July 2, 1957 E. G. ANDREWS ET AL 2,797,862

DIGITAL COMPUTER

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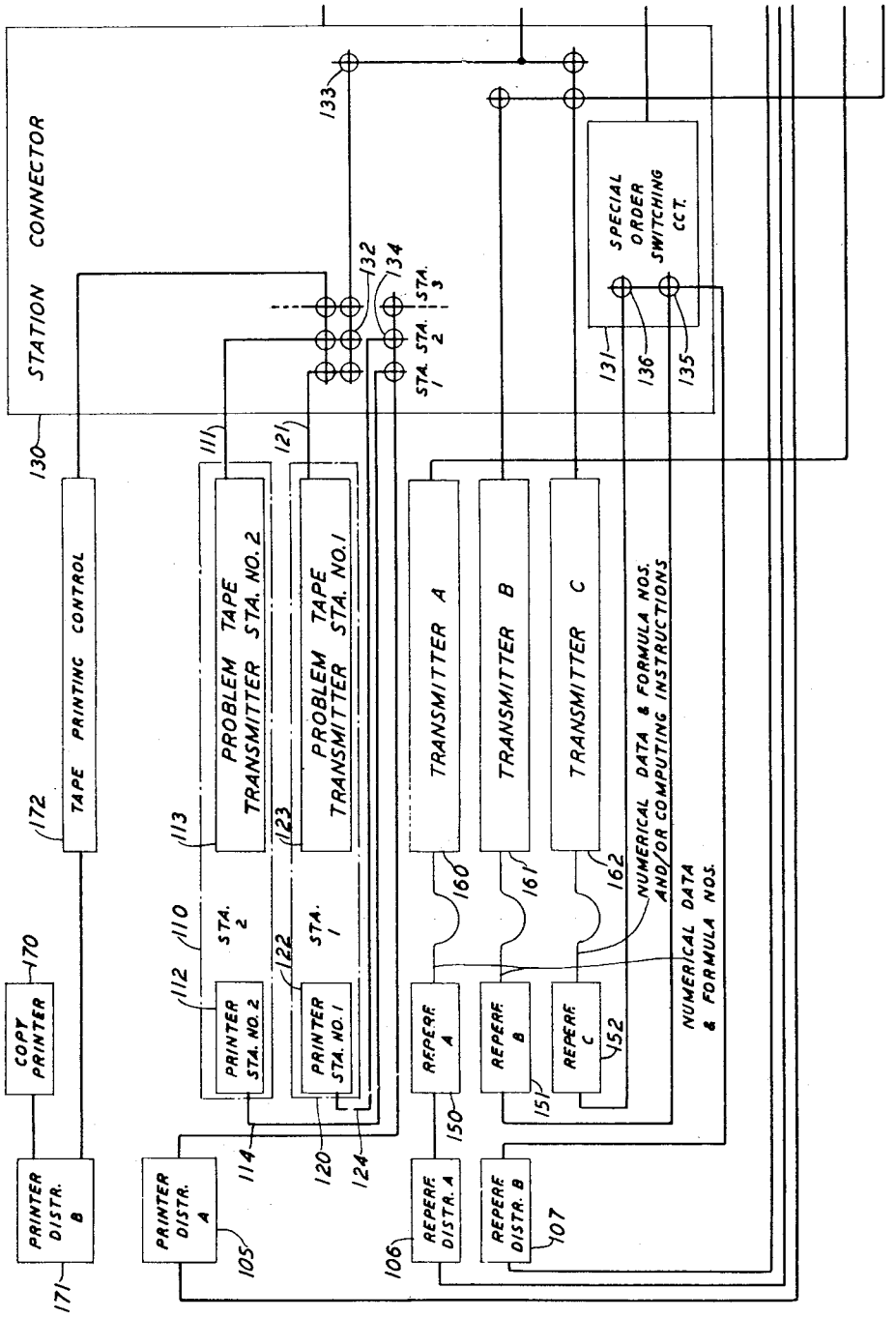

FIG. 1

INVENTORS E. G. ANDREWS
O. CESAREO
P. B. MURPHY

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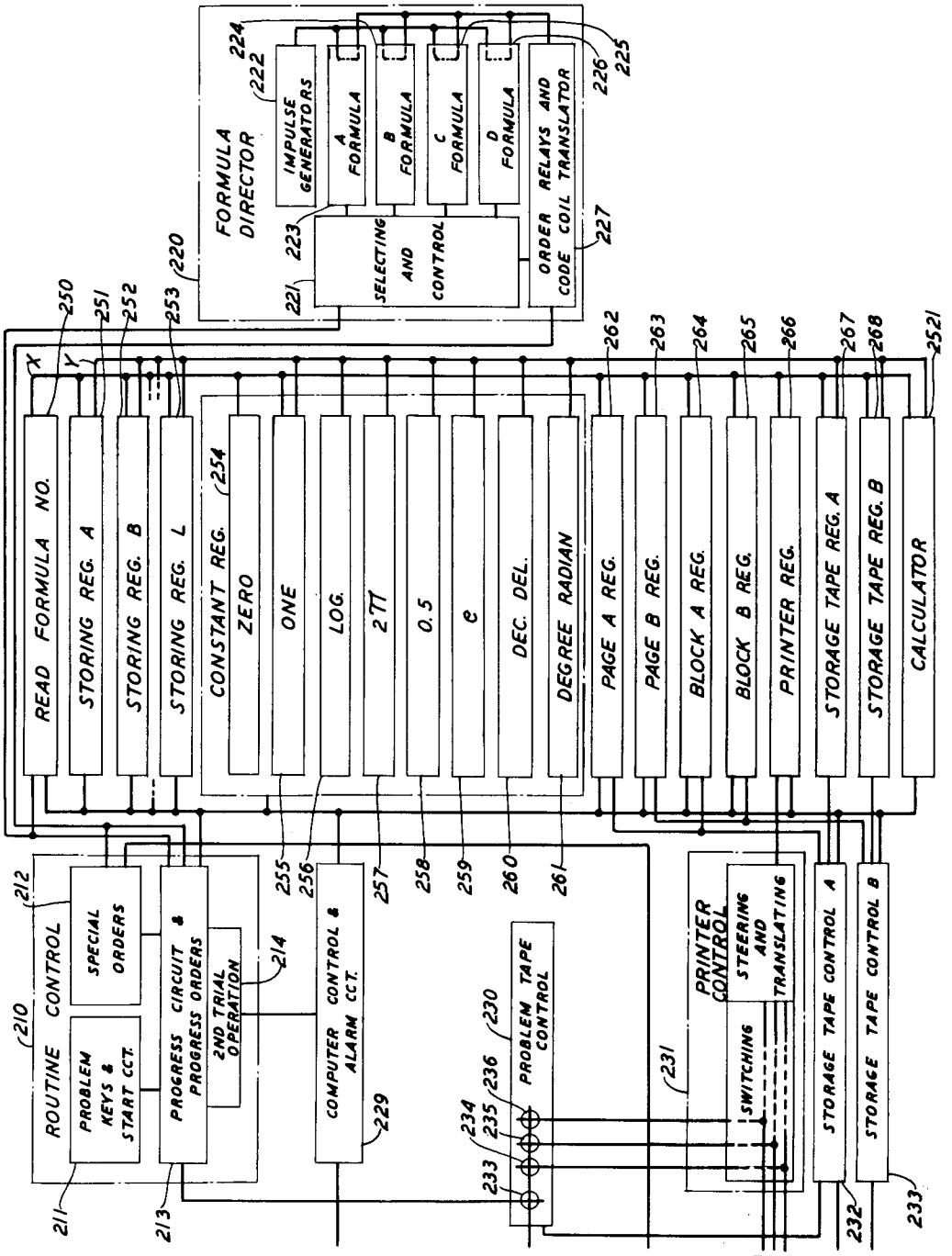

FIG. 2

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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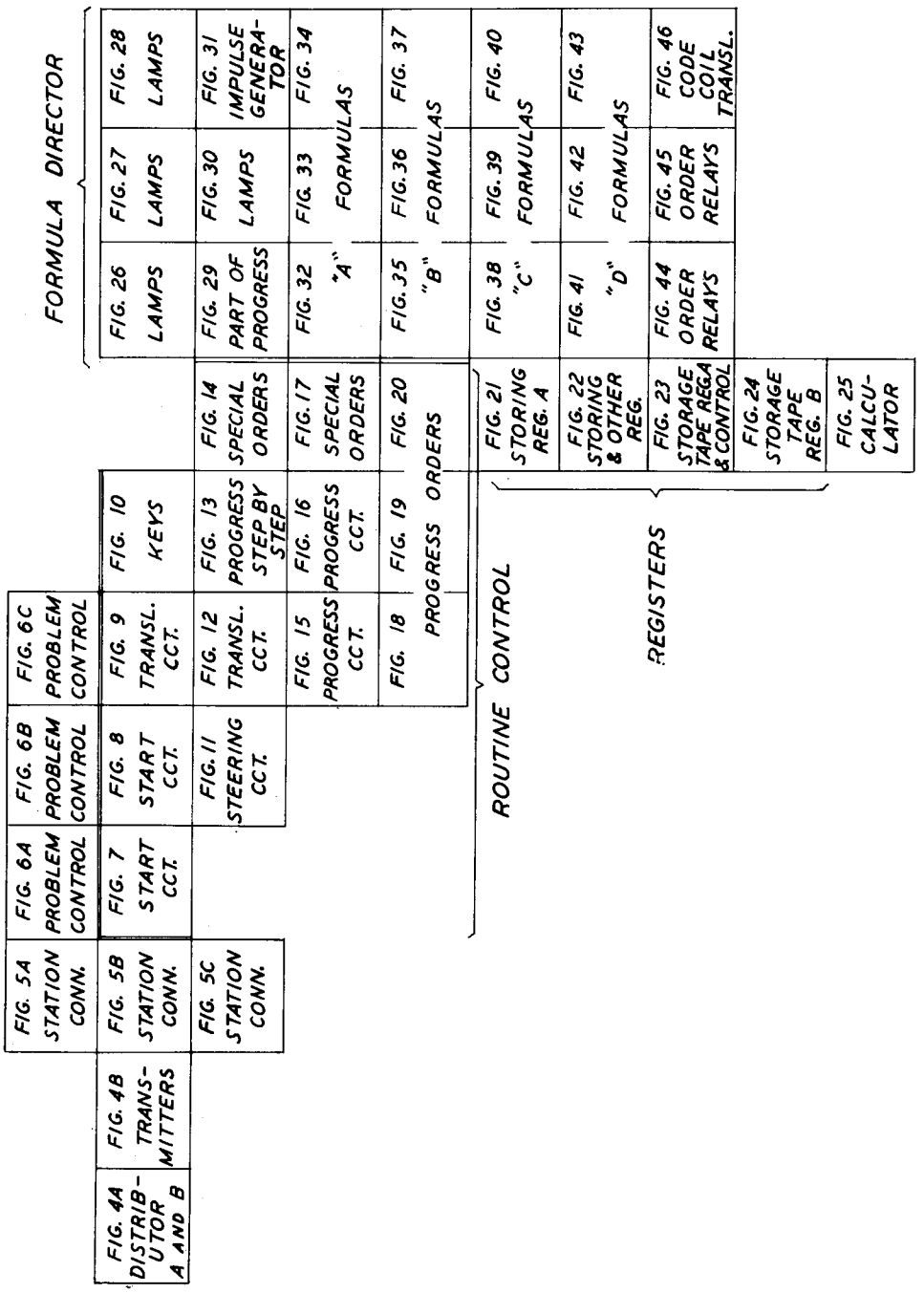

