutines must consist of an even number of lines excluding call-
number and ending sentinel.

Example: (non-functional)

```
000   XYZ012   00009%
001     V   1RG   W   890
002     V   3RG   W   892
003     R   810   U   847
004     V   894   V   1PS
005     B   894   L   911
006   00   000   T   1CN
```

```
007   A-M010   M00111
008     V   894   Q01012
```

```
009     W   1RG   U00013
```

```
010   000008   000009
```

```
011    [   ]
```

```
012     W   3PS   00   000
```

```
013     ######   ######
```

Call-word
1RG = A
3RG = B
A x B = C
1PS = C
if C > 0 → Controlled exit
Internal subroutine references
Normal exit
Constant
Temporary storage
Normal exit
Ending sentinel
PERMANENT CONSTANTS

900 R 904 U 901
901 C 905 B 904
902 A- 939 C 904
903 B 905 00 000
904 [00 000 U (fff)]
905 [ contents of rA ]

This goes to 000

Generalized Overflow

906 000800 000000
907 003000 000000
908 002000 000000
909 001000 000000
910 040000 000000
911 000000 000000
912 -000000 000000
913 010000 000000
914 -100000 000000
915 001000 000000
916 000001 000000
917 000000 000001
918 000001 000001
919 020000 000000

plus zero

minus zero - sign extractor

.1, SL1

-.1, SF1

.01

unit, left instruction

unit, right instruction, counter unit,
1 x 10^-11

unit, both instructions

.2
020 (unused)

021 050000 000000
022 099999 999999
023 (unused)

024 016666 666667
025 041666 666667
026 083333 333333
027 013888 888889
028 016841 268410
029 024801 587302
030 000000 000000
031 027557 319224
032 078539 816340
033 015915 194309
034 025052 108355
035 020876 756988
036 000111 000000
037 000000 000111
038 043429 448190
039 000000 000001

\[
\begin{array}{c}
0.5 \\
\frac{1}{2} \\
1/3! \\
1/4! \times 10 \\
1/5! \times 10^2 \\
1/6! \times 10^2 \\
1/7! \times 10^3 \\
1/8! \times 10^4 \\
1/9! \times 10^5 \\
\pi/4 \\
1/2\pi \\
1/11! \times 10^7 \\
1/12! \times 10^8 \\
\text{address extractor left} \\
\text{address extractor right} \\
\log_{10} 10^8 \\
\text{CF constant}
\end{array}
\]
RULES FOR GENERATIVE ROUTINES

Some routines in the library are called generative routines rather
than subroutines. If the information calls for one of this class of routines,
the normal compilation process is interrupted and the generative routine
is executed rather than copied. The requirements placed on these generative
routines by the compiler are as follows:

1. The first line of the generative routine is 360. This must be a call-
word identifying the generator, i.e., GHICCO  F0000F. Only a generative
routine may be identified by a call-word, beginning with "G".

2. Line 361 is the entrance line. The compiler will read the 360 - 419
block into the memory and then transfer control to line 361 leaving the
input register empty.

3. The library, including all generative routines, is on Servo 6. If the
generative routine is more than a block long it will read itself into
429 - 999 leaving R1 empty.

4. The exit line of the generative routine must read 00 000  U 002).
When control is transferred to 002 the compiler will be reread into the
memory.

5. The specifications for the generative routine are included with the
information in the line(s) immediately following the call-word for the
generative routines. The section of the compiler coding which picks up
successive words of information is used by the generative routine to
obtain these specifications. The instruction pair, R 073  U 069,
will place successive words of specifications in 103, until the
requirements of the generator are met.

6. Each finished line of generated coding should be placed in 101. The
instruction pair, R 064  U 059, will enable this line to be transferred
to the output block. Lines of generated coding are counted and completed blocks are written on the generated library tape by the compiler.

7. The output of the generative routine will ordinarily be C-10 Code relative to CCG, or may be any modifications thereof which are understood by the compiler. (See rules for Subroutine Construction)

8. The compiler will put a call-word in the CCO position of the first block of generated coding. It will insert a pair of skip orders at the end of the coding if necessary to make it an even number of lines, then insert a word of ignores, and write the routine on the generated library tape.
INFORMATION WRITING

In order to produce a running program for the solution of a problem, the compiler must be supplied with information describing the sequence of operations in the solution. Every running program will have certain standard blocks necessary to perform the functions required by all problems.

There are five blocks written on the running tape before compilation takes place.

Block 1 - An initial read block which will read blocks 2 through 5 into the running program memory in fixed locations for the duration of the problem. This block is replaced in 000-059 by the special read instructions.

Block 2 - A partial block of permanent constants to occupy 900-939.

Block 3 - Floating-decimal arithmetic, 720-739

Block 4 - Floating-decimal arithmetic and temporary storage, 840-899.

Block 5 - Special read instructions, 000-059. This block contains the forward and backward reads which make possible the transfers from one segment to another.

As the running program is executed, the arguments are first placed in the working storage block. Each computational step operates on these arguments and places the results in the working storage block. Accordingly, planning the computation largely consists of planning the use of this block. Each operation, ordered by a call-word, must include words which specify the location of operands and the location where the result is to be placed in working storage.

