1

UNITED STATES ATOMIC ENERGY COMMISSION

LA-1475

FOUR-ADDRESS, EIGHT-DIGIT FLOATING DECIMAL CODING SYSTEM FOR THE C. P. C. MODEL II (NO. 1 BOARDS)

By
Dura W. Sweeney

September 1952

Los Alamos Scientific Laboratory

Technical Information Service, Oak Ridge, Tennessee

INSTRUMENTATION

In the interest of economy, this report has been reproduced direct from copy as submitted to the Technical Information Service.

PRINTED IN USA
PRICE 35 CENTS
Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

Work performed under
Contract No. W-7405-eng-36.

AEC, Oak Ridge, Tenn.-W28589

ABSTRACT

This paper introduces the latest set of control panels designed for the C.P.C. The panels are wired for general-purpose use for all problems which can be reduced to a chain of arithmetic operations. Since the C.P.C. operates normally at the rate of 150 cards per minute with a fixed amount of calculate-time between cards, the problem has been to design control panels which make maxium use of this calculate-time and still retain a simple and flexible coding system.

The design of this set of control panels contains both single and double operations (three and four address codes). Channel X has been extended to permit addresses to all eight counter-groups, and an improved set of transcendental functions is available. The coder will still have the advantages of automatic resetting of the counter-groups, the availability of four possible instruction fields, SRI and SRO, and other operations present in older designs.

This paper is organized so that an experienced coder can get a complete summary of all possible operations and controls, as well as the printing and card layout in the last six pages. All items in the summary as well as other aids to coders are fully explained in the main text.

507 003

FOUR-ADDRESS, EIGHT-DIGIT FLOATING DECIMAL CODING SYSTEM FOR THE C. P. C. MODEL II (NO. 1 BOARDS)

By Dura W. Sweeney

INTRODUCTION

This paper introduces the latest set of control panels designed for the C.P.C. The panels are wired for general-purpose use for all problems which can be reduced to a chain of arithmetic operations. Since the C.P.C. operates normally at the rate of 150 cards per minute with a fixed amount of calculate-time between cards, the problem has been to design control panels which make maxium use of this calculate-time and still retain a simple and flexible coding system. The best use of the available calculate-time is made when there are two operations performed, one of them being addition. A single operation does not use all the calculate-time, and the time required for a double operation in which the operations are combinations of multiply and divide will in the majority of cases exceed the calculate-time.

The design of this set of control panels contains both single and double operations (three and four address codes). Channel X has been extended to permit addresses to all eight counter-groups, and an improved set of transcendental functions is available. The coder will still have the advantages of automatic resetting of the counter-groups, the availability of four possible instruction fields, SRI and SRO, and other operations present in older designs.

This paper is organized so that an experienced coder can get a complete summary of all possible operations and controls, as well as the printing and card layout in the last six pages. All items in the summary as well as other aids to coders are fully explained in the following pages.

Three-and Four-Address Coding Systems

A three-address coding system is a system in which the coder may address two numbers to read into the calculating unit and store the result of an operation between the two. A four-address coding system allows the coder to read three numbers into the calculating unit and store the result of the calculation, which now is an operation between two of the numbers and a further operation between the third number and the result of the first operation. Both systems, including several **transcendental** functions and some special operations, are now available to the coder in one set of control panels.

Floating-Decimal Calculations

A floating-decimal system represents all numbers in "scientific" notation; as $x = x_o \cdot 10^p$, where x_o consists of an eight digit number* in the range, $1 \leq x_o < 10$; the number is considered as an integer and seven decimals; p, the exponent of 10, is represented as 50 + p where p has the range $-50 \leq p < 50$ so that $100\pi = 3.1415927 \cdot 10^2$ is represented as 3141592752, and $1/\pi = 3.1830989 \cdot 10^{-1}$ is represented as 3183098949. This system has a range of p large enough to handle most problems encountered. The ease of coding for this system rather than a

* A true floating decimal number contains a digit not zero in the high-order (left-hand) position.

507 005

Floating-Decimal Calculations (con't)

fixed decimal system is apparent, as the coder does not need to know the magnitudes of numbers during the calculation for scaling purposes since the machine automatically scales the result at the end of each operation.

In multiplication, the x_o's are multiplied and the exponents added. In division, the x_o's are divided and the exponents differenced. In addition, the number with the smaller exponent is shifted to the right the same number of places as the difference of the exponents before it is added to the number with the larger exponent. There is normally no loss of figures in multiplication or division, but the addition of two similar numbers with opposite sign may occur with a consequent loss of the high-order significant digits. The machine in this case will shift the remaining digits to the left and reduce the exponent to again put the number in floating decimal notation. The now right-hand digits will be zero.

In the case where two identical numbers are subtracted, causing a complete figure loss, the result will be all zeros including the exponent. Rounding is automatic. The C.P.C. design is such that the result of a division by zero is zero.

If the machine operates upon numbers which are not in true floating-decimal form correct results will be obtained except in division. If there are more high-order zeroes in the denominator than in the numerator, the result will be zero.

ADDRESSES, CHANNELS, AND STORAGE

For the machine to perform a calculation, two or three numbers and an operational code must be read into the calculating unit of the machine, and the machine must be told where to store the result. The machine is told by addresses where to read the numbers from storage or where to read results into storage. Therefore, there are two types of addresses: an address to read from a storage position or an address to read into a storage position. Addresses punched in columns 1-2, 5-6, or 4 of the instruction field will read the numbers from storage onto channels A, B, or X, respectively; the channel in turn will deliver the number to the calculating unit. The result of a calculation is read onto channel C from the calculating unit and an address in columns 7-8 of the instruction field will instruct channel C to read the number into the storage addressed.

There are eight counter-groups and a possibility of forty-eight storage registers into (or from) which numbers may be read over the channels. Also available are positions on each card from which punched numbers may be read onto channels A, B, or X. There are two positions for each channel.

Channel A, B, and X Addresses

The addresses 91 thru 98 in channels A or B and addresses 1 thru 8 in channel X will read-out the numbers stored in counter-groups 1 thru 8, respectively, onto the channel addressed. The forty-eight storage regis-

Channel A, B, and X Addresses (cont'd)

ters are divided into groups of eight, called storage banks. Two storage banks comprise a storage unit. They are:

Storage Unit #1: 11 thru 18 and 21 thru 28.

Storage Unit #2: 31 thru 38 and 41 thru 48.

Storage Unit #3: 51 thru 58 and 61 thru 68.

The addresses to storage registers are 11-68 (above) for channels A or B. The storage registers may not be read out on channel X.

There are positions available upon each card from which punched numbers may be read onto channels A, B, or X. A 90 (or 99) address punched in channel A of a card reads from columns 11-20 (or 51-60) of that card. A 90 (or 99) address punched in channel B of a card reads from columns 21-30 (or 61-70) of that card. A 0 (or 9) address punched in channel X of a card reads from columns 61-70 (or 51-60) of that card. It will be noted that an A address of 99 reads the same number as an X address of 9, and a B address of 99 reads the same number as an X address of 0. An X-punch over the low-order (right-hand) digit of the number signifies that the entire number is negative. For example, $-\gamma = -.57721566$ is punched in the card as $577215664\overset{x}{9}$.

The punches 9X in channels A or B or an X-punch in channel X of a card will allow the result of the operation ordered by the previous card which is on channel C to read onto channel A, B, or X as addressed without interfering with the proper storage of that number as addressed in channel C of the previous card.

The numbers in the counter-groups or storage registers are never

Channel A, B, and X Addresses (cont'd)

destroyed upon read-out, and may be addressed to read-out as many times as desired.