FIG. 3

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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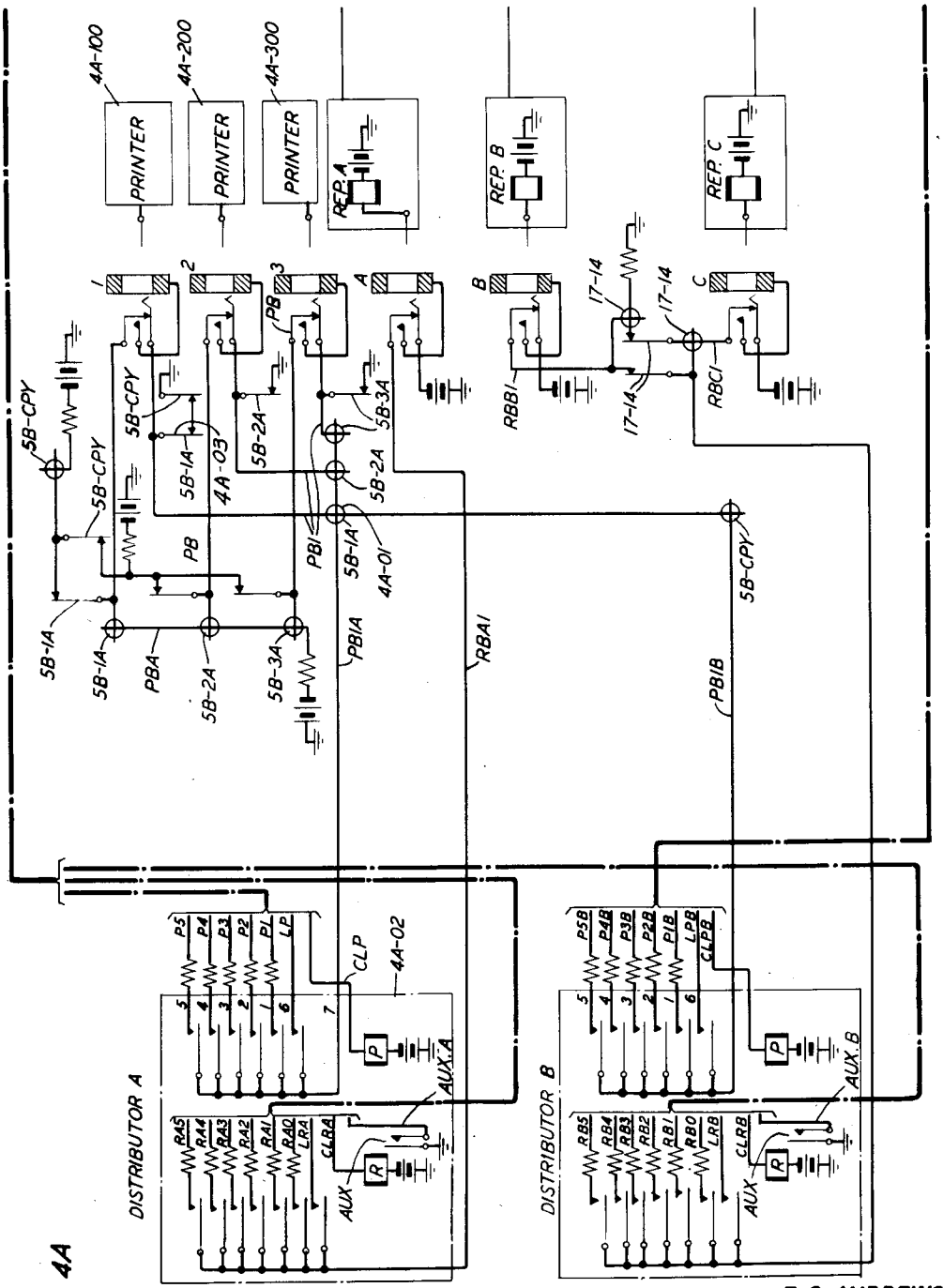

FIG. 4A

INVENTORS E G ANDREWS
O CESAREO
P B MURPHY

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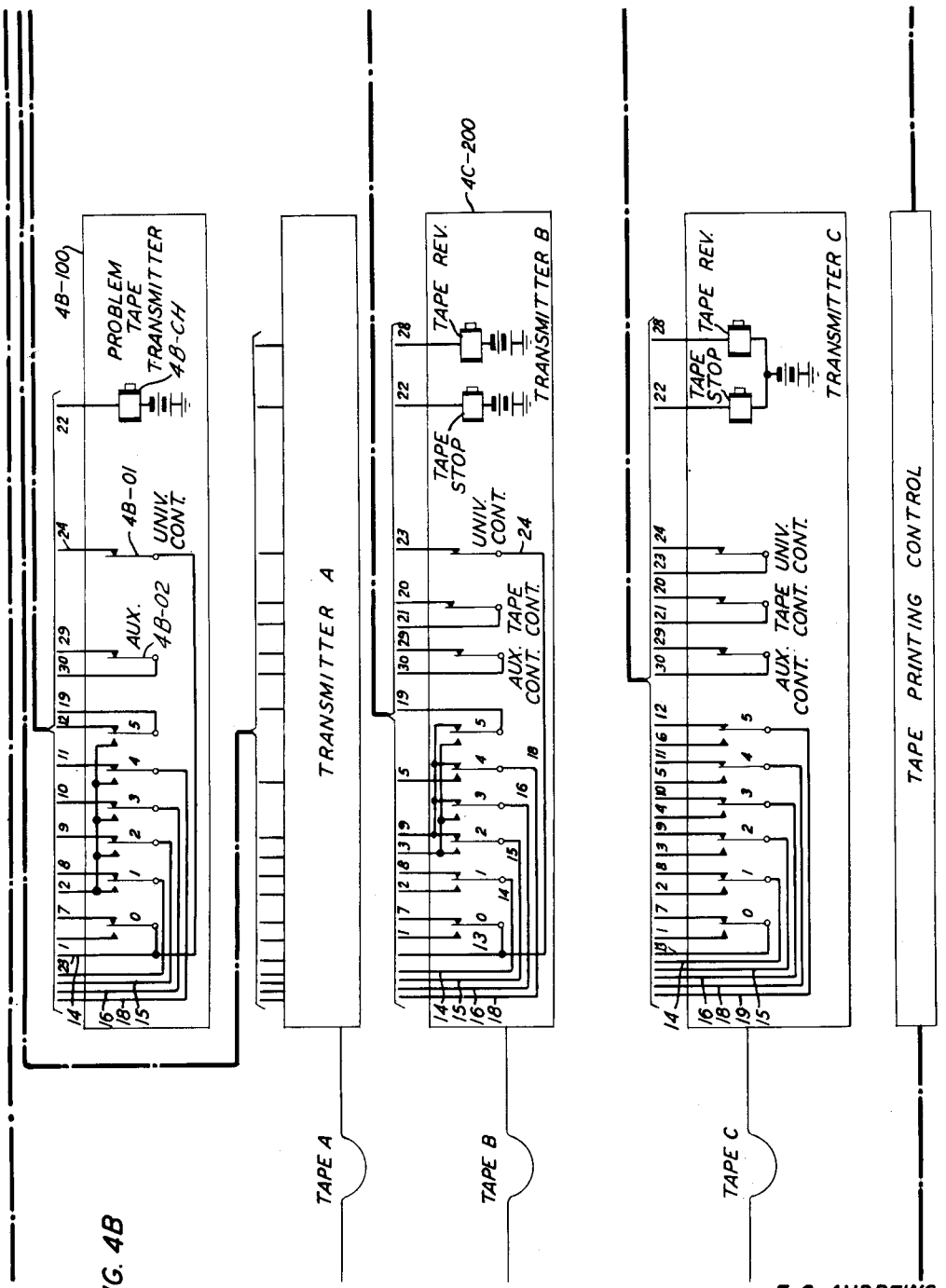