Information is written, operation by operation, using the following types of call-words with appropriate additional words: standard call-words using
three-address form; call-words for subroutines requiring single-address form;
genrative routine call-words; new coding call-words; and sentinel call-words.
These types of call-words are described in detail below.

Three-address Call-words

Many mathematical subroutines call for two or less arguments and one
result. In referring to such subroutines, only one word of information is
required.

Example:

\[ \text{A + B = C} \quad \text{AMO(A)} \quad \text{(B)(C)} \]
\[ \text{\sin x = Y} \quad \text{T30(x)} \quad \text{COCO(y)} \]

The brackets indicate a three-digit field. The programmer fills in
any even number in the COO-058 range, which corresponds to the relative
position of this quantity in the working storage block.

NOTE: The floating decimal library includes a translator which expands to
single address form this line of information, so if new subroutines are added
to the floating-decimal library, their full 12-digit call-words must be added
to the list incorporated in the translator. (Block 5 of Floating Decimal
library tape)

Single-address Call-words

Some subroutines require other than two arguments and a result as
provided for in the three-address call-words. The information calling for
such a subroutine must be written in the one (single-address) form.

Example:

\[ \text{10002} \quad \text{POPOG} \]
\[ \text{10000} \quad \text{MIN(x)} \]
\[ \text{10000} \quad \text{COP} \]
\[ \text{20000} \quad \text{(ten #))} \]
\[ \_ _ _ _ _ _ _ _ _ \text{13} \_ _ _ _ _ _ _ _ _ \]
The Q20 subroutine is a four-line routine in the floating-decimal library. When executed it brings one operand from working storage and tests to see if it is a word of sentinels (2s). It has two controlled exits, (1CN and 2CN) depending upon the results of this test. (h is the current operation number of the sequence, (x) is the address of the argument in working storage, (op)#B) is the operation number to which control is to be transferred if the test is met, and (op)#A) is for all the other cases.)

Generative Routine Call-words

An operation calling for a routine of the generative type requires three or more lines of information.

Example:

```
000002
080006
BLOCKA
180000
```

The first line is a call for the G11 generative routine. The 002 indicates that this routine requires two lines of specifications. The next two lines are specifications interpreted by the generative routine, and the last line is a "dummy" argument required by the compiler for any operation which cannot be fully described in one line. The dummy argument must include operation number (hhhh) in the problem sequence.

New Coding Call-words

New coding, if used, requires a minimum of three lines of information.

Example:

```
080002
810000 820000
830000 900000
180000
```
The sample problem which follows illustrates all of the different types of information, except the "segment" sentinel.
STATEMENT OF THE OPTICAL RAY PROBLEM

Evaluate the optical rays which will result from passing given rays through given surfaces. The rays are defined by \( X, Y, Z, L, M, \) and \( N. \)

The surfaces are defined by \( 1/r, n, n', \) and \( d. \)

The equations are as follows:

\[
\sin^2 I = [(X/r - 1)^2 + (Y/r)^2 + (Z/r)^2 - [L(X/r - 1) + M(Y/r) + N(Z/r)]^2 (1)
\]

\[
\sin^2 I' = (n/n')^2 \sin^2 I (2)
\]

\[
\cos I = (1 - \sin^2 I)^{1/2} (3)
\]

\[
\cos I' = (1 - \sin^2 I')^{1/2} (4)
\]

\[
K = (n/n' \cos I) - \cos I' (5)
\]

\[
p = \frac{[X(X/r - 1) + Y(Y/r) + Z(Z/r) - X]}{\cos I - [L(X/r - 1) + M(Y/r) + N(Z/r)]} (6)
\]

\[
X_1 = X + Lp
\]

\[
X' = X_1 - d
\]

\[
Y' = Y + M_p
\]

\[
Z' = Z + N_p
\]

\[
L' = n/n' L + K(X_1/r + 1)
\]

\[
M' = n/n' M + K(Y'/r)
\]

\[
N' = n/n' N + K(Z'/r)
\]

The resultant ray
The given rays are as follows:

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>L</th>
<th>M</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1.245093</td>
<td>.89258</td>
<td>.96126</td>
<td>-.2.156435</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>- .840292</td>
<td>.01134</td>
<td>.93969</td>
<td>-.3.420274</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1.245093</td>
<td>.39864</td>
<td>.93969</td>
<td>-.3.420274</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>-1.080377</td>
<td>.829435</td>
<td>.90272</td>
<td>-.1.3916</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>1.245093</td>
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</tr>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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<td>.053824</td>
<td>.96126</td>
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<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The given surfaces are as follows:

<table>
<thead>
<tr>
<th>1/r</th>
<th>n</th>
<th>n'</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.463823650</td>
<td>1</td>
<td>1.553</td>
</tr>
<tr>
<td>2</td>
<td>.108705950</td>
<td>1.553</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>-.0876827</td>
<td>1</td>
<td>1.631</td>
</tr>
<tr>
<td>4</td>
<td>-.453605361</td>
<td>1.631</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>.17777657</td>
<td>1</td>
<td>1.625</td>
</tr>
<tr>
<td>6</td>
<td>-.14830923</td>
<td>1.625</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

- 18 -
PROBLEM ANALYSIS

It was decided to use the Floating-Decimal Subroutine Library for the computation.