There must be one card following a channel C address to a counter-group before a read-out from that counter-group can be addressed in channels A, B, or X. For example: If counter-group 5 is addressed to read-in on card k, the earliest it may be addressed to read-out is on card k + 2.

There must be two cards following a channel C address to a storage register before a read-out from that storage register can be addressed in channels A or B. For example: If storage register 32 is addressed to read-in on card k, the earliest it may be addressed to read-out is on card k + 3.

Channel C Addresses

The addresses 91 thru 98 or 11-68 in channel C will deliver the results of the calculation to the proper counter-group or storage register as addressed. No address is necessary in channel C to make the result available for listing (see printing). A channel C address to a counter-group or a storage register will reset that storage to zero before the result of the calculation reads in.

In no case may the coder address the same counter-group or storage register to read-in upon two successive cards.

INPUT OF INFORMATION

The reading of numbers from card positions onto channels A, B, or X has been discussed in the previous section dealing with "Channels." This method of input may be used to read numbers onto the channels for immediate usage in a calculation. It may also be used to read numbers from the card into storage positions. A similar method will transfer numbers from one storage position to another. The above methods involve the input or transfer of a single number. Another method of input, called Spread-Read-In (SRI), will read-in eight numbers simultaneously into the eight counter-groups.

Input of Transfer of One Number

Assume the coder wants to read a number punched in columns 11-20 of the card into storage register 23, or that he wants to transfer the number in storage register 56 to counter-group 4; the coding is as follows;

Instruction Field Column	Input to 23	Transfer to Ctr-group 4
1-2 (A address)	90	56
3 (operation)	1	1
4 (X address)	Blank	Blank
5-6 (B address)	Blank	Blank
7-8 (C address)	23	94

Spread-Read-In

This method of input will read the numbers punched in a card in columns 1-10, 11-20, 21-30, etc.,* into counter-groups 1 thru 8, respectively.

* An X-punch over the low-order (right-hand) digit of any group would signify that the number is negative.

Spread-Read-In (cont'd)

The SRI operation requires two cards; first the SRI control card, followed by the SRI card which contains the information to be read into the counter-groups.

The SRI control card must contain a 90 punched in columns 7-8 of the instruction field. (An SRI may be addressed from any one of the four instruction fields.) The SRI control card will automatically reset all eight counter-groups to zero before the read-in from the next card, except if instructed not to reset.

Any or all of the counter-groups may be instructed not to reset before read-in by control punches in the SRI control card. A Y-punch in column 10 of the SRI control card will prevent counter-group 1 from resetting, so that the number punched in columns 1-10 of the SRI card will add to whatever number is stored in that counter-group; similarly for the other seven counter-groups. The numbers are added in absolute value including the exponents. If either number is negative, the result is negative; if both are negative the result is negative, and only if both are positive is the result positive. The coder may therefore retain a particular number stored in a counter-group by punching a Y in the appropriate column of the SRI control card and punching zeros (or leaving blank) the appropriate ten positions of the SRI card.

The card preceding an SRI control card may not address a counter-group to read-in. Any of the counter-groups may be addressed to read-out onto channel A, B, or X as early as the next card after the SRI card.

507 011

OUTPUT OF INFORMATION

The coder is mainly interested in a printed tabulation of the results of a calculation, but occasionally will require a permanent, punched record of the results of a calculation, or he may require a punched record of intermediate results of the calculation which may be fed back into the machine at a later stage, particularly so if the problem exceeds the storage capacity of the machine. If a problem is exceptionally long, it is wise to punch a few key values at suitable time intervals so that in case of a card-jam or machine error the problem may be restarted without retreating to the first stages of the calculation. The operation which punches a card is called Spread-Read-Out (SRO).

Spread-Read-Out

A 6 punch in column 9 of the instruction field will start a minor program which will punch the numbers and signs stored in counter-groups 1 thru 8 into a card in positions 1-10, 11-20, 21-30, etc., respectively.* These punched cards may be fed back into the machine as SRI cards if they are properly filed behind an SRI control card.

The SRO instruction will also give a printed record of the contents of the eight counter-groups, on one line. The printed record will contain an asterisk (*) in the far left-hand position as an identifying mark.

The card following the card containing the SRO instruction must be blank in that instruction field.

---

* If the number is negative, the machine will punch an X over the low-order (right-hand) digit of the number.

Spread-Read-Out (cont'd)

The card containing the SRO instruction may not address a counter-group to read-in.

D.P.D.T. Switches #2 or #3 may be used to modify the SRO instruction. Switch #2 instructs the machine to print the contents of the counter-groups and prevents the punching. Switch #3 instructs the machine to punch the contents of the counter-groups and prevents the printing.

The SRO instruction never resets the counter-groups.

This operation requires approximately six card times.

Printed Information

The SRO operation will automatically print the contents of the eight counter-groups except as modified by D.P.D.T. Switch #3. The SRI operation will print the numbers read into the eight counter-groups if there is an X-punch in column 5 of the instruction field of the SRI control card, or if Set-Up Change Switch #1 is in "ON" position. See page 41 for the order in which the numbers are printed on the paper.

The two printing operations described above are special in that they print the numbers read into or out of all eight counter-groups; the normal printing operation lists the addresses and operations punched in a card as well as the numbers addressed.

The C.P.C. prints at the rate of 150 lines per minute, i.e., at the same rate as it normally calculates. To achieve this speed of printing the control panels have been wired to print the numbers as they are read into and out of the calculating unit. Since the calculating unit reads

<u>Printed Information</u> (cont'd)

out onto channel C the result of an operation at the same time as the new numbers and operation code are read in for the next operation, the machine will print on one line the addresses, operations code, and the numbers addressed on a particular card, as well as the channel C result of the previous card, and other information to aid the coder.

The printing mecnanism has 89 type bars. The left-hand 44 positions are called alphamerical type bars, the right-hand 45 positions are called numerical type bars. The machine is wired to print the numbers addressed on channels A, B, or X and the previous C result in the alphamerical field.

If there is no address punched in channels A, B, or X, nothing will print in those type bars. Channel C will always print regardless of whether or not an address is punched. The sign of the number prints to the right of the number. If the number is positive, nothing prints; if the number is negative, one of several symbols will print (the symbol is described at the appropriate place below).

Type Bar	Printed Result
a2-a 11	The number addressed on channel A.
a12	The sign of the number addressed on channel A. (If negative, it prints as an N or a 9)
a13-a22	The number addressed on channel B.
a23	The sign of the number addressed on channel B. (If negative, it prints as an N or a 9)
a24-a33	The number addressed on channel X.
a34	The sign of the number addressed on channel X. (If negative, it prints as a 9)
a35-a44	The result of the previous calculation which reads out onto channel C.
n 1	The sign of channel C. (If negative, it prints as an asterisk (*))

Printed Information (cont'd)

The channel addresses, the operations code, and other special information print from the numerical field as follows:

n 1	The sign of the number on channel C (see above).
n2	Print 2 if operation i.
n3-n4	The numbers punched in columns 1-2 of the instruction field (channel A address). A 9X address prints as 9CR.
n5	The Y-punch in column 2 of the instruction field (change the sign of A) prints here as an asterisk (*).
n6	The Y-punch in column 1 of the instruction field (absolute value of A) prints here
n7-n12	as a CR.
n7-n12	The numbers or symbols printed here refer to the operations. See "Operations" for an explanation of the code.
n7	Prints 1 if operation A.
n8	Prints 3 if operation M.
n9	Prints 4 if operation D.
n10	Prints CR if operation N, 5 if $\sqrt{\lvert A\rvert}$, 6 if e^B, 7 if $\ell n\lvert B\rvert$, 8 if sin B or cos B, and 9 if arctan B.
n 11	Prints * if operation n, or 8 if cos B.
n12	Prints 2 if operation I.
n13-n14	The numbers punched in columns 5-6 of the instruction field (channel B address). A 9X address prints as 9CR.
n15	A Y-punch in column 6 of the instruction field (change sign of B) prints here as an asterisk (*).