FIG. 4B

INVENTORS E.G ANDREWS
O. CESAREO
P.B MURPHY

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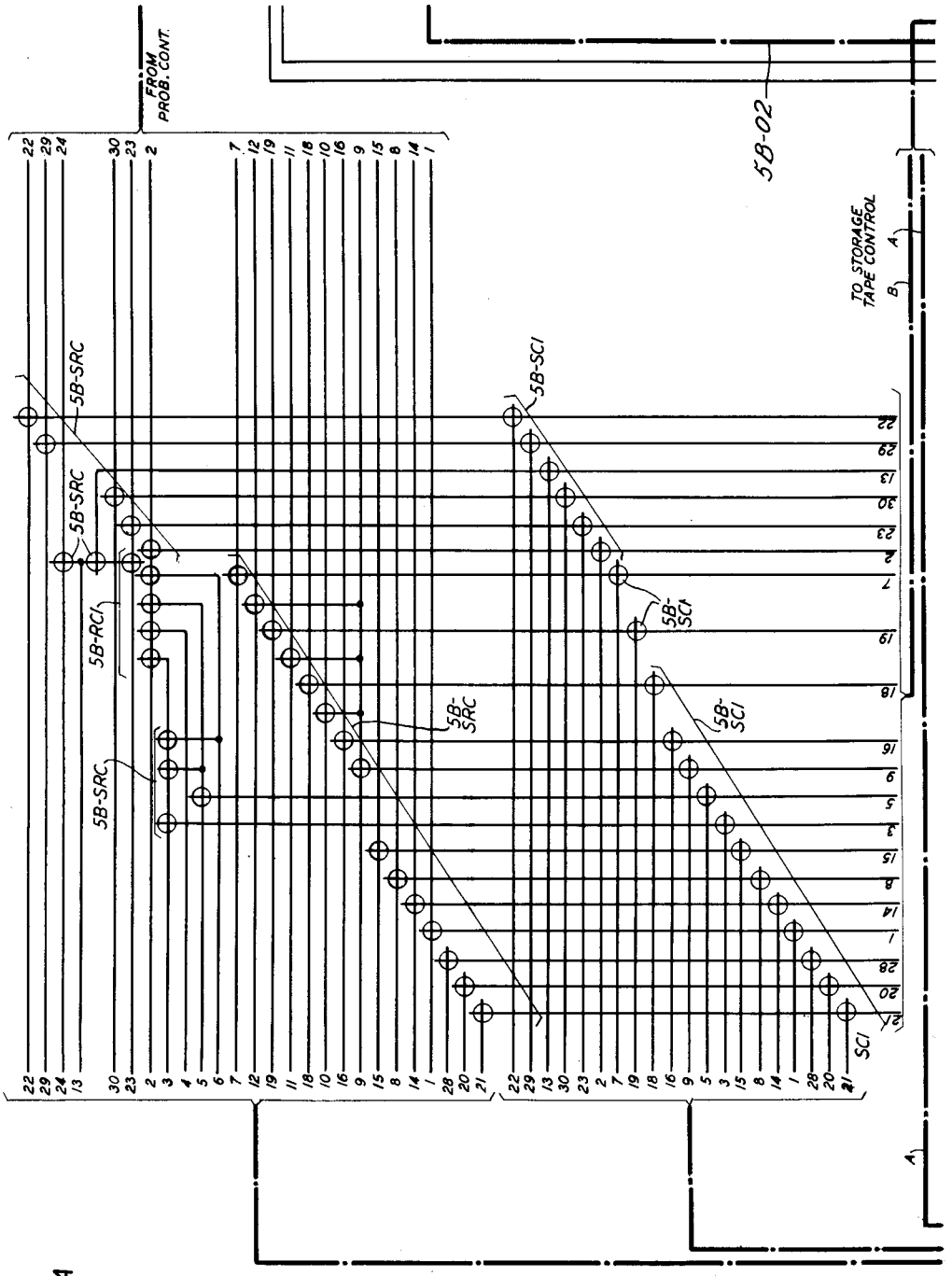

FIG. 5A

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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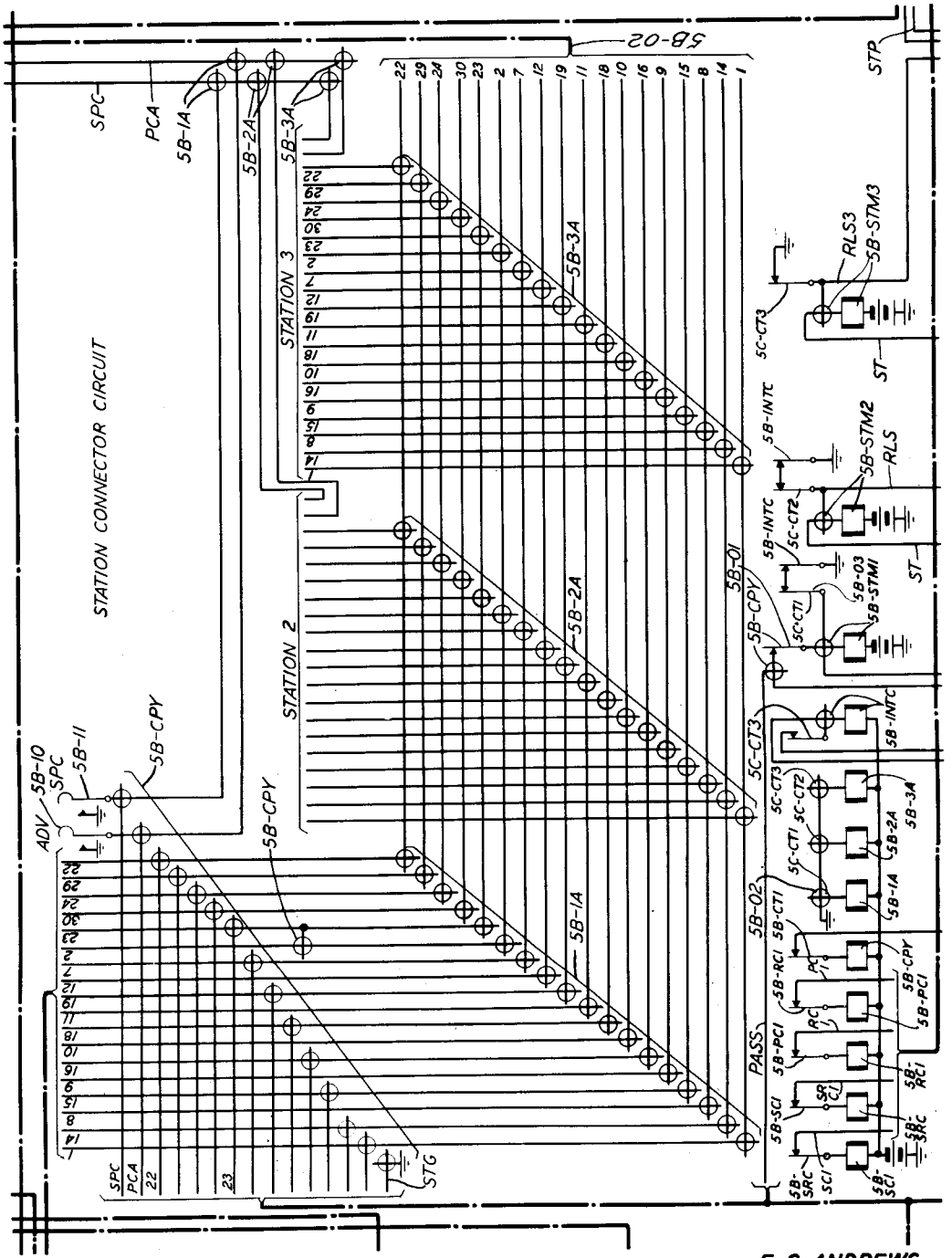