A cursory glance at the amount of calculation necessary to take one ray through one surface seemed to make it inadvisable to pass all rays through successive surfaces in parallel. To simplify data-handling one tape was prepared with one ray described in each block of data. The surfaces were described, one per block, on a second data tape.

Because the ray tape was longer than the surface tape, it was decided to pass one ray through all surfaces, put out the result, rewind the surface tape, and repeat for successive rays. The flow chart illustrates this plan.

RUNNING PROGRAM - MEMORY ALLOCATION

000 - 059 Initial read and special read instructions (standard)
060 - 119 Input Block - ray data
120 - 179 Input Block - surface data
180 - 239 Working Storage (standard)
240 - 779 Running Program
780 - 839 Arithmetic - 2-word floating-decimal \{ Used by subroutines
840 - 899 Arithmetic and Temporary Storage
900 - 939 Permanent Constants
940 - 999 Output Block - resultant ray data

As the running program is executed, the arguments are brought from the working storage block, and the results are deposited in the working storage block. Accordingly, planning the computation consists of planning the use of this block with the capabilities of the subroutine library in mind.
FLOW CHART OF OPTICAL RAY PROBLEM

START

CONSTANTS → W. S.

Nth RAY → W. S.

WRITE Zs ON OUTPUT

ARE ALL RAYS USED?

Yes

REWIND ALL TAPES

STOP

No

ARE ALL SURFACES USED?

Yes

RESULT RAY → OUTPUT

No

Mth SURFACE → W. S.

M + 1 → M

WRITE OUTPUT

REMIND SURFACES

N + 1 → N

COMPUTE Nth RAY THRU Mth SURFACE
# Optical Ray Problem - Use of Working Storage

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<th></th>
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<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
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<td>Z</td>
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<td>L</td>
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<tr>
<td>45</td>
<td>X'</td>
<td>46</td>
<td>Y'</td>
<td>47</td>
<td>Z'</td>
<td>48</td>
<td>n'/n' L</td>
</tr>
<tr>
<td></td>
<td>52</td>
<td></td>
<td>L'</td>
<td></td>
<td></td>
<td></td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td></td>
<td>N'</td>
<td></td>
<td></td>
<td></td>
<td>59</td>
</tr>
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<td>14</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>22</td>
<td>24</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>6</td>
<td>1/r</td>
<td>6</td>
<td>n</td>
<td>6</td>
<td>d</td>
</tr>
<tr>
<td>27</td>
<td>(1-sin^2T)</td>
<td>32</td>
<td>K</td>
<td>6</td>
<td>d</td>
<td>8</td>
<td>X/r</td>
</tr>
<tr>
<td>9</td>
<td>-(X/r - 1)</td>
<td>54</td>
<td>Y'/r</td>
<td>49</td>
<td>X_2/r</td>
<td>55</td>
<td>Y'/r</td>
</tr>
<tr>
<td>50</td>
<td>-(X_2/r - 1)</td>
<td>51</td>
<td>(X_3/r - 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>30</td>
<td>32</td>
<td>34</td>
<td>36</td>
<td>38</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Z/r</td>
<td>12</td>
<td>(X/r - 1)^2 = A</td>
<td>13</td>
<td>(X/r)^2 = B</td>
<td>14</td>
<td>(L/r)^2 = C</td>
</tr>
<tr>
<td>57</td>
<td>Z'/r</td>
<td>15</td>
<td>A+B</td>
<td>16</td>
<td>A+B+C</td>
<td>23</td>
<td>sin^2 I</td>
</tr>
<tr>
<td>58</td>
<td>K Z'/r</td>
<td>24</td>
<td>n'/n'</td>
<td>25</td>
<td>(n'/n')^2</td>
<td>29</td>
<td>cos I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>cos I</td>
<td>40</td>
<td>-ρ</td>
<td>31</td>
<td>n'/n' cos I</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>Y/r = H</td>
<td>43</td>
<td>Y/ρ</td>
<td>35</td>
<td>Z/r = I</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>0+H+I</td>
<td></td>
<td></td>
<td>38</td>
<td>J</td>
<td>44</td>
</tr>
</tbody>
</table>
An outline of the data-handling, computation, and control steps for the problem solution is given below:

A. The given equations contain certain constants which can be moved into the working storage block and left there.
   Op # 0  Read constants into input block
   Op # 1  Move constants to working storage

B. The flow chart next shows a ray being moved to working storage.
   Op # 2  Read ray into input block
   Op # 3  Move ray to working storage

C. The next box calls for a test to see if all rays have been used.
   Op # 4  Test for sentinel. If not, go on to the next operation.

D. Next, a surface is moved to the working storage area.
   Op # 5  Read surface into input block
   Op # 6  Move surface to working storage

E. Test to see if all surfaces have been used, and if not, go on to the next operation.
   Op # 7  Test for sentinel

Now the computation can be planned and the operations explicitly stated starting with operation 8. The chart represents working storage area for each 2-word floating-decimal number. The odd-numbered locations are not shown because the numbers are arranged so that the exponent follows each quantity, and the two words are always handled together. The numbers at the left in each box are operation numbers.