Printed Information (cont'd)

n16	A Y-punch in column 5 of the instruction field (absolute value of B) prints here as CR.
n17-n19	See "Operations" for explanation of the code.
n17	Prints 1 if operation a.
n18	Prints 3 if operation m.
n19	Prints 4 if operation d.
n21	Prints a 9 if there is a channel X address.
n22	The numbers punched in column 4 of the instruction field (channel X address). An X prints as CR.
n23	A Y-punch in column 4 of the instruction field (change sign of X) prints here as an asterisk (*).
n24	A Y-punch in column 7 of the instruction field (absolute value of X) prints here as CR.
n25-n26	The number punched in columns 7-8 of the instruction field (channel C address) or the 90 which is the SRI control card instruction.
n28	This type bar will print a 1, 2, 3, or 4 depending upon which instruction field the machine is operating in.
n30-n33	Prints the numbers punched in columns 10, 40, 50, and 80. Usually the card or serial number.
n34	Column 9 of the instruction field prints here. If there are multiple punches, only the highest will print
n35-n44	Prints the numbers punched in columns 71-80 of the card.

Hammersplit Control

The tabulator will print zeros from all type bars to the right of a type bar printing a character not zero if no digit or symbol is ordered to print from those type bars. These printed zeros may be suppressed through the use of Hammersplit controls. There are 89 Hammersplits corresponding to the 89 type bars. A Hammersplit in the "up" position will lock out all zeros to the right of that position until a type bar prints a character not zero.

Therefore, for the proper listing of normal calculational operations the following Hammersplits should be in the "up" position to prevent the printing of extraneous zeros:

Alphamerical: 1,11, 12, 22, 23, 33, 34, 44.

Numerical: 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 22, 23, 24, 26, 28, 33, 34, 44.

For the proper printing of SRI and SRO information there are too many Hammersplits used on the numerical side. If only SRI or SRO cards are listing, the numerical Hammersplits should be 1, 11, 12, 22, 23, 33, 34, 44. This will allow zeros properly present in the numbers to print correctly.

Listing and Print Spacing Controls

Set-Up Change Switch #1 in "ON" position will print a line for each card fed into the tabulator. This switch is normally used to list every calculation when testing the machine or when the coder is checking out a

507 017

Listing and Print Spacing Controls (cont'd)

newly coded calculation on the machine.

Set-Up Change Switch #1 in "OFF" position will not print any card unless there is an X-punch in the proper column.

There are two X-punches which control printing. An X-punch in column 1 of the instruction field will order an Immediate List. An X-punch in column 5 of the instruction field will order a Delay List.

Immediate List

An X-punch in column 1 of the instruction field of a card will print the numbers addressed on channels A, B, or X; the addresses and operations code punched in that instruction field as well as the channel C result of the previous card.

Delay List

An X-punch in column 5 of the instruction field of a card will print the channel C result of that card; and the channel addresses, the numbers addressed, and the operations code punched in the instruction field of the next card.

Paper Spacing

Set-Up Change Switch #2 in "OFF" position will allow a single space between each line of printing. The switch in "ON" position will double-space before each print instruction.

A 7 punch in column 9 of the instruction field will cause a double-space before the next listing instruction only.

Paper Spacing (cont'd)

Either of the above orders for double-spacing may be given at any time before a list instruction. The double-space order will be "remembered" until the next list instruction is given.

The single-or double-spacing takes place before the next print instruction except that the machine will not space before listing the result of the first print order after cards are fed into the machine. The machine will not remember a space instruction if the cards are run out of the machine.

Each sheet of paper in the tabulator contains 66 lines upon which information may be printed. The machine is coded so that only 60 lines of printing will occur, at which time the paper will "restore" automatically to the next sheet.

The "restore" operation may be instructed by the coder before 60 lines have been printed. A 9 punch in column 9 of the instruction field will "restore" the paper to the next sheet before the next card feeds into the machine.

An 8 punch in column 9 of the instruction field will space a half sheet of paper before the next card feeds into the machine. If the tabulator is printing in the upper half of the paper, the paper will space to the start of the lower half. If the tabulator is printing in the lower half of the sheet, the paper will "restore" to the next sheet.

INSTRUCTION FIELDS

It sometimes becomes necessary during a problem to calculate a particular result by one of several different methods. The method may be a function of the variable. For example, the coder may have information in tabular or graphical form to be entered during a calculation. This information may be "fitted" by several different polynomials which are functions of the range. The coder then may punch as many as four of these polynomials into the four instruction fields and select one of the polynomials to be calculated either conditionally or unconditionally by shifting to one of the four instruction fields.

The instruction card layout is described on page 43. The instruction fields are as follows:

#1 (normal)	Columns 1-9 of the card.
#2	Columns 31-39 of the card.
#3	Columns 41-49 of the card.
#4	Columns 71-79 of the card.

Therefore, when a reference is made to a column of the instruction field, this does not necessarily mean the corresponding column of the card. For example: The channel A address is punched in columns 1-2 of the instruction field. These punches may be in columns 1-2, 31-32, 41-42, or 71-72 of the card, depending upon whether the machine is reading instructions from field #1, #2, #3, or #4, respectively.

Instruction field #1 is the normal field, and the machine will return to that field when the last card is run out of the machine or if an instruction field shift is ordered, and the machine is not instructed to go to field #2, #3, or #4. Therefore, upon first starting to run cards into the machine, the instructions are taken from field #1.

The shifting process takes two cards. If the shift is ordered from a certain instruction field upon card number k, card number k + 1 will still read its addresses from that instruction field, but card number k + 2 will read its addresses from the new instruction field.

There are two methods of shifting, a conditional shift or an unconditional shift. The conditional shift depends upon the sign of channel C. For example: Card k contains an X-punch in column 9 of the instruction field of that card. If the channel C result of the calculation performed upon card k is negative, from card k + 2 the machine will read instructions from the new field (#2, #3, or #4) punched in column 9 of the card k, or field #1 if there was not a 2, 3, or 4 punch. If the channel C result is positive, the calculation will continue in the instruction field of card k until the new shift order is given. The unconditional shift is ordered by a 5 punch in column 9 of the instruction field. The timing for the shift is the same as for the conditional shift, but the machine will definitely be in the new instruction field two cards later.

The coder may shift from any instruction field to any other instruction field upon proper address. Caution must be observed so that the calculation or result of the card following an instruction to shift fields fits properly (or does not interfere) with the calculation in both the original and the shifted field. Caution must also be observed in ordering shifts upon two successive cards. For example: If the coder from field #1 should instruct a conditional field shift to field #3 on card k and to field #4 on card k + 1, and the results of both cards k and k + 1 were negative, then the machine would read its instructions from field #3 on card k + 2 and from field #4 on card k + 3. The machine would then continue in field #4 after card k + 3 until instructed to shift again.

OPERATIONS

The <u>only possible</u> calculational operations are shown on page 46.

The arithmetic operations are virtually self-explanatory except for the design in which the order of the operations in column 3 of the instruction field takes place. The three address codes perform only a single operation such as A + B, A•B, or A/B, and require only a single punch in the operations column. The four address codes require multiple punches since they perform two operations. The design is such that a 3 punch takes precedence over a 4 or a 1 punch, and a 4 punch takes precedence over a 1 punch. A Y-punch will interchange the order of precedence of the operations, a 2 punch will interchange the order in which B and X are used in the calculation, and a 0 and a 2 punch will interchange the order in which A and X are used in the calculation. The wiring code gives the order of operations such that a capital letter means the first operation and a small letter stands for the second operation. A capital letter does not necessarily imply a second operation, but a small letter definitely means a first operation has preceded it. For example:

A means add the first number to the second number: A + B, A + X if I, or X + B if i.