FIG. 5B

INVENTORS E. G. ANDREWS
O. CESAREO
P. B. MURPHY

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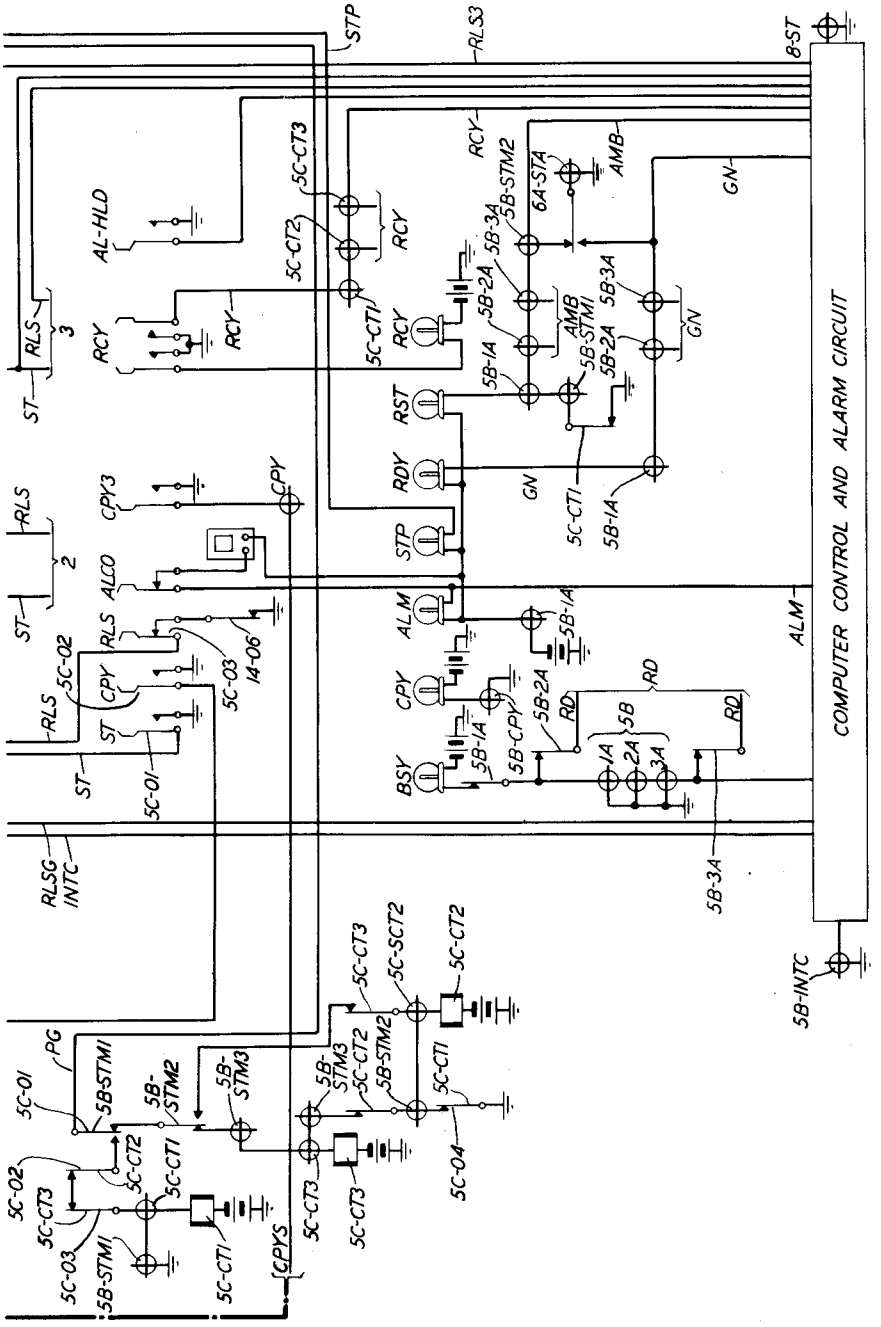

FIG. 5C

INVENTORS E. G. ANDREWS
O. CESAREO
P. B. MURPHY

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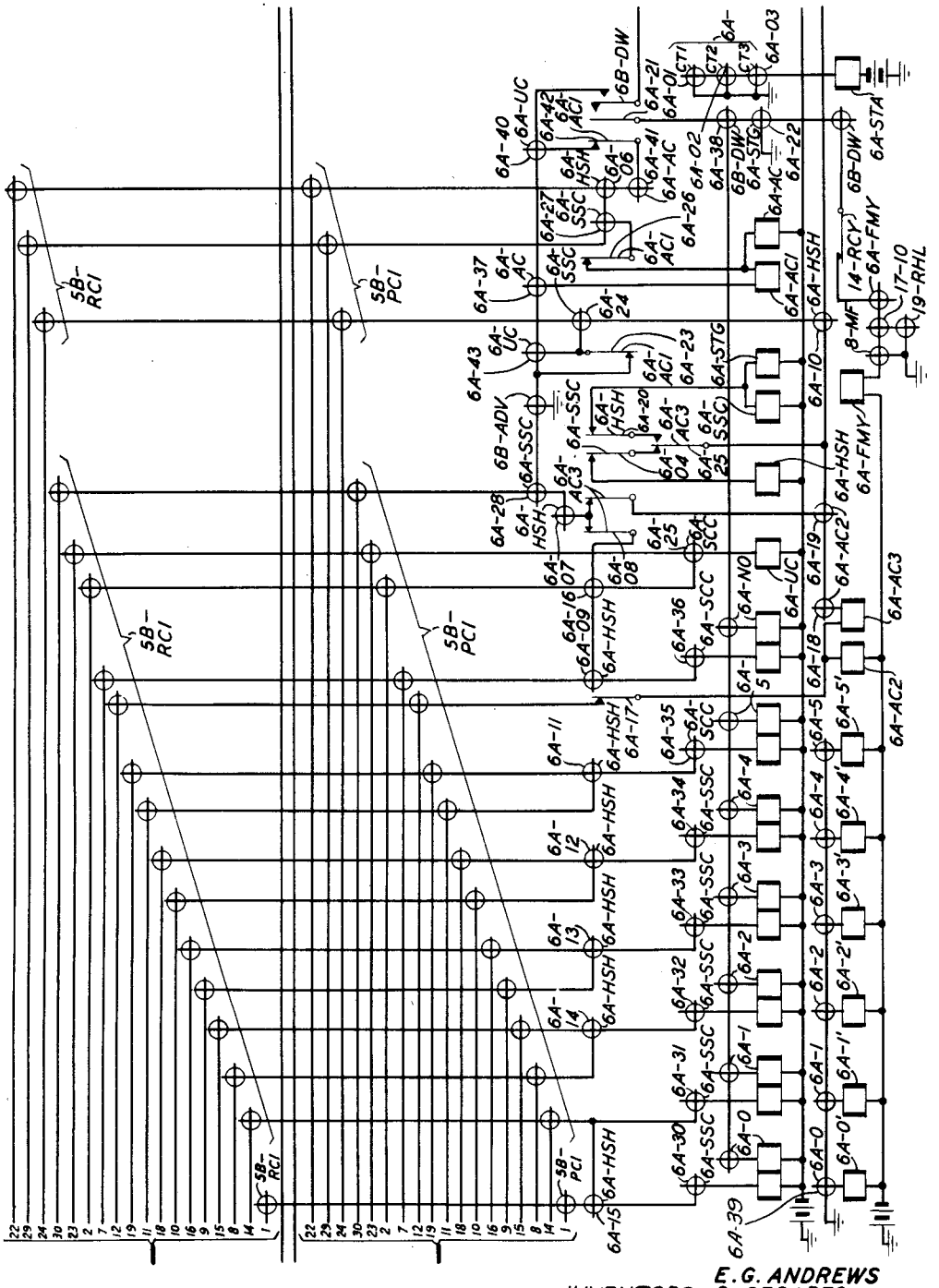

FIG. 6A

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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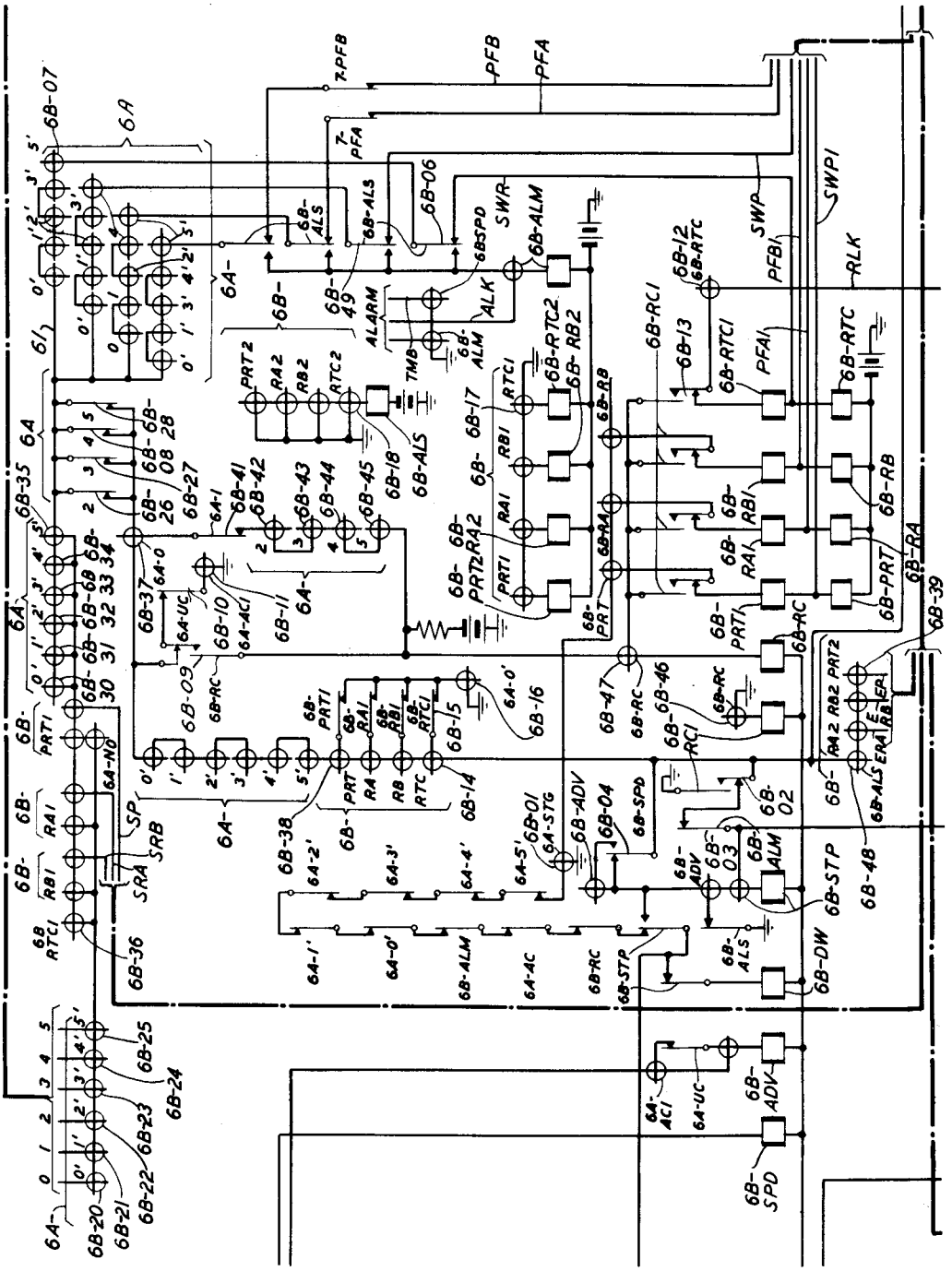