F. Compute sin² I from equation (1)
   Op # 8  Multiply X · 1/r = X/r
   Op # 9  Subtract X/r - 1

   - 22 -
Op # 10 Multiply $Y \cdot \frac{1}{r} = \frac{Y}{r}$
Op # 11 Multiply $Z \cdot \frac{1}{r} = \frac{Z}{r}$
Op # 12 Multiply $(X/r - 1)^2 = A$

G. Compute $\sin^2 I$ from equation (2)
H. Compute $\cos I$ from equation (3)
I. Compute $\cos I'$ from equation (4)
J. Compute $k$ from equation (5)
K. Compute $X_1$ and $Y_1$, $Z_1$, $L$, $M$, $N$: the resultant ray.
L. Return and repeat D

Op # 61 Unconditional transfer to Operation 5

M. Entry point from E when ray has passed through all surfaces.
Op # 62 Transfer ray from working storage to output block
Op # 63 Write output block and rewind surface tape for next ray
Op # 64 Unconditional transfer to Operation 2

N. Entry point from C. All rays have passed through all surfaces.
Operation 3 sent sentinels to working storage instead of ray.
Op # 65 Transfer sentinels from working storage to output block.

O. End of Problem
Op # 66 Write sentinel block twice, rewind all tapes and stop.

The foregoing analysis demonstrates the manner in which the problem is broken down into operations, each of which can be executed by a single subroutine. Now all that is necessary is to translate the operation descriptions into A-2 information by providing the proper call-words and associated arguments, results, etc., as required. Normally, information can be written directly from the flow-charts and the equations.
It may be helpful to explain in detail the meaning of the information for a few of the different operations in the optical ray problem (page 26).

Operation 0 is a read routine which does not appear in the library. The first line contains the new-coding sentinel, with the number of lines of coding (001) in digits 10, 11, 12. The second line is the line of new coding to be inserted in the running program. The third line is a required dummy line (the "lrg" has no meaning here) with the operation number (00000) in digits 5, 6, 7, 8, 9.

Operation 1 calls for a generative subroutine which produces the proper instructions for data transfers in the memory, the first line contains the call-word to be used in searching the library tape. Digits 10, 11, 12 indicate the number of lines of specifications (001) which follow the call-word. The specifications (second line) indicate that 4 words (040) are to be transferred starting with line 60 (060), to another area of the memory beginning at line 192. The third line is the dummy word again, and indicates Operation 1.

Operation 4 is an example of information in the single-address code. The first line is the call-word, identifying the subroutine. Digits 4, 5, 6 indicate the number of lines of coding (004) in the subroutine when it is inserted in the running program. Digits 7, 8, 9 state that this is part of the floating-decimal library (FOO). The ignore in position 12 is a sentinel signifying a call-word. The second line, in digits 10, 11, 12, states the position in working storage of the argument (lrg) required for this subroutine. Digits 5, 6, 7, 8, 9 of the lrg line always contain the operation number (00004) This is a sentinel test routine; two exits are required. These are specified in lines 3 and 4. If the test is not passed the first exit (lcn) is to operation 5 (00005). If the test is passed the second exit (2cn) is to operation 65 (00065).
Operation 8 shows the three-address type of information, requiring only one word to call for the subroutine and specify the operands. Reading from the left, "AMO" designates "arithmetic, multiply" (this will be a floating-decimal multiplication since we are working with that library); "000" is the location of the multiplier in working storage, "X" in this problem; "016" is the location of the multiplicand (1/r); and "024" indicates where the result (X/r) shall be placed.

The last word of information, following Operation 66, is the ending sentinel.
### INFORMATION FOR OPTICAL RAY PROBLEM

<table>
<thead>
<tr>
<th>Op.</th>
<th>GMNL.CQ</th>
<th>DFL.001</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>GMNL.CQ</td>
<td>DFL.001</td>
<td>Read necessary constants from T2 into O60, leaving RI empty</td>
</tr>
<tr>
<td></td>
<td>120000</td>
<td>300060</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1PG000</td>
<td>000000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>GMNL.CQ</td>
<td>DFL.001</td>
<td>Move constants to W. S. block</td>
</tr>
<tr>
<td></td>
<td>000001</td>
<td>040192</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1PG000</td>
<td>001000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>GMNL.CQ</td>
<td>DFL.001</td>
<td>Read ray into O60 block leaving RI empty</td>
</tr>
<tr>
<td></td>
<td>120000</td>
<td>300060</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1PG000</td>
<td>002000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>GMNL.CQ</td>
<td></td>
<td>Move ray to W. S. block</td>
</tr>
<tr>
<td></td>
<td>000001</td>
<td>120180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1PG000</td>
<td>003000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>GMNL.CQ</td>
<td></td>
<td>If 000 holds valid ray, go on to Op. 5, if Z's are in 180, go to Op. 65</td>
</tr>
<tr>
<td></td>
<td>020004</td>
<td>F00001%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1PG000</td>
<td>004000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1CH000</td>
<td>000005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2CH000</td>
<td>000065</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GMNL.CQ</td>
<td>DFL.001</td>
<td>Read surface into 120 block leaving RI empty</td>
</tr>
<tr>
<td></td>
<td>150000</td>
<td>300120</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1PG000</td>
<td>005600</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GMNL.CQ</td>
<td></td>
<td>Move surface to W. S. block</td>
</tr>
<tr>
<td></td>
<td>000001</td>
<td>080196</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1PG000</td>
<td>006000</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7</td>
<td>070004</td>
<td>FC0001</td>
<td>If 016 holds valid surface, go on to Op. 8; if Z's are in 016, go to Op. 62</td>
</tr>
<tr>
<td>9</td>
<td>016024</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>016026</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>016028</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>024030</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>026032</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>028034</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>032030</td>
<td>A + B</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>034032</td>
<td>A + B + C</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>024036</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>026038</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>028040</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>038036</td>
<td>D + E</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>040038</td>
<td>D + E + F</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>038040</td>
<td>(D + E + F)^2</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>040034</td>
<td>(A + B + C) - (D + E + F)^2 = sin^2 I</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>020030</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>030032</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>034036</td>
<td>(n/n')^2 sin^2 I = sin^2 I'</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>034018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>036040</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>014034</td>
<td>(1 - sin^2 I)^{1/2} = cos I</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>014032</td>
<td>(1-sin^2 I')^{1/2} = cos I'</td>
<td></td>
</tr>
</tbody>
</table>
\( \text{form } n/n' \cos I \)