M means multiply the first number by the second number: AB, AX if I, or XB if i.

D means divide the first number by the second number: A/B, A/X if I, or X/B if i.

a means add the result of the first operation to the third number.

507 023

m means multiply the result of the first operation by the third number.

d means divide the result of the first operation by the third number.

An example of the coding is as follows:

Code Punch	Wiring Code	Operation
1	A	A + B
3	M	AB
1,3	M,a	(AB) + X
1,2,3	M,a,I	(AX) + B
0,1,2,3	M,a,i	(XB) + A
Y,1,3	A,m	(A + B)X
Y,1,2,3	A,m,I	(A + X)B
Y,0,1,2,3	A,m,i	(X + B)A

B and X interchange is coded by the symbol I, the code punch is a 2.

A and X interchange is coded by the symbol i, the code punch is a 0 and a 2.

There is no operation A,a.

The special operations which may be used only with the arithmetic operations are an X-punch in column 3 and an X-punch in column 7 of the instruction field. These instructions are, respectively, Do Not Shift Left and Do Not Round, their wiring codes are N and n.

Do Not Shift Left (N)

This operation is useful in a variety of ways. It can be used to convert floating decimal numbers to a fixed-decimal system. For example:

Do Not Shift Left (N) (cont'd)

If the coder punches the operation A and N, addresses one of the factors of the addition to read-in as 0000000051, and the other factor as the number to be converted to fixed decimal, all the channel C results will be arranged as two integers and six decimals with the exponent 51. If any factor has an exponent greater than or equal to 51 the number will read-out on channel C unchanged. If any factor has an exponent less than 51, it will be shifted to the right until it is in the form of two integers and six decimals. If the numbers are shifted to the right, they will be properly rounded.

The operation is also useful in checking the answers from the solution of several simultaneous equations. If the solutions are fed into the left-hand side of the equation and the operation N is used, and that result as well as the original right-hand side of the equations are printed together, the coder can tell at a glance the accuracy of the solution.

Another use of this order which may speed up the rate of calculation is in the cross-product and sum of two columns of numbers. If the N operation is coded for all operations except the last, and if a loss of figures might occur in the individual sums, the number will not shift left with the consequent time loss, and the machine will only shift to the left after the last operation. This result will have the exponent of the largest cross-product.

Do Not Round (n)

This operation is used mainly for finding the integral part of a number. If the coder punches the operation A and n, and addresses one

Do Not Round (n) (cont'd)

of the factors to read-in as 0000000057, and reads in the other factor as the number of which the integral part is desired, the machine will shift off to the right the decimal part of the number and then shift the integral part back to the left without rounding. If the exponent is greater than or equal to 57, the number will be unchanged.

Transcendental Operations

The transcendental operations are coded as 5, 6, 7, 8, 0 and 8, or 9 and will calculate, respectively, the square root of the absolute value of the number addressed on channel A, the exponential of the number addressed on channel B, the natural logarithm ($\log_e$) of the absolute value of the number addressed on channel B, the sine of the number addressed on channel B, the cosine of the number addressed on channel B, and the arctangent of the number addressed on channel B. Other numbers must be addressed to read-in on channels A and X of the last five operations. They are listed under the proper functions below.

Square Root of |A|

Operation code punch 5; wiring code R.

The range of A is $10^{-50} \leq |A| < 10^{50}$.

The operation requires approximately three card times.

The error is not more than one or two in the eighth figure.

The coder does not have to address other numbers to read-in on channels B or X.

The method of computation is as follows: The number A is considered

507 026

Square Root of $|A|$ (cont'd)

as $x_o \cdot 10^p$. If p is even, the result on channel C is $\sqrt{|x_o|} \cdot 10^{p/2}$.

If p is odd, the result on channel C is $\sqrt{10|x_o|} \cdot 10^{\frac{p-1}{2}}$. The method of getting the square root is the Newton iteration technique:

$$y_{n+1} = \frac{1}{2}\left[\frac{z}{y_n} + y_n\right] \text{where z is } |x_o| \text{ or } 10|x_o|.$$

When y_{n+1} equals y_n, that result and the proper exponent is read out onto channel C. The starting value for y_o is generated in the machine as 999999pp, where pp is the nines-complement of the exponent of A. For example: If the exponent of A is 53, y_o would be 99999946.

Exponential of B

Operation code punch 6; wiring code E.

The range of B is $|B| < 50 \ln 10 = 115.12925$.

The operation requires approximately six card times.

The error is not more than one in the seventh figure.

The coder must address $\ln 10 = 2302585150$ to read-in on channel A and $\frac{1}{2}\ln 10 = 1151292550$ to read-in on channel X.

If the range of B is exceeded, the exponent will be out of the range $-50 \leq p \leq 50$. The result on channel C will be correct except for the wrong exponent. For example, $e^{-150} = 7.1750960 \cdot 10^{-66}$ will read out as 7175096016, and $e^{150} = 1.3937096 \cdot 10^{65}$ will read out as 1393709715.

The method of computation is as follows. B is positioned so that a division by $\ln 10$ will give only the integral part as the quotient. Define this quotient as i and the remainder as r. This splits B into two

507 027

Exponential of B (cont'd)

numbers such that $B = i \ln 10 + r$. Since $e^{i \ln 10} = 10^i$, then $e^B = e^{i \ln 10 + r} = 10^i \cdot e^r$. A further reduction is now made. The absolute value of r is now tested to see whether it is less than or greater than $\frac{1}{2} \ln 10$.

If $|r| \leq \frac{1}{2} \ln 10$, $e^B = 10^i \cdot e^r$. If $|r| > \frac{1}{2} \ln 10$, $e^B = 10^{i + \frac{|r|}{r}} \cdot e^{r - \frac{|r|}{r} \ln 10}$

The argument of either of the above exponentials is now less than $\frac{1}{2} \ln 10$ in absolute value, and the series calculated is:

$$\sum_{n=0}^{17} \frac{x^n}{n!} .$$

Logarithm of |B|

Operation code punch 7; wiring code L.

The range of B is $10^{-43} < |B| < 10^{43}$.

The operation requires approximately nine card times.

The error is not more than one in the seventh figure.

The coder must address $\sqrt{10} = 3162277750$ to read-in on channel A and $\ln 10 = 2302585150$ to read-in on channel X.

If the range of B is exceeded, the number will be calculated properly, but since the machine can only sense two integers, and any number greater than $43 \ln 10$ is greater than 100, the high-order digit will be discarded, and the next eight digits will be read out. For example, $\ln 9.8765432 \cdot 10^{47} = 110.511662$ will read out as 1051166251.

The method of computation is as follows: Consider B as $x_o \cdot 10^p$.

Logarithm of $|B|$ (cont'd)

Then, if $x_o \leq \sqrt{10}$

$$\ell n\ (x_o \cdot 10^p) = \ell n x_o + p \ell n 10,$$

$$\text{where } \ell n x_o = 2 \sum_{n=0}^{13} \frac{y^{2n+1}}{2n+1}, \quad y = \frac{x_o - 1}{x_o + 1},$$

or if $x_o > \sqrt{10}$

$$\ell n\ (x_o \cdot 10^p) = \ell n(\frac{x_o}{\sqrt{10}}) + (p + \tfrac{1}{2}) \ell n 10,$$

$$\text{where } \ell n \frac{x_o}{\sqrt{10}} = 2 \sum_{n=0}^{13} \frac{y^{2n+1}}{2n+1}, \ y = \frac{x_o - \sqrt{10}}{x_o + \sqrt{10}}.$$

Sine of B

Operation code punch 8; wiring code S.