FIG. 6B

INVENTORS E. G. ANDREWS
O. CESAREO
P. B. MURPHY

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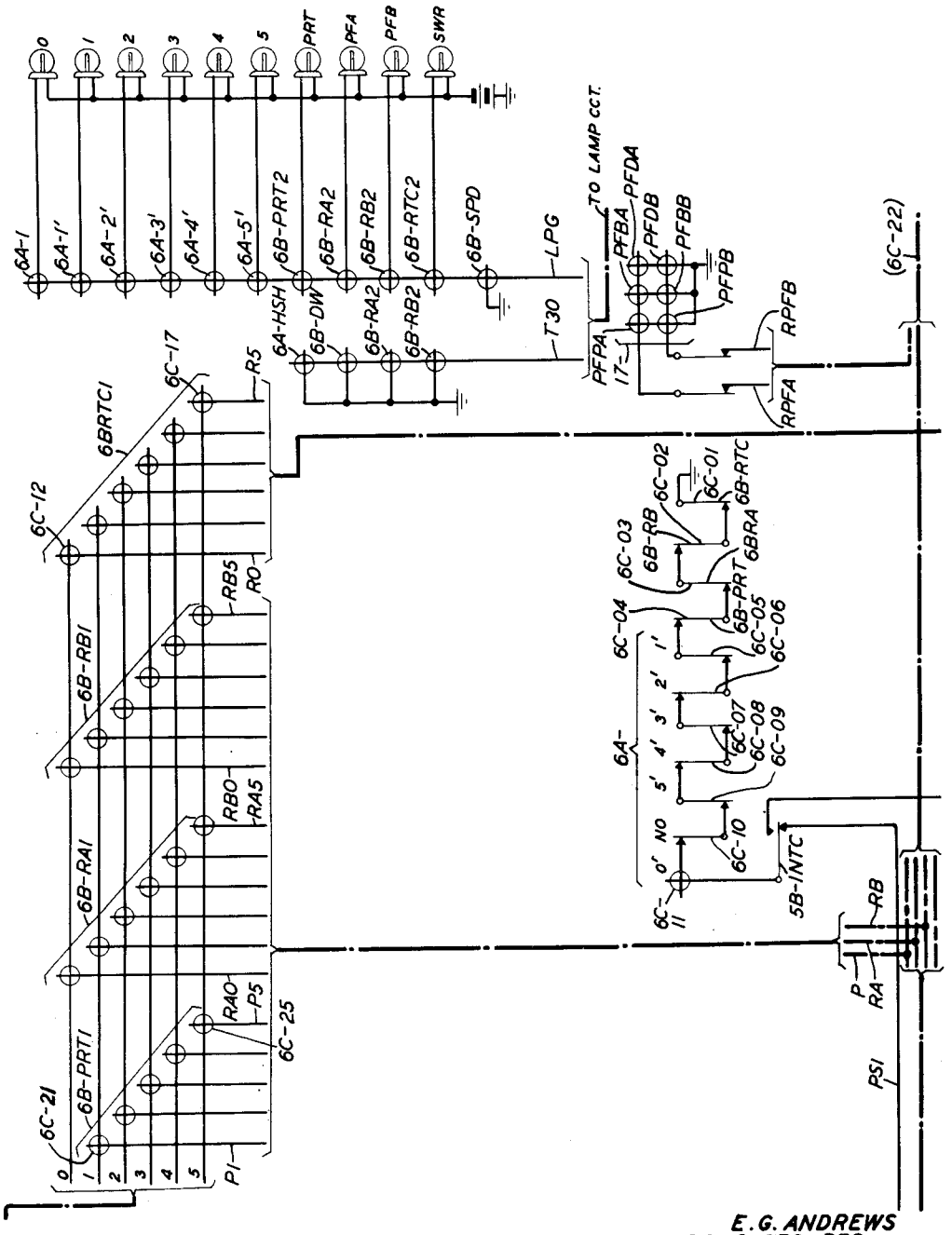

FIG. 6C

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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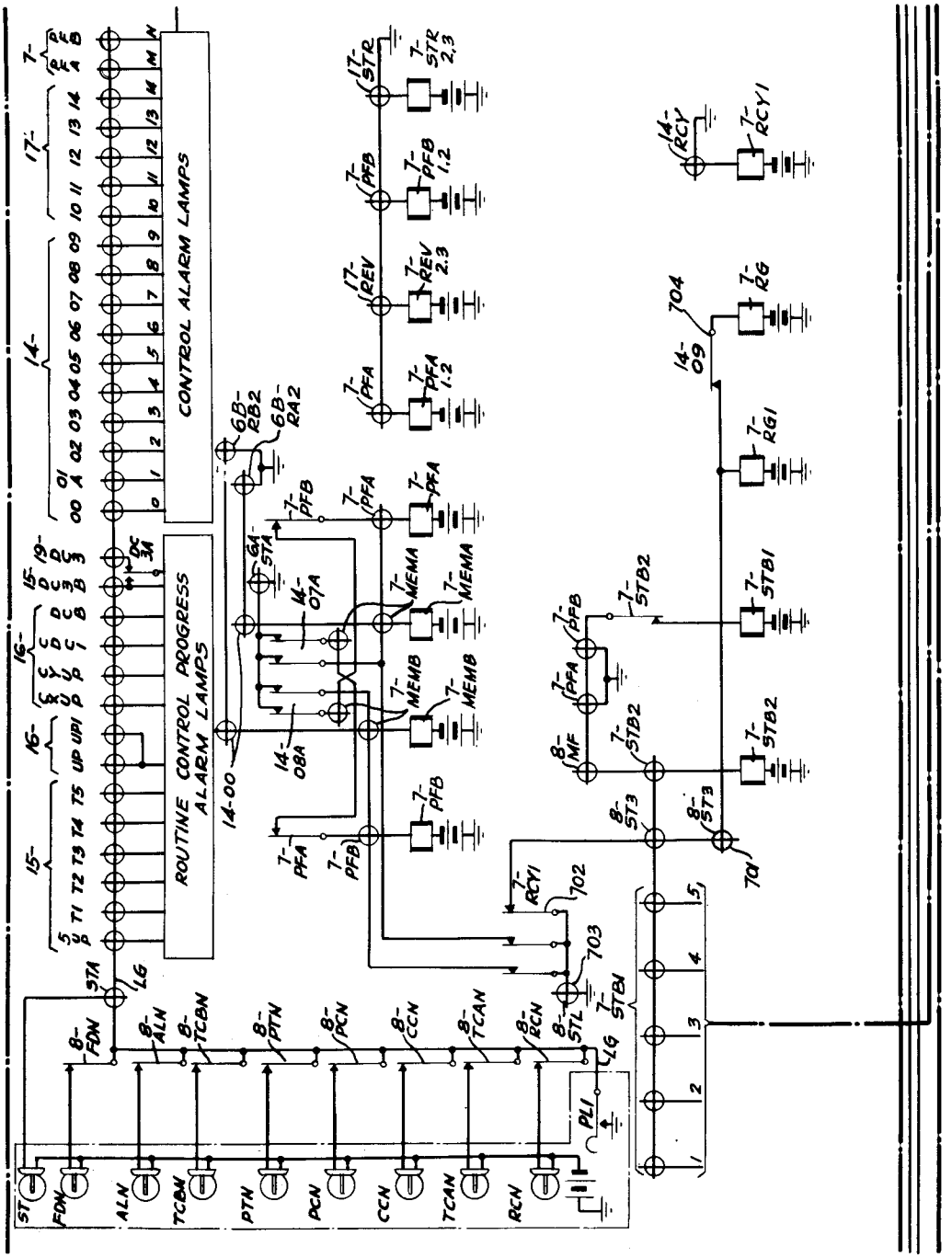