\( (n/n' \cos I) - \cos I' = K \)

\( X(X/r - 1) = C \)

\( Y(Y/r) = H \)

\( Z(Z/r) = I \)

\( G + H \)

\( G + H + I \)

\( (G + H + I) - X = J \)

\( \cos I - (D + E + F) = Q \)

\( j/o = \rho \)

\( \text{form } L\rho \)

\( \text{form } M\rho \)

\( \text{form } N\rho \)

\( X + L\rho = X_1 \)

\( X_1 - d = X' \)

\( Y + M\rho = Y' \)

\( Z + N\rho = Z' \)

\( n/n' L \)

\( X_1/r \)

\( X_1/r - 1 \)

\( K(X_1/r - 1) \)

\( n/n' L + K(X_1/r - 1) = L' \)

\( n/n' M \)

\( y'/r \)

\( K(y'/r) \)

\( K(y'/r) + n/n' M = M' \)

\( z'/r \)

\( K(z'/r) \)

\( n/n' N \)
60  AA0000  020000  \frac{v}{p} V + K(\pi r) = N^1

61  U00002  F00002  Go back to Op. 5
     1RG000  060000
     1CN000  000005

62  GM0000  060000  Move resultant ray to output block
     000180  170940
     1RG000  062000

63  QNL.CQ  DEL.CQ1  Write output block and rewind surface tape
     740940  620000
     1RG000  063000

64  U00002  F00002  Go back to Op. 2
     1RG000  064000
     1CN000  000002

65  GM0000  000001  Move \Pi's to output block
     000180  010940
     1RG000  055000

66  QNL.CQ  DEL.CQ4  Write 2 bks. of sentinels, rewind all tapes and stop
     740940  740940
     840000  820000
     830000  810000
     900000  900000
     1RG000  066000

FINNL  INPG 2
A few statistics on this problem may be of interest.

After the flow-chart was drawn, the information was written in one-half a day. The problem was compiled in 2 1/2 minutes, and was solved in 3 1/2 additional minutes. The running program was just over one segment. (This could have been avoided, but it was designed to test the compiler)

The data-handling is cumbersome because the CAT' generative routine was the only one in existence at the time.
OPERATING INSTRUCTIONS

1. Mount tapes as follows:
   Servo 1  A-2 Compiler  with ring
   Servo 2  blank         no ring
   Servo 3  blank         no ring
   Servo 4  Information   *
   Servo 5  blank         no ring
   Servo 6  Subroutine library  with ring
   * If the information is to be retained, insert a ring, and retain
     comma breakpoint.

2. Initial read Servo 6, and let it run on continuous.
   * When stopped on the comma breakpoint, remove the tape from
     Servo 4, and substitute a blank with no ring. Release breakpoint.

3. Normal printouts are:
   "end translation"
   "end Sweep 1"
   "end Sweep 2"
   "end compile"

4. The running program is on Servo 4. Put in a ring, label it, and move
   it to Servo 1 if the problem is to be run immediately.

Error print-outs which may occur during compilation:

1. [ word of info. ]  If this print-out occurs before "end of
   translation" has been written on the supervisory
   control, the programmer has written a word of
   information which has been identified as a call-
   word to be translated, but the complete 12-digit

- 31 -
2. [ word of info.]
   NOTS T0FED
   If this print out occurs after "end of translation" has been printed on the supervisory control, and before "end S-1" has been printed, the programmer has called for a generative routine which is not in the library.

3. [ word of info.]
   INFQ WORDS?
   A word of information has failed to satisfy any of the tests. There may be a transcription error.

4. [ word of info.]
   NDSE Q-OUTY?
   The word of information carries an operation number (h) which is not in the expected sequence. Line 059 is a variable line which is now prepared to pick up this word in the current block of information. (120-179) A search around this location should help identify the offending word if it is not immediately recognizable.

5. [ word of info.]
   SEGME NT...
   TOOL ARGED
   This print-out indicates that the programmer has enclosed more than the 539 allowable lines with the "segment" sentinels. The two words of information (a call-word and first argument) will locate the subroutine which will not fit in the segment.

6. [ word of info.]
   MLCH INFOY
   The compiler can store no more than sixty descriptive words (i.e., argument, control or
result word) applying to a single call-word. This print-out indicates that the limit has been exceeded. Memory location 660 will contain the call-word, and the 660 block contains the words of information that have been stored.