The range of B is $10^{-7} < |B| < 10^5$, B is in radians.

The operation requires approximately six card times.

The error is not more than one in the seventh decimal.

The coder must address $\pi = 3141592750$ to read-in on channel A and $\frac{1}{2}\pi = 1570796350$ to read-in on channel X.

If B is in the range $10^{-50} \leq |B| < 10^{-7}$, the result will be all zeros including the exponent. If B is in the range $10^5 \leq |B| < 10^{50}$, the machine will calculate, but the result will bear no relationship to sin B.

The method of computation is as follows. B is positioned properly in the range of five integers and seven decimals according to the exponent of B. (If $|B| \leq 10^{-7}$, B is shifted out of the machine to the right so that all zeros result.) Now a division by π will give only the integral part

Sine of B (cont'd)

as the quotient. Define this quotient as i and the remainder as r. This splits B into two numbers such that $B = i\pi + r$. A further reduction is now made. The absolute value of r is tested to see whether it is less than or greater than $\frac{1}{2}\pi$, and i is tested to see whether it is even or odd. These tests determine in which quadrant B lies, and the argument y, obtained from r is:

First quadrant:	i even,	$\lvert r\rvert \leq \frac{1}{2}\pi$;	$y = r$.
Second quadrant:	i even,	$\lvert r\rvert \geq \frac{1}{2}\pi$;	$y = -r + \frac{\lvert r\rvert}{r}\pi$.
Third quadrant:	i odd,	$\lvert r\rvert \leq \frac{1}{2}\pi$;	$y = -r$.
Fourth quadrant:	i odd,	$\lvert r\rvert \geq \frac{1}{2}\pi$;	$y = r - \frac{\lvert r\rvert}{r}\pi$.

The argument, y, is now less than $\frac{1}{2}\pi$, and the series calculated is:

$$\sin B = \sum_{n=0}^{8} (-)^n \frac{x^{2n+1}}{(2n+1)!} \quad .$$

Cosine of B

Operation code punch 0 and 8; wiring code C.

The range of B is $10^{-7} < |B| < 10^5$, B is in radians.

The operation requires approximately six card times.

The error is not more than one in the seventh decimal.

The coder must address $\pi = 3141592750$ to read-in on channel A and $\frac{1}{2}\pi = 1570796350$ to read-in on channel X.

The method of computation is the same as for sin B except that $\frac{1}{2}\pi$ is added to B before the division by π.

Arctangent of B

Operation code punch 9; wiring code T.

The range of B is $10^{-7} < |B| < 10^{50}$.

The operation requires approximately nine card times.

The error is not more than one in the seventh decimal.

The coder must address 0.1 = 1000000049 to read-in on channel A and $\frac{5}{2}\pi$ = 7853981650 to read-in on channel X.

If B is in the range $10^{-50} \leq |B| \leq 10^{-7}$, the result will be all zeros including the exponent. If B is in the range $10^{7} \leq |B| < 10^{50}$ the result will be $\frac{1}{2}\pi$.

The method of computation is as follows: The reciprocal of B is found. B and its reciprocal are tested to see which is less than or equal to 1.0 in absolute value. The smaller value is now shifted into the form of one integer and seven decimals. This value is now tested to determine whether it is less than or greater than 0.4 in absolute value. This will place B in one of four ranges, and the function calculated is as follows:

$$10^{-50} \leq |B| \leq 0.4 \qquad \arctan B = \frac{|B|}{B} \arctan |B| ,$$

$$0.4 < |B| \leq 1.0 \qquad \arctan B = \frac{|B|}{B}\left[\frac{1}{4}\pi + \arctan \frac{|B| - 1}{|B| + 1}\right],$$

$$1.0 < |B| \leq 2.5 \qquad \arctan B = \frac{|B|}{B}\left[\frac{1}{4}\pi - \arctan \frac{(1/|B|) - 1}{(1/|B|) + 1}\right], \text{ and}$$

$$2.5 < |B| \leq 10^{50} \qquad \arctan B = \frac{|B|}{B}\left[\frac{1}{2}\pi - \arctan \frac{1}{|B|}\right] .$$

The arguments above are now less than 0.43 and the series calculated is:

$$\sum_{n=0}^{13} (-)^n \frac{x^{2n+1}}{2n+1}$$

Allied Functions

This section is presented as an aid to the coder in transposing the transcendental functions already programmed for the machine to some of their allied functions.

The exponential and hyperbolic functions

$$a^b = e^{b \ln a}$$

$$\sinh y = \frac{1}{2}\left[e^y - e^{-y}\right].$$

$$\cosh y = \frac{1}{2}\left[e^y + e^{-y}\right].$$

$$\tanh y = \left[e^{2y} - 1\right] \Big/ \left[e^{2y} + 1\right].$$

The logarithmic and arc-hyperbolic functions

$$\operatorname{arcsinh} y = \ln\left[y + \sqrt{y^2 + 1}\right].$$

$$\operatorname{arccosh} y = \pm \ln\left[y + \sqrt{y^2 - 1}\right].$$

$$\operatorname{arctanh} y = \frac{1}{2}\ln\left[(1+y)/(1-y)\right].$$

$$\ln(a + ib) = \frac{1}{2}\ln(a^2 + b^2) + i \arctan (b/a).$$

The circular functions

$$\tan y = \sin y/\cos y.$$

$$\cot y = \cos y/\sin y.$$

$$\sec y = 1/\cos y.$$

$$\csc y = 1/\sin y.$$

<u>The arc-circular functions</u>

$$\arcsin y = \arctan\left[y \Big/ \sqrt{1 - y^2}\right].$$

$$\arccos y = \arctan\left[\sqrt{1 - y^2} \Big/ y\right].$$

$$\text{arccot}\, y = \pi/2 - \arctan y.$$

OTHER CONTROL OPERATIONS

This section explains the miscellaneous controls and switches not covered in other sections.

Y-Punches in Columns 1-7 of the Instruction Field

These punches concern changing the sign or taking the absolute value of numbers addressed on channels A, B, or X, except for a Y in column 3. There is no operation for subtraction, but the operation may be performed by changing the sign of one of the numbers addressed and adding.

A Y-punch in column 2 of the instruction field will change the sign of the number addressed on channel A so that the number delivered to the calculating unit will be -(A). A Y-punch in column 1 of the instruction field will drop the sign of A so that the number delivered to the calculating unit will be $|A|$. Both of the above punches would send $-|A|$ to the calculating unit. Similarly for the numbers addressed on channels B or X. See page 45 for the column in which the Y-punch should be placed.

Machine Stop if Channel C is Negative

If there is a 1 punch in column 9 of the instruction field, the machine will examine the channel C result of that card and will stop the machine if the number is negative. The "Stop" light on the 418 will turn on, and no more cards will be fed into the machine. To restart, press the "Final Total" button and the "Start" button simultaneously.

Set-Up Change Switch #3

This switch must always be in the "ON" position for the proper operation of the machine.

D.P.D.T. Switch #1 and 80-80 List

If this switch is in "A" position it will treat every card except the first card as an SRI card. This switch may be used to list the information actually punched in the card in the order in which it is punched. If there are multiple punches, only the largest will print. A blank card should be placed in front of the deck to be listed.

D.P.D.T. Switches 4 thru 9

If there is an X-punch in column 25 of a card, and D.P.D.T. switches 4 thru 9 are in "A" position, the channel C result of the previous card and the numbers punched in columns 71-80 of the card will be compared. If the numbers as well as the signs do not compare, the machine will stop. The main usage of this procedure is in machine testing.