FIG. 7

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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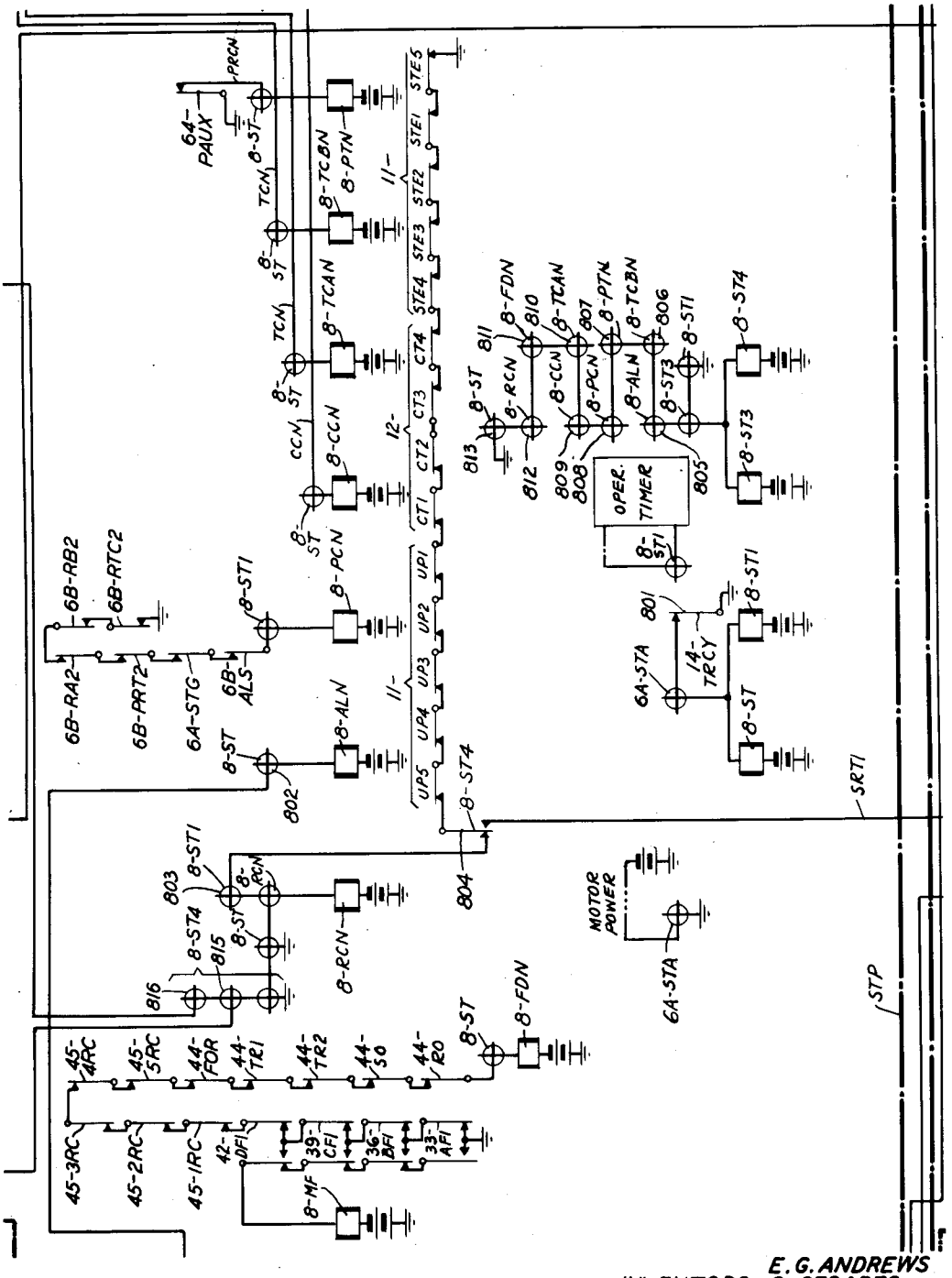

FIG. 8

INVENTORS E. G. ANDREWS
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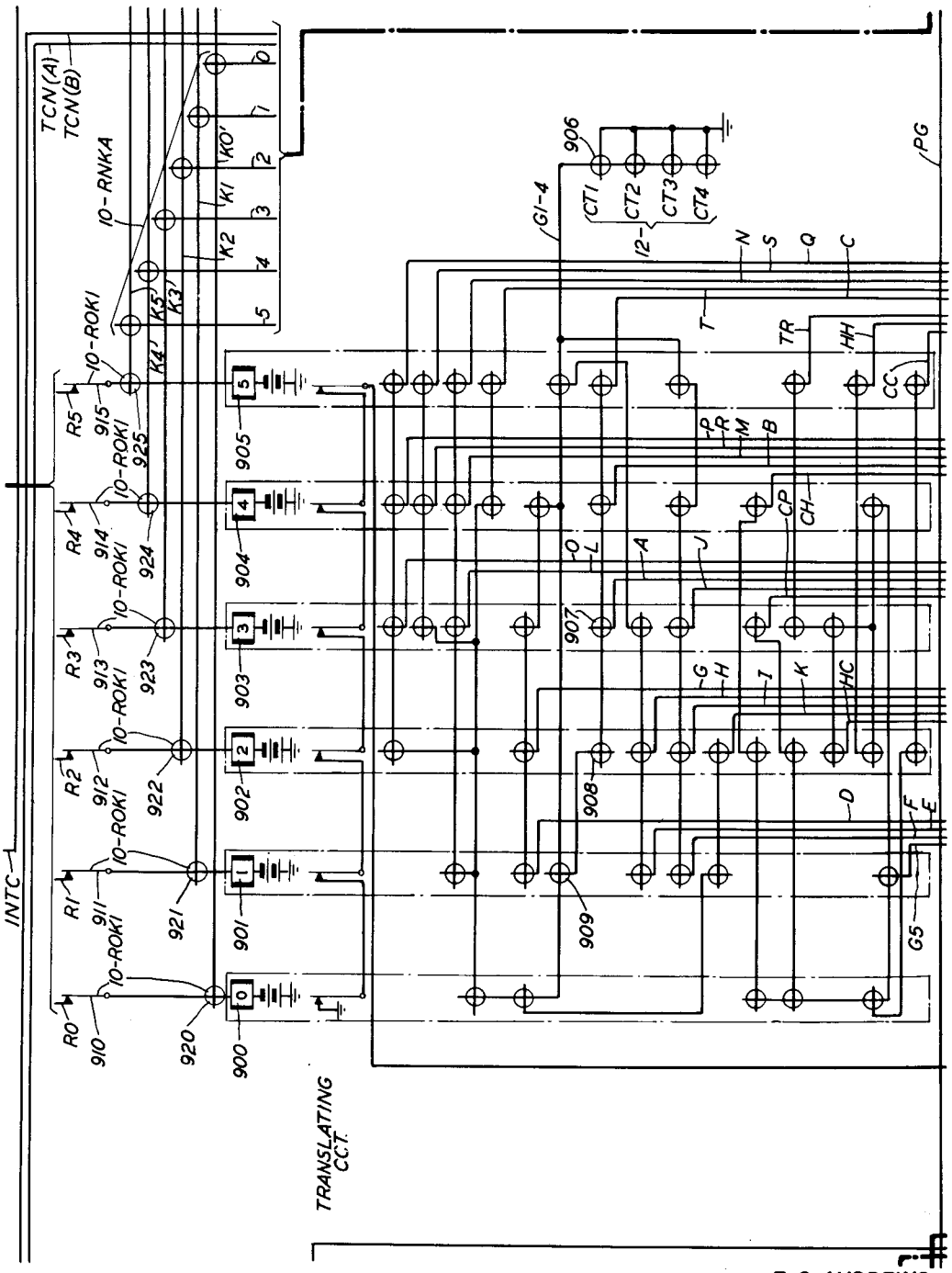

FIG. 9

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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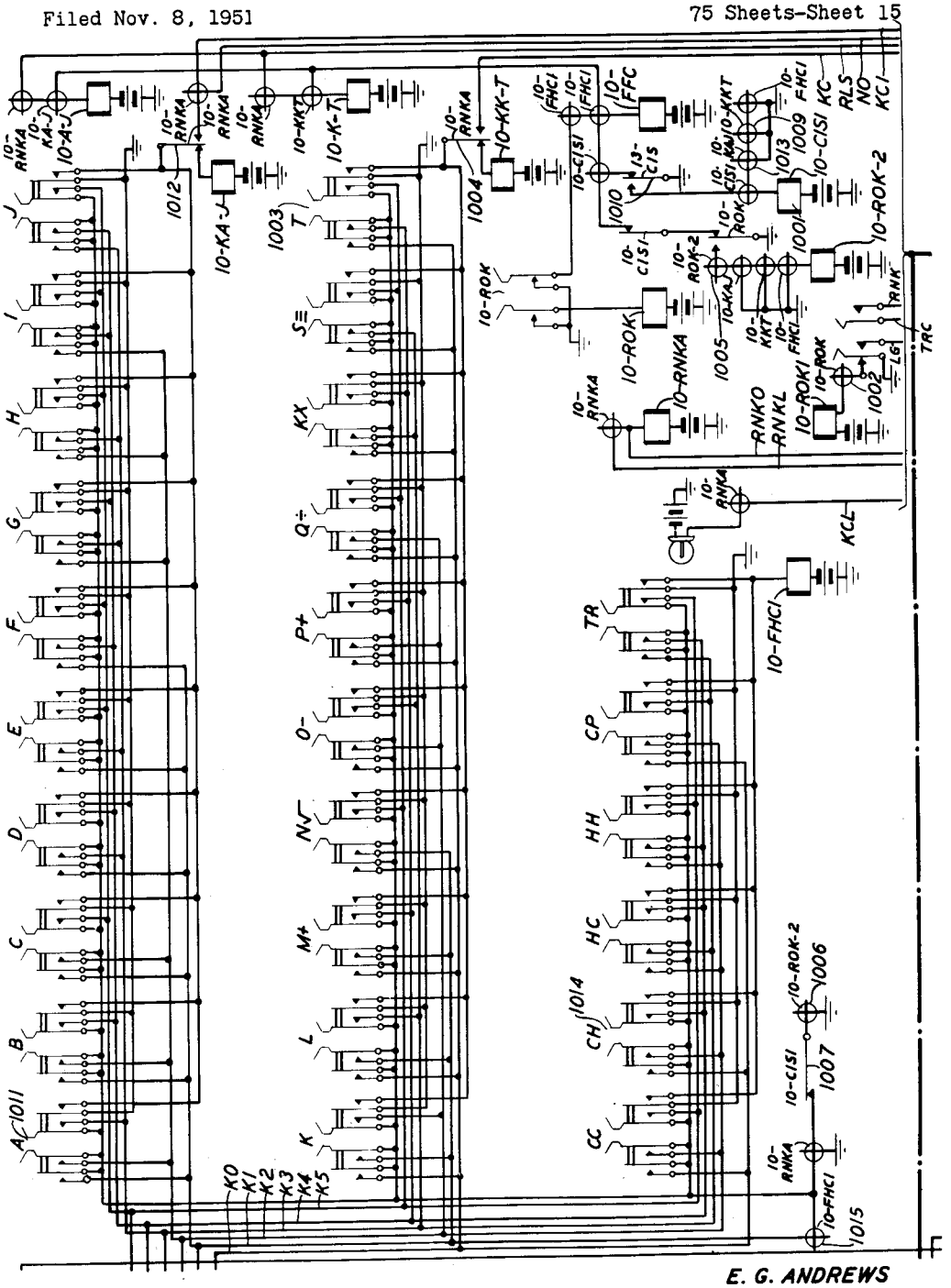