7. **NEWL** **N.LIB**
   [ word of info. ]
   The word of information is a call-word for a subroutine which is not in the library.

8. **NEWLS TOPED**
   [Line of Subroutine]
   [1RG or 2PS or 3CN etc.]
   Memory location 660 contains the call-word for the current subroutine. This subroutine has a line which contains 1PS, for example, in lieu of an address. The information ordering this subroutine did not include a word, 1PS000 CO0(x), stating the specific address for this result.

9. **NEWL** **TAPE**
   The running tape is 1955 blocks long. If this is expected, and there is no danger of running off the tape, SCICR to 529 and let it run.

**NOTE:** As a general rule, after an error print-out, it will be better to correct this information and recompile. A word of zeros can be inserted to block out incorrect words of information.
All subroutines in the floating-decimal library are built to operate on quantities $(\bar{A})$ represented by two computer words $(A$ and $a')$, where $\bar{A} = A \cdot 10^{a'}$. The number $A$ has a sign and eleven digits to the right of the decimal point; the number $a'$ has the sign of the exponent and eleven digits to the left of the decimal point.

**Examples:**

<table>
<thead>
<tr>
<th>Quantity $(\bar{A})$</th>
<th>Floating-Decimal Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>- .006</td>
<td>-00000 000000 = A</td>
</tr>
<tr>
<td>- 60</td>
<td>-00000 000002 = a'</td>
</tr>
<tr>
<td>+ 3025.5</td>
<td>-00000 000003 = a'</td>
</tr>
<tr>
<td>+.030255</td>
<td>030255 000000 = A</td>
</tr>
<tr>
<td></td>
<td>000000 000004 = a'</td>
</tr>
<tr>
<td></td>
<td>030255 000000 = A</td>
</tr>
<tr>
<td></td>
<td>-00000 000001 = a'</td>
</tr>
</tbody>
</table>

Except where specifically mentioned, the subroutines are designed to produce results accurate to at least ten digits for inputs of any size. The subroutines have been computer-tested for at least thirty different operands covering the complete range of allowable inputs.
A-2 FLOATING-DECIMAL SUBROUTINE LIBRARY

Add
Subtract
Multiply
Divide
Add to a limit
Change sign
Raise variable to a power
Input Generator
Move Generator
Output Generator
Logarithm
Root
Arctan
Cosine
Sine
Exponential
Test for Sentinel
Unconditional Transfer
Type-in
Print-out

AAC004  F00001
AS0004  F00001
AM0004  F00001
AD0004  F00001
AAL012  F00001
AN1002  F00001
APH048  F00001
GMI000  F00001
GMI000  C00001
GMI000  F00001
LAU118  F00001
RNA154  F00001
TAT118  F00001
TC0100  F00001
TS0106  F00001
X+AC96  F00001
QZ0004  F00001
U00002  F00001
BTI002  F00001
TTY004  F00001
Operation Performed - floating-decimal arithmetic

\[ \bar{A} + \bar{B} = \bar{C} \]
\[ \bar{A} - \bar{B} = \bar{C} \]
\[ \bar{A} \times \bar{B} = \bar{C} \]
\[ \frac{\bar{A}}{\bar{B}} = \bar{C} \]

[ \bar{A} = A, a' = normalized number and its exponent ]

Allowable Inputs

Full floating-decimal range.

Form of Information

\[ \text{AAO}(A) \quad (B)(C) \]
\[ \text{ASO}(A) \quad (B)(C) \]
\[ \text{AMO}(A) \quad (B)(C) \]
\[ \text{AOO}(A) \quad (B)(C) \]

(A) means to insert the relative address of A in working storage (000 - 058).

The normalized number must be in the even location with its exponent in the next higher location.
Operation Performed - floating-decimal add to a limit

\[ \bar{x} + \Delta \bar{x} \rightarrow \bar{x} \]

If \( \bar{x} = \bar{L}_X \), \rightarrow 2CH

If \( \bar{x} \neq \bar{L}_X \), \rightarrow 1CH

(\( \bar{x} = x, x' \))

Form of Information

\[
\begin{align*}
\text{AAL012} & \quad \text{FOCOT} \\
1\text{RG00h} & \quad \text{hhh} ( ) \\
2\text{RG000} & \quad \text{ccc} ( ) \\
3\text{RG000} & \quad \text{ccc} ( ) \\
4\text{RG000} & \quad \text{ccc} ( ) \\
5\text{RG000} & \quad \text{ccc} ( ) \\
6\text{RG000} & \quad \text{ccc} ( ) \\
1\text{CN000} & \quad 0 \ ( \text{op} \rightarrow ) \\
2\text{CN000} & \quad 0 \ ( \text{op} \rightarrow ) \\
1\text{PS000} & \quad \text{ccc} ( ) \\
2\text{PS000} & \quad \text{ccc} ( ) \\
\end{align*}
\]

The limit of \( X \) should be one increment larger than the largest \( X \) on which calculations are to be performed.
Operation Performed - floating-decimal number transfer
- IBC $\rightarrow$ IBS

Form of Information

\( AN1(IGC) COC(IRS) \)

( ) = The working storage location of the quantity involved.
Operation Performed - raise to an integral power.

\[ u^n = v \]

(U, n, and V all in standard two-word floating-decimal form)

Allowable Inputs

n must be a whole number. If n is greater than 9 the routine asks if it should continue, and then stops. Hit the start bar to continue.