A CODING EXAMPLE

The following example is offered not as a guide to an experienced coder but as an indication to the beginner of the use of the coding sheet, and where the numbers appear on the printed page both for long listing and short listing.

The example chosen is the calculation of an arctangent. It is calculated in sixteen cards by using a continued fraction expansion and in three cards by coding the automatic calculation.

The problem is to be able to calculate the arctangent for any value in the range $10^{-50} \leq |z| < 10^{50}$. The argument is reduced to one which requires a minimum of terms in the continued fraction.

If $10^{-50} \leq |z| < (\sqrt{2} - 1)$, $\quad \arctan z = \frac{|z|}{z}\left[0.0 + \arctan |z|\right]$.

If $(\sqrt{2} - 1) \leq |z| \leq (\sqrt{2} + 1)$, $\quad \arctan z = \frac{|z|}{z}\left[\frac{\pi}{4} + \arctan \frac{|z| - 1}{|z| + 1}\right]$.

If $(\sqrt{2} + 1) < |z| < 10^{50}$, $\quad \arctan z = \frac{|z|}{z}\left[\frac{\pi}{2} + \arctan \frac{-1}{|z|}\right]$.

The value of the argument on the right-hand side of any of the above equations is less than $|\sqrt{2} - 1|$. The continued fraction expansion for any of the above arguments is:

$$\arctan y = \cfrac{y}{1 + \cfrac{y^2}{3 + \cfrac{4y^2}{5 + \cfrac{9y^2}{7 + \cfrac{16y^2}{9 + \cfrac{25y^2}{11 + \cfrac{36y^2}{13}}}}}}} = \cfrac{y}{1 + \cfrac{y^2}{3 + \cfrac{y^2}{\frac{5}{4} + \cfrac{y^2}{\frac{4\cdot 7}{9} + \cfrac{y^2}{\frac{9\cdot 9}{4\cdot 16} + \cfrac{y^2}{\frac{4\cdot 11\cdot 16}{9\cdot 25} + \cfrac{y^2}{\frac{9\cdot 13\cdot 25}{4\cdot 16\cdot 36}}}}}}} .$$

507 036

The coding is as follows:

	1.	Store z.
Card #1	2.	Shift to field #3 if $\lvert z\rvert < (\sqrt{2} - 1)$.
Card #2	3.	Shift to field #2 if $\lvert z\rvert > (\sqrt{2} + 1)$.
Card #3-6	4.	In field #1 calculate $y = \frac{\lvert z\rvert - 1}{\lvert z\rvert + 1}$, y^2, and store $\frac{\pi}{4}$. In field #2 calculate $y = \frac{-1}{\lvert z\rvert}$, y^2, store $\frac{\pi}{2}$, and shift back to field #1. In field #3 calculate $y = \lvert z\rvert$, y^2, store 0.0, and shift back to field #1.
Card #7-13	5.	Calculate the continued fraction and add 0.0, $\frac{\pi}{4}$, or $\frac{\pi}{2}$ depending upon the range.
Card #14	6.	Calculate $\frac{\lvert z\rvert}{z}$ and multiply by previous result.
Card #15	7.	List z and arctan z (note double-space order).

The next page is the coding sheet. On the lower part of the coding sheet will be found the coding for automatically calculating the same function. The two pages following the coding sheet give the complete listing of the calculations for four arguments distributed in the range, both for the card-programmed calculation as well as the machine programmed calculation. The bottom part of the second page contains the controlled listing for the same calculations. The arguments chosen are 0.1, 0.6, 1.7, and 11.3. The results, in floating decimal notation, are as follows:

z	Correct	Card-programmed	Machine-programmed
0.1	9966865248	9966865248	9966865048
0.6	5404195049	5404194949	5404194949
1.7	1039072350	1039072350	1039072250
11.3	1482530750	1482530750	1482530850

507 037

PROBLEM *Calculation of arctan z*

FLOATING DECIMAL CPC Model 2	Instruction Field 1										A Normal ctr-group 2	B Normal ctr-group 3	Instruction Field 2 ctr-group 4										Instruction Field 3 ctr-group 5										A Transfer ctr-group 6	B Transfer ctr-group 7	Instruction Field 4 ctr-group 8									
	A		O	X	B		C		F																																			
OPERATION Card Col.	1	2	3	4	5	6	7	8	9	10	11 — 20	21 — 30	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	51 — 60	61 — 70	1	2	3	4	5	6	7	8	9	10
Store z	9	0	1				9	1			1 —— 49																																	
$\lvert z\rvert - (\sqrt{2}-1)$	Y 9	X	1		9	0			X 3			414213564$\overset{X}{9}$																																1
$(\sqrt{2}+1) - \lvert z\rvert$	9	0	1		Y 9	Y 1			X 2		2414213650																																	2
$1+\lvert z\rvert$ — —	9	0	1		Y 9	1					1 —— 50																																	3
$\frac{\lvert z\rvert-1}{\lvert z\rvert+1}$ $-\frac{1}{\lvert z\rvert}$ $\lvert z\rvert$	9	0	Y 4	X	Y 9	1	9	2			1 —— 5$\overset{X}{0}$		9	0	4		Y 9	1	9	2			Y 9	1	1				9	2														4
$\left(\frac{\lvert z\rvert-1}{\lvert z\rvert+1}\right)^2$ $\left(-\frac{1}{\lvert z\rvert}\right)^2$ $(\lvert z\rvert)^2$	9	X	3		9	X	9	3					9	X	3		9	X	9	3			9	X	3		9	X	9	3														5
Store $\frac{\pi}{4}$ $\pi/2$ 0.0	9	0	1				9	4			7853981649	1570796350			1		9	0	9	4			9	9	1				9	4			0000000000											6
$A_7 = 11\frac{9\cdot16}{9\cdot25} + y^2/13\frac{9\cdot25}{4\cdot16\cdot36}$	9	0	01 24	3	9	0					3128888950	1269531250																																7
$A_6 = 9\frac{9}{4\cdot16} + y^2/A_7$	9	0	01 24	3	9	X					1265625—50																																	8
$A_5 = 7\frac{7}{9} + y^2/A_6$	9	0	01 24	3	9	X					3111111150																																	9
$A_4 = 5\frac{1}{4} + y^2/A_5$	9	0	01 24	3	9	X					125 —— 50																					1												0
$A_3 = 3 + y^2/A_4$	9	0	01 24	3	9	X					3 —— 50																					1												1
$A_2 = 1 + y^2/A_3$	9	0	01 24	3	9	X					1 —— 50																					1												2
$A_1 = 0.0[\text{or } \pi/4, \text{or } \pi/2] + y/A_2$	9	4	01 24	2	9	X																										1												3
arctan $z = \frac{\lvert z\rvert}{z} A_1$	Y 9	1	Y3 4	X	9	1																										1												4
list —, —, z, arctan z	X			1					7																							1												5
	9	0	1				9	1			6 —— 49																																	
→	Repeat Cards										1-15																																	
	9	0	1				9	1			17 —— 50																																	
→	Repeat Cards										1-15																																	
	9	0	1				9	1			113 —— 51																																	
→	Repeat Cards										1-15																																	
Store z	9	0	1				9	1			1 —— 49																																	
Calculate arctan z	9	0	9	9	9	X					1 —— 49																						7853981650											1
list —, —, z, arctan z	X			1					7																																			2
	9	0	1				9	1			6 —— 49																																	
	9	0	9	9	9	X					1 —— 49																						7853981650											1
	X			1					7																																			2
	9	0	1				9	1			17 —— 50																																	
	9	0	9	9	9	X					1 —— 49																						7853981650											1
	X			1					7																																			2
	9	0	1				9	1			113 —— 51																																	
	9	0	9	9	9	X					1 —— 49																						7853981650											1
	X			1					7																																			2