FIG. 10

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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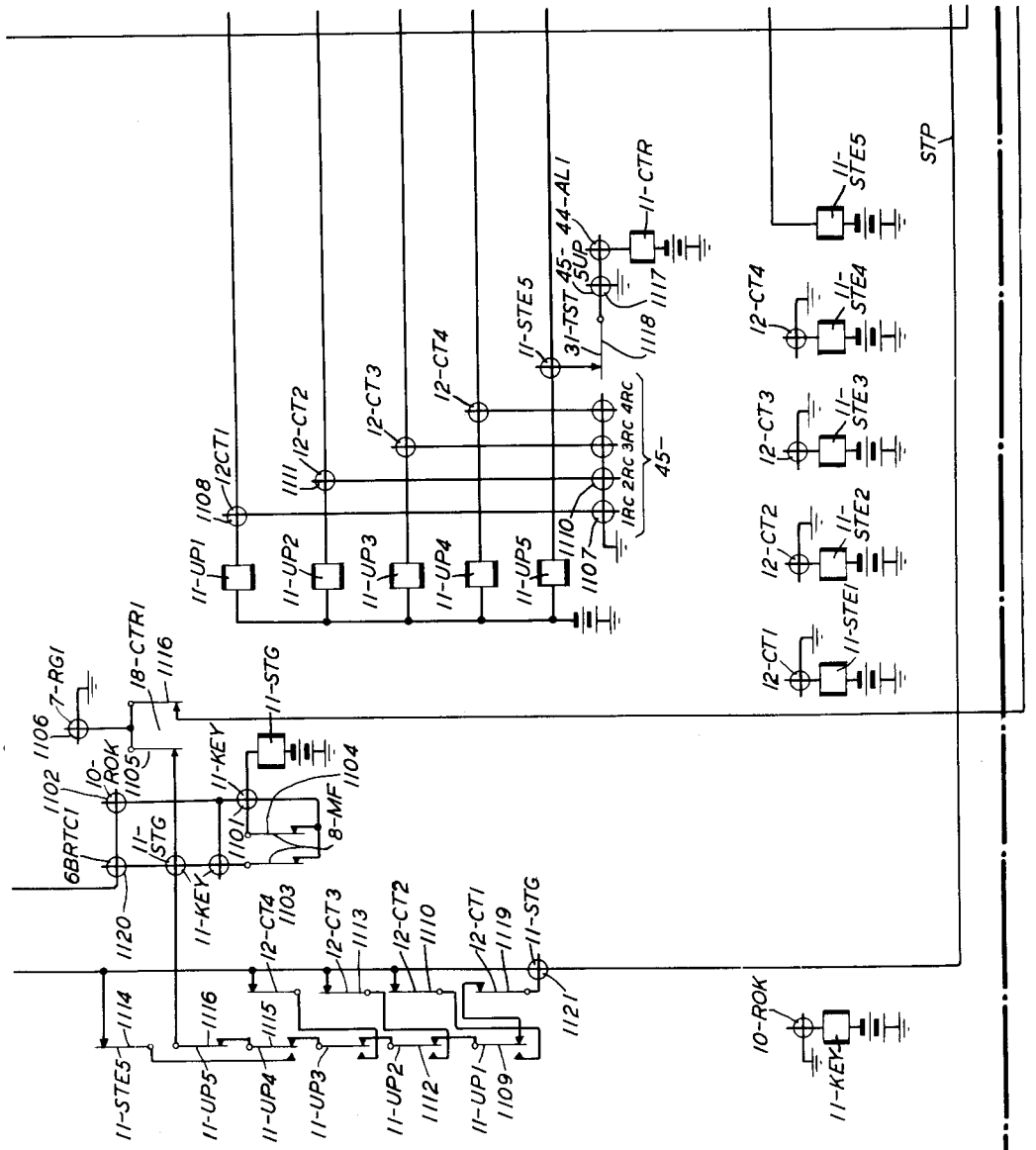

FIG. 11

INVENTORS E. G. ANDREWS
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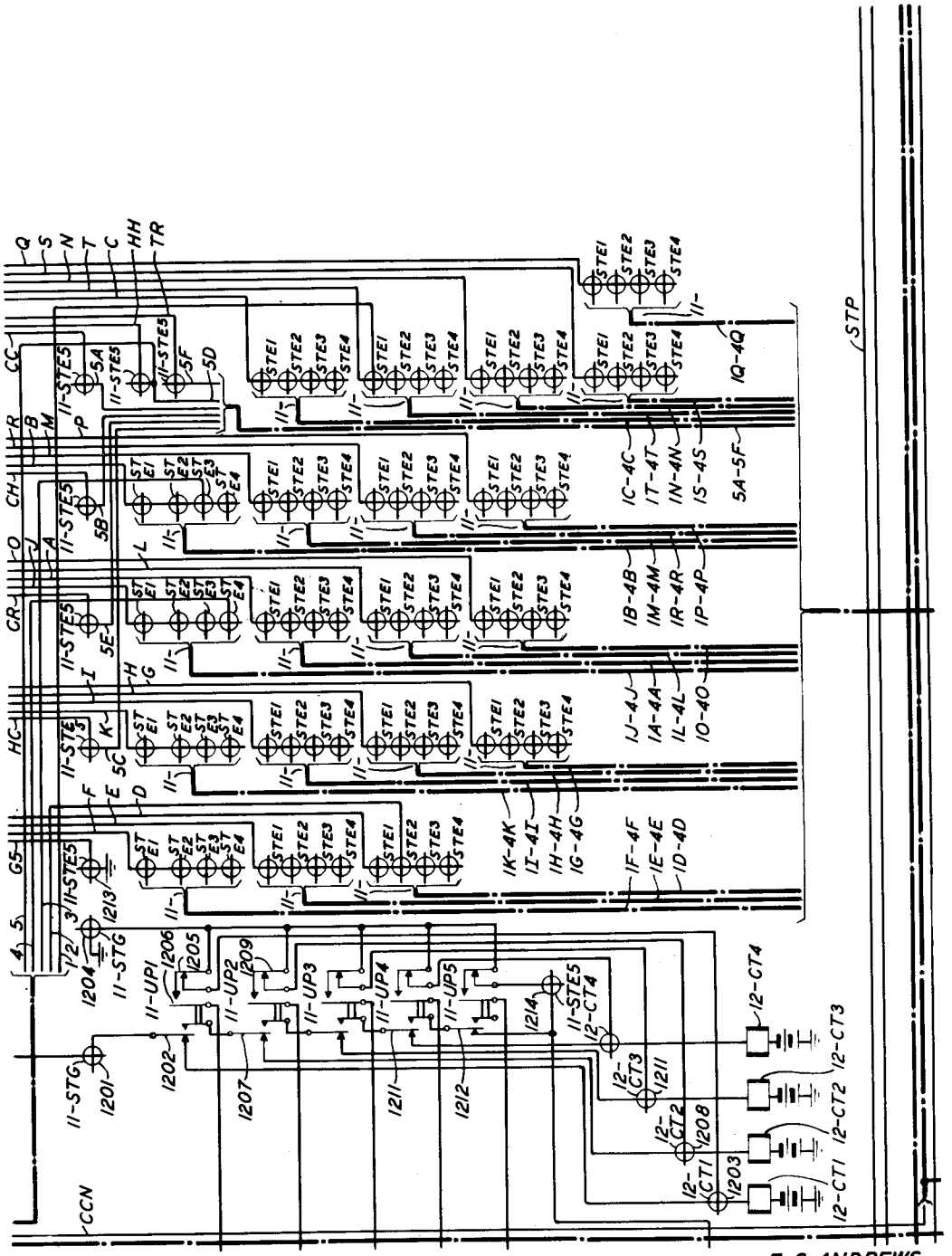

FIG. 12

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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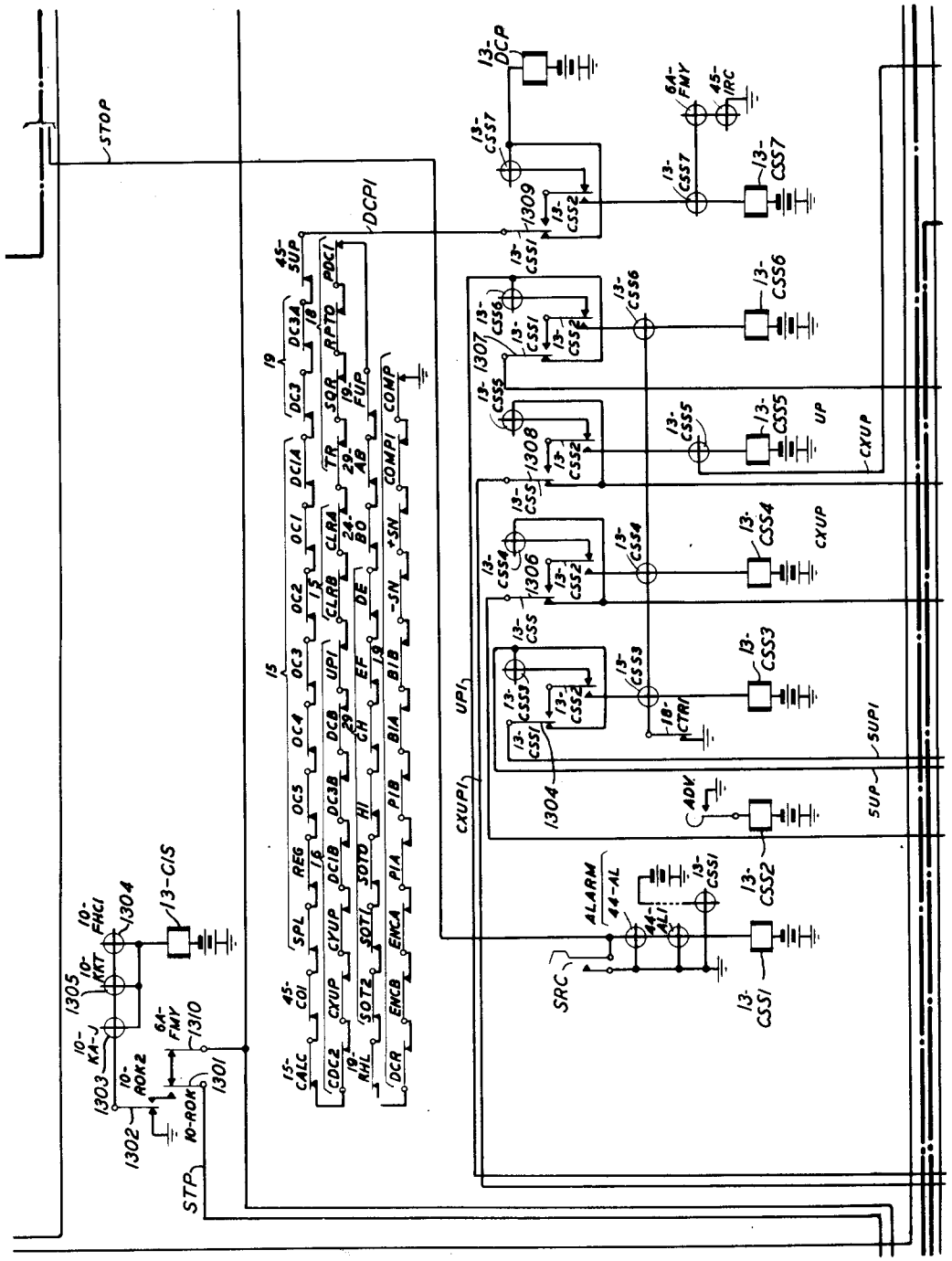