Form of Information

\[ A^n (u) (n)(v) \]

Note: In a problem involving this routine, n must be included with the input data, or brought into the working storage block separately before this routine is called for.
Operation Performed

A generative routine which will produce the coding necessary to move successive items from an input block to working storage, reading (non-continuous) from tape initially and after the last item is transferred out of the input block.

Form of Information

GM1000 C00002
ITILKS WS,(w)
SERVOh BLOCKX
1500hh hhh000

SS = 1, 2, 3, 4, 5, 6, 7*, 10, 12, 15, 20 or 30

(* 7 items per block, last four words in block filled with zeros)

w = relative working storage address for first word of item. (000 - 059)

if SS > 1; w must be even

if SS > 9; w must be divisible by 10

n = any servo number

X = A or B only, A = 060 block, B = 120 block

h = the operation serial number

ANALYSIS OF THE TWELVE GENERATE SUBROUTINES

<table>
<thead>
<tr>
<th>SS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>15</th>
<th>20</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>of lines</td>
<td>8</td>
<td>8</td>
<td>80</td>
<td>52</td>
<td>70</td>
<td>48</td>
<td>42</td>
<td>8</td>
<td>42</td>
<td>52</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Av. time millisecond for item</td>
<td>2.59</td>
<td>2.67</td>
<td>5.59</td>
<td>4.78</td>
<td>7.07</td>
<td>5.18</td>
<td>6.65</td>
<td>3.00</td>
<td>8.66</td>
<td>12.67</td>
<td>5.44</td>
<td>6.17</td>
</tr>
</tbody>
</table>

Note: The coding produced by this generative routine does not include the sentinel test which will recognize the end of the data.
Operation Performed

A generative routine which will produce the coding necessary to move one or more (consecutive) words from one area within the memory to another area within the memory.

Form of Information

\[
\begin{align*}
00000 & \ 000001 \\
000(m_1) & \ dd0(m_2) \\
15000 & \ hhh000
\end{align*}
\]

\(dd\) = the number of words to be moved
\(m_1\) = the location of the first word
\(m_2\) = the location to which the first word is to go.

Note: If this routine is used to move a quantity into working storage, the absolute location, 180 - 239, must be used rather than the relative location, 000 - 059.
Operation Performed

A generative routine which will produce the coding necessary to move items from working storage to consecutive lines in the output block, writing the output on tape when the block is full.

Form of Information

| GM0000 | 000002 |
| US.(w) | ITEMSS |
| ONSERV | Q.FLXX |
| IFO0h | hhh000 |

SS = 1, 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 30

(* Block will be written after seven items have been placed in it.)

w = relative working storage address for first word of item (000 - 059)

if SS > 1; w must be even

if SS > 9; w must be divisible by 10

n = any servo number

x = not variable, 940 block is only output block

h = the operation serial number.
Operation Performed - compute the logarithm

Given: U and $\log_{10} A$
Calculate: $\log_{A} U$

Allowable Inputs
U must be greater than zero

Form of Information

$\text{LAU}(U) \quad (\log_{10} A)(\log_{A} U)$

( ) means the relative working storage address of the quantity called for.

Note: In a problem involving this routine, $\log_{10} A$ must be included with the input data, or brought into the working storage area separately before the routine is called for.

\[
\begin{align*}
\log_{10} 2 &= 0.30102 \quad 999566 \\
\log_{10} 10 &= 0.00000 \quad \text{(in 938)} \\
\log_{10} e &= 0.43429 \quad 448190 \quad \text{(in 913)} \\
\log_{10} 10 &= 0.00000 \quad 0.00001 \quad \text{(in 917)}
\end{align*}
\]

Accuracy

This subroutine has not been fully checked.
Operation Performed - compute nth root

Given: N and A

Calculate: \( N\sqrt[\text{A}] \)

Allowable Inputs

A may be any size, but N must be no greater than A.

Form of Information

\[ \text{PHA}(A) \quad (N)(\sqrt[\text{A}] \) \]

(\( \cdot \)) means the relative work storage address of the quantity called for.
Operation Performed - trigonometric functions

\[ \arctan A = V \]
\[ \cos A = V \]
\[ \sin A = V \]

Allowable Inputs

The input quantity is in radians, and may be of any size.

Form of Information

\[ \tan(A) \quad 000(V) \]
\[ \cos(A) \quad 000(V) \]
\[ \sin(A) \quad 000(V) \]

( ) means the relative working storage address of the quantity called for.
Operation Performed: raise to a power

Given: \( U \) and \( \log_{10} \theta \)

Calculate: \( \theta^U = V \)

Allowable Inputs

The input quantities may be of any size except the multiplication of \( U \) times \( \log_{10} \theta \) must not result in an exponent greater than \((-00000\ 00000)\) or less than \((-00000\ 00001)\).

Form of Information

\[
X+U(\theta) \quad (\log_{10} \theta)(V)
\]

( ) means the relative working storage address of the quantity called for.

Accuracy

The routine has not been thoroughly computer checked, but the results are accurate as far as we have been able to check them with existing logarithm tables.
Operation Performed:

Compares an operand with a word of 2s.