1000000049				90	1					91	1	1	
1000000049	4142135649N		1000000049	9CR	CR1		90				1	13	1
2414213650	1000000049N		3142135649*	90	1		91*CR				1	22	2
			2314213650								3	3	3
1000000049				91	CR1					92	3	4	4
1000000049	1000000049		1000000049	9CR		3	9CR			93	3	55	5
			1000000048	99	1					94	3	6	6
3128888950	1269531250	1000000048		290		4	90	1	93		1	7	7
1265625050	3136765850	1000000048	3136765850	290		4	9CR	1	93		1	8	8
3111111150	1268813050	1000000048	1268813050	290		4	9CR	1	93		1	9	9
1250000050	3118992550	1000000048	3118992550	290		4	9CR	1	93		1	10	
3000000050	1253206250	1000000048	1253206250	290		4	9CR	1	93		1	11	1
1000000050	3007979550	1000000048	3007979550	290		4	9CR	1	93		1	12	2
	1003324550	1000000049	1003324550	294		4	9CR	1	92		1	13	3
1000000049	1000000049	9966865248	9966865248	91	CR	4	91	3	9CR		1	14	4
		1000000049	9966865248						91		1	157	5
6000000049				90	1					91	1		
6000000049	4142135649N		6000000049	9CR	CR1		90				1	13	1
2414213650	6000000049N		1857864449	90	1		91*CR				1	22	2
1000000050	6000000049		1614213650	90	1		91 CR				1	3	3
1000000050N	6000000049	1600000050	1600000050	90	1		91 CR	4	9CR	92	1	4	4
2500000049N	2500000049N		2500000049*	9CR		3	9CR			93	1	5	5
7853981649			6250000048	90	1					94	1	6	6
3128888950	1269531250	6250000048	7853981649	290		4	90	1	93		1	7	7
1265625050	3178119750	6250000048	3178119750	290		4	9CR	1	93		1	8	8
3111111150	1285290750	6250000048	1285290750	290		4	9CR	1	93		1	9	9
1250000050	3159738250	6250000048	3159738250	290		4	9CR	1	93		1	10	
3000000050	1269780150	6250000048	1269780150	290		4	9CR	1	93		1	11	1
1000000050	3049221150	6250000048	3049221150	290		4	9CR	1	93		1	12	2
7853981649	1020497050	2500000049	1020497050	294		4	9CR	1	92		1	13	3
6000000049	6000000049	5404194949	5404194949	91	C	4	91	3	9CR		1	14	4
		6000000049	5404194949						91		1	157	5
1700000050				90	1					91	1		
1700000050	4142135649N		1700000050	9CR	CR1		90				1	13	1
2414213650	1700000050N		1285786450	90	1		91*CR				1	22	2
1000000050	1700000050		7142136049	90	1		91 CR				1	3	3
1000000050N	1700000050	2700000050	2700000050	90	1		91 CR	4	9CR	92	1	4	4
2592592649	2592592649		2592592649	9CR		3	9CR			93	1	5	5
7853981649			6721536448	90	1					94	1	6	6
3128888950	1269531250	6721536448	7853981649	290		4	90	1	93		1	7	7
1265625050	3181833950	6721536448	3181833950	290		4	9CR	1	93		1	8	8
3111111150	1286749750	6721536448	1286749750	290		4	9CR	1	93		1	9	9
1250000050	3163347650	6721536448	3163347650	290		4	9CR	1	93		1	10	
3000000050	1271248250	6721536448	1271248250	290		4	9CR	1	93		1	11	1
1000000050	3052873550	6721536448	3052873550	290		4	9CR	1	93		1	12	2
7853981649	1022017150	2592592649	1022017150	294		4	9CR	1	92		1	13	3
1700000050	1700000050	1039072350	1039072350	91	CR	4	91	3	9CR		1	14	4
		1700000050	1039072350						91		1	157	5
1130000051				90	1					91	1		
1130000051	4142135649N		1130000051	9CR	CR1		90				1	13	1
2414213650	1130000051N		1088578651	90	1		91*CR				1	22	2
1000000050	1130000051		8885786050*	90	1		91 CR				1	3	3
1000000050N	1130000051		1230000051	90		4	91 CR			92	2	4	4
8849557548N	8849557548N		8849557548*	9CR		3	9CR			93	2	55	5
	1570796350		7831466847		1		90			94	2	6	6
3128888950	1269531250	7831466847	1570796350	290		4	90	1	93		1	7	7
1265625050	3135057750	7831466847	3135057750	290		4	9CR	1	93		1	8	8

IA-1475

507 039

40

3111111150	1268123050	7631466847	1268123050	290		4	9CR	1	93		1	9	9
1250000050	3117286750	7631466847	3117286750	290		4	9CR	1	93		1	10	
3000000050	1252512350	7831466847	1252512350	290		4	9CR	1	93		1	11	1
1000000050	3006252650	7831466847	3006252650	290		4	9CR	1	93		1	12	2
1570796350	1002605150	88495575489	1002605150	294		4	9CR	1	92		1	13	3
1130000051	1130000051	1482530750	1482530750	91	CR	4	91	3	9CR		1	14	4
		1130000051	1482530750						91		1	157	5
1000000049				90	1					91	1		
1000000049	1000000049	7853981650	1000000049	90		9	9CR		99		1	1	1
		1000000049	9966865048						91		1	27	2
6000000049				90	1					91	1		
1000000049	6000000049	7853981650	6000000049	90		9	9CR		99		1	1	1
		6000000049	5404194949						91		1	27	2
1700000050				90	1					91	1		
1000000049	1700000050	7853981650	1700000050	90		9	9CR		99		1	1	1
		1700000050	1039072250						91		1	27	2
1130000051				90	1					91	1		
1000000049	1130000051	7853981650	1130000051	90		9	9CR		99		1	1	1
		1130000051	1482530850						91		1	27	2
		1000000049	9966865248						91		1	157	5
		6000000049	5404194949						91		1	157	5
		1700000050	1039072350						91		1	157	5
		1130000051	1482530750						91		1	157	5
		1000000049	9966865048						91		1	27	2
		6000000049	5404194949						91		1	27	2
		1700000050	1039072250						91		1	27	2
		1130000051	1482530850						91		1	27	2

507 040

40

IA-1475

SUMMARY

ORDER OF PRINTING INFORMATION

SRI or SRO Listing

Type Bar	
a1	An * prints only if SRO.
a2-a11	Contents of counter-group 1.
a12	Sign of counter-group 1 (as CR if negative).
a13-a22	Contents of counter-group 2.
a23	Sign of counter-group 2 (as * if negative).
a24-a33	Contents of counter-group 3.
a34	Sign of counter-group 3 (as CR if negative).
a35-a44	Contents of counter-group 4.
n1	Sign of counter-group 4 (as * if negative).
n2-n11	Contents of counter-group 5.
n12	Sign of counter-group 5 (as CR if negative).
n13-n22	Contents of counter-group 6.
n23	Sign of counter-group 6 (as * if negative).
n24-n33	Contents of counter-group 7.
n34	Sign of counter-group 7 (as CR if negative).
n35-n44	Contents of counter-group 8.
n45	Sign of counter-group 8 (as * if negative).

Hammersplit Control

If only SRI or SRO cards are listed, the Hammersplits in "up" position are:

a 1, 11, 12, 22, 23, 33, 34, 44.

n 1, 11, 12, 22, 23, 33, 34, 44.

If the proper listing of other calculations is desired without extraneous zeros being printed, the Hammersplits should be in "up" position as shown on the next page.

ORDER OF PRINTING INFORMATION

Calculational Listing (Not SRI or SRO)

Type Bar	
a2-a11	Number addressed on channel A.
a12	Sign of number (as 9 or N if negative).
a13-a22	Number addressed on channel B.
a23	Sign of number (as 9 or N if negative).
a24-a33	Number addressed on channel X.
a34	Sign of number (as 9 if negative).
a35-a44	Channel C result of previous card.
n1	Sign of number (as * if negative).
n2	2 if A and X interchange, (i).
n3-n4	Channel A address.
n5	* if minus A.
n6	CR if $\|A\|$.
n7	1 if operation A.
n8	3 if operation M.
n9	4 if operation D.
n10	CR if No Shift Left, 5 if $\sqrt{\|A\|}$, 6 if e^B, 7 if log $\|B\|$, 8 if sin B, 8 if cos B, or 9 if arctan B.
n11	* if No Round operation, 8 if cos B.
n12	2 if B and X interchange, (I).
n13-n14	Channel B address.
n15	* if minus B.
n16	CR if $\|B\|$.
n17	1 if operation a.
n18	3 if operation m.
n19	4 if operation d.
n21-n22	Channel X address.
n23	* if minus X.
n24	CR if $\|X\|$.
n25-n26	Channel C address.
n28	Instruction field number.
n30-n33	Number punched in columns 10, 40, 50, 80, (Serial Number).
n34	Number punched in column 9 of instruction field.
n35-n44	Number punched in columns 71-80.

Hammersplits in "up" position

a 1, 11, 12, 22, 23, 33, 34, 44.

n 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 22, 23, 24, 26, 28, 33, 34, 44.

INSTRUCTION CARD LAYOUT

Each instruction card is divided into fields as follows:

Card Column	Assignment
1-9	Instruction field #1 (normal).
10	Thousands digit of card number.
11-20	Normal channel A card read-in.
21-30	Normal channel B card read-in.
31-39	Instruction field #2.
40	Hundreds digit of card number.
41-49	Instruction field #3.
50	Tens digit of card number.
51-60	Alternate channel A card read-in and alternate channel X card read-in.
61-70	Alternate channel B card read-in and normal channel X card read-in.
71-79	Instruction field #4.
80	Units digit of card number.

Columns 1-9 of the instruction field are as follows:

Column	Assignment
1-2	Channel A address
3	Operations code
4	Channel X address
5-6	Channel B address
7-8	Channel C address
9	Control punches

SUMMARY OF CHANNEL ADDRESSES

Channel A Address Col. 1-2	Number Delivered to Channel A
9X	Result of previous calculation.
90	Number punched in columns 11-20 of this card.
91-98	Number stored in the counter-group addressed.
99	Number punched in columns 51-60 of this card.
11-68	Number stored in the storage register addressed.

Channel B Address Col. 5-6	Number Delivered to Channel B
9X	Result of previous calculation.
90	Number punched in columns 21-30 of this card.
91-98	Number stored in the counter-group addressed.
99	Number punched in columns 61-70 of this card.
11-68	Number stored in the storage register addressed.

Channel X Address Col. 4	Number Delivered to Channel X
X	Result of previous calculation.
0	Number punched in columns 61-70 of this card.
1-8	Number stored in the counter-group addressed.
9	Number punched in columns 51-60 of this card.

Channel C Address Col. 7-8	Storage Receiving Result from Channel C
91-98	Counter-groups 1-8 as addressed.
11-68	Storage Registers 11-68 as addressed.
90	SRI instruction, all counters read-in from next card.

A blank card will perform no operation and will read zeros onto Channel C.

SUMMARY OF CONTROL OPERATIONS

X and Y control punches in columns 1-7 of instruction field

Column	X Punch	Y Punch
1	List this card.	Absolute value of A.
2	C to A transfer if 9 in column 1.	Change the sign of A.
3	Do not shift left.	Interchange order of operations.
4	C to X transfer.	Change the sign of X.
5	List the following card.	Absolute value of B.
6	C to B transfer if 9 in column 5.	Change the sign of B.
7	Do not round.	Absolute value of X.

Control punches in column 9 of instruction field

Punch	Operation
X	Change instruction field if C is negative.
1	Machine stop if C is negative.
2	Change to instruction field #2.
3	Change to instruction field #3.
4	Change to instruction field #4.
5	Change instruction field unconditionally.
6	Spread-read-out, (SRO).
7	Double space before next list order.
8	Restore one-half sheet of paper.
9	Restore to next sheet of paper.

Switch Controls

Set-Up Change Switch	In "ON" Position
1	List every card.
2	Double space every list order.
3	MUST ALWAYS BE "ON".

D.P.D.T. Switches	In "A" Position
1	80-80 list: See page 35
2	ON SRO: Print but do not punch.
3	ON SRO: Punch but do not print.
4	Comparing:
5	Comparing:
6	Comparing:
7	Comparing: See page 35
8	Comparing:
9	Comparing:

SUMMARY OF CALCULATIONAL OPERATIONS

Arithmetic Operations

(The operation in parentheses is the first operation)

Code Punch Col. 3	Operation	Wiring Code	Calculate Selector
1	A + B	A	4
3	AB	M	6
4	A/B	D	7
1,3	(AB) + X	M,a	6,12
1,2,3	(AX) + B	M,a,I	6,12,5,11
0,1,2,3	(XB) + A	M,a,i	6,12,2,3
Y,1,3	(A + B)X	A,m	4,13
Y,1,2,3	(A + X)B	A,m,I	4,13,5,11
Y,0,1,2,3	(X + B)A	A,m,i	4,13,2,3
1,4	(A/B) + X	D,a	7,12
1,2,4	(A/X) + B	D,a,I	7,12,5,11
0,1,2,4	(X/B) + A	D,a,i	7,12,2,3
Y,1,4	(A + B)/X	A,d	4,14
Y,1,2,4	(A + X)/B	A,d,I	4,14,5,11
Y,0,1,2,4	(X + B)/A	A,d,i	4,14,2,3

The above operations require one card time if there is no loss of figures necessitating a shift to the left.

Code Punch Col. 3	Operation	Wiring Code	Calculate Selector
3,4	(AB)/X	M,d	6,14
2,3,4	(AX)/B	M,d,I	6,14,5,11
0,2,3,4	(XB)/A	M,d,i	6,14,2,3
Y,3,4	(A/B)X	D,m	7,13
Y,2,3,4	(A/X)B	D,m,I	7,13,5,11
Y,0,2,3,4	(X/B)A	D,m,i	7,13,2,3
0,3	(AB)X	M,m	6,13
0,4	(A/B)/X	D,d	7,14
0,2,4	(X/B)/A	D,d,i	7,14,2,3

These operations will in the majority of cases require two card times; one card time otherwise.

Transcendental and Special Operations

Code Punch Col. 3	Operation	Requirements and Usage	Wiring Code	Calculate Selector
5	$\sqrt{\lvert A \rvert}$	No read-in on B necessary	R	8,9
6	e^B	Read-in $\ln 10$ on A and $1/2 \ln 10$ on X	E	12,15,16
7	$\ln \lvert B \rvert$	Read-in $\sqrt{10}$ on A and $\ln 10$ on X	L	10,13
8	sin B	Read-in π on A and $\pi/2$ on X	S	11,15,16
0,8	cos B	Read-in π on A and $\pi/2$ on X	C	2,11,15,16
9	arctan B	Read-in 1/10 on A and $5\pi/2$ on X	T	7,17,18
X	Do not shift left	Used only with arithmetic operations	N	16,18
X in Col. 7	Do not round	Used only with arithmetic operations	n	Channel shift

See page 26 for estimate of time required for operations, range of arguments, and accuracy of results for transcendental functions. See page 24 for usage of special operations.