If # --> 1CH
If = --> 2CH

Form of Information:

```
020004 F1000Fh
1'608h addr(w)
1CH000 0(op#)
1CH000 0(op#)
```

w = relative working storage address of operand

h = the operation serial number

op# = the operation number to which control is to be transferred.
Operation Performed
An unconditional transfer

Form of Information

\( h = \text{the operation serial number} \)

\( \text{op} \neq \text{the operation to which control is to be transferred.} \)
Operation Performed - type in; print out

BTI calls for four type-ins

YTO prints out four quantities and then stops

Form of Information

\[ \text{BTI}(A) \ (B)000 \]
\[ \text{YTO}(A) \ (B)000 \]

\[ A = \text{location of first type-in or print-out, } A + 1 \text{ is assumed to be the location of the second type-in or print-out} \]

\[ B = \text{location of third type-in or print-out, } B + 1 \text{ is assumed to be the location of the fourth type-in or print-out.} \]
The system described herein has a certain amount of built-in flexibility. It is the original A-2 Compiler with modifications I and II. Much greater flexibility can be achieved by programmers familiar with the compiler coding. The following remarks will indicate some of the changes which could be made to the existing compiler.

The running program memory allocation should be variable. Some problems might require only one block of compiled program to be memory-contained, with the remainder of the memory free for data, and/or routines fixed in the memory as are the present floating decimal arithmetic routines.

Once a subroutine has been compiled, it should be possible to modify its exits and its references to working storage, so it can be reused with other operands in another portion of the program. As currently written the A-2 Compiler recompiles such a routine each different time it is called for.

Compilation time can be shortened a great deal. A call for a floating-decimal arithmetic routine necessitates a library search to obtain the proper and transfer orders. The compiler could recognize this type of call-word and generate the necessary orders. The library should have generative routines in one section and other routines in a separate section since the two types are searched for at different times in the compilation process. However, it should be emphasized that since compilation time must be compared with human programming time, and since the product is a ready-to-use, checked, program tape, compilation time is not significant.

The compiler should make the working storage memory assignments. This will allow the programmer to use mathematical symbols in information-writing, and relegate to the computer the planning of the working storage area.
Continuous reads on data tapes can now only be used on short problems, because the programmer may not know whether or not the running program will fit in one segment.* The whole problem of data-handling needs a great deal more study.

* Multi-segment programs require that rI be available at all times for the reading of other segments.
Note: This list has been included as a reference for terms used in the manual which may be confusing and/or new to the reader. The definitions given pertain to the use of these terms in the manual, although conventional usage and definitions have been considered where possible.

**Arrays** .............. An operand or unit of data which must be specified and located prior to execution of an operation.

**Call-word** ............ A computer word used as a descriptive code and identification key in referencing routines in the compiler library.

**Executive Routine** ...... A program which operates upon input instructions or specifications usually written in a language more convenient that computer code, and produces coding which will be executed by the computer in producing results, either computational or data-processing.

**Generative Coding** .... See Generative Routines

**Generative Routines** .... Routines which operate upon specifications describing the process for which the computer is to be programmed, to produce (generate) machine (G-10) coding. As an element of an automatic programming system, generative routines must be written in conformance with the requirements of the system, and the generated coding they produce must also conform.

**Operation** ............. The smallest sub-division of a program requiring a single reference to one of the elements in the compiler system, such as a subroutine. Operations are ordered by the
programmer and are numbered serially throughout a

given program.

*Pseudo-code* ............ Computer words other than the machine (C-10) code,
design with regard to facilitating communications
between programmer and computer. Since a pseudo-code
can not be directly executed by the computer, there must
be programmed a modification, interpretation or
translation routine which converts the pseudo-codes to
machine instruction and routines.

*Record* ................. Intermediate output of compilation process which
contains segmenting and memory allocation information in
operation number sequence.

*Relative Coding* ........ Coding which may be systematically inserted in any
portion of the memory. It depends on the relationship
between the memory addresses it contains, rather than
fixed, explicit addresses. A compiling system will be
capable of automatically transforming relative coding to
a fixed location in the memory.

*Result* .................. A numerical quantity or unit of data resulting from the
execution of an operation.

*Running Program (tape)* . A set of machine (C-10) instructions which, when
executed by the computer, produce results. With respect
to automatic coding, the running program (tape) is the
output of executive type routines, i.e., compilers.

*Segment* .................. A part of the complete running-program which can be
entirely stored in the memory. A program which exceeds
memory capacity is divided into segments. [Segments
may be designated by the programmer for optimum efficiency, but if they are not specified, A-2 will automatically segment a program."

**Specifications**

Computer words other than machine code designed for the convenience of the programmer in describing the characteristics of a problem or process to an executive routine. The executive routine will operate upon the specifications to produce the required machine (C-10) coding.

**Subroutine**

A unit of coding which is complete and performs a specific function and which may be useful in different programs. As one element of an automatic programming system it must conform to the arbitrary requirements of the system which transforms it for a specific application.

**Temporary Storage**

A part of the memory set aside for use during the execution of a subroutine. All temporary storage registers are considered available at the start of each subroutine.

**Working Storage**

That part of the memory set aside for the use of all sub-routines as required. Data which is to pass from one subroutine to another is stored in working storage.