FIG. 13

INVENTORS E. G. ANDREWS
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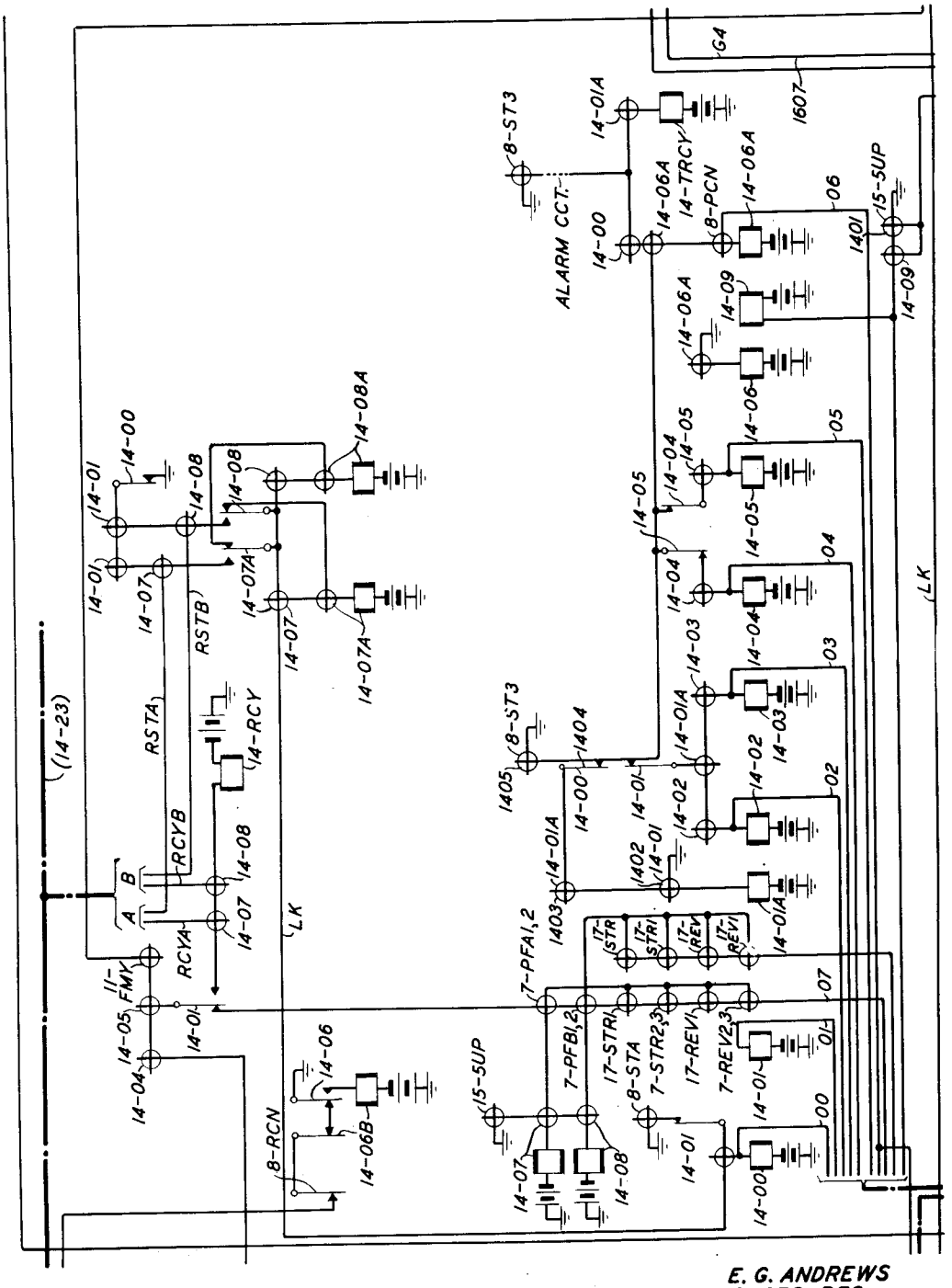

FIG. 14

INVENTORS E. G. ANDREWS
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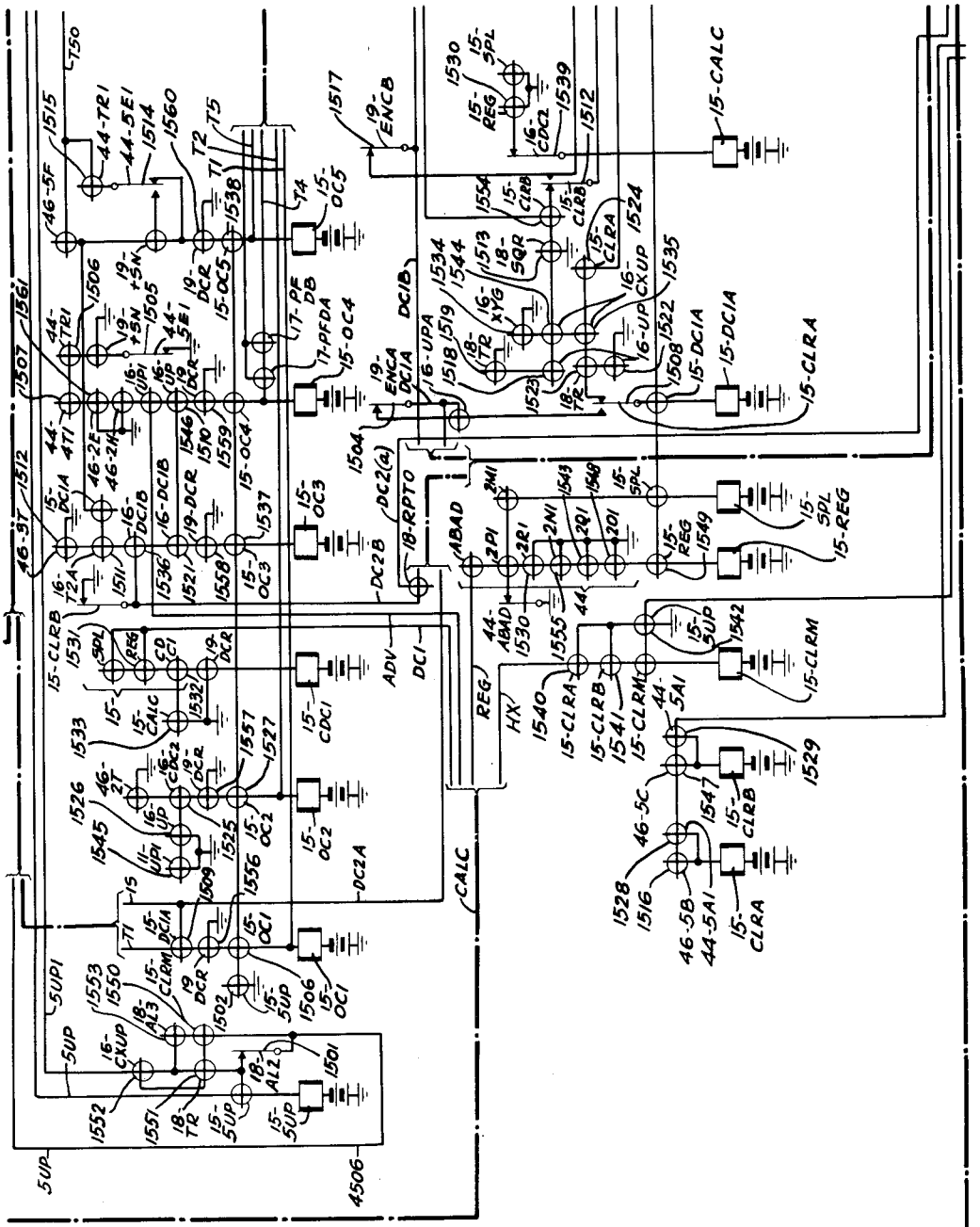

FIG. 15

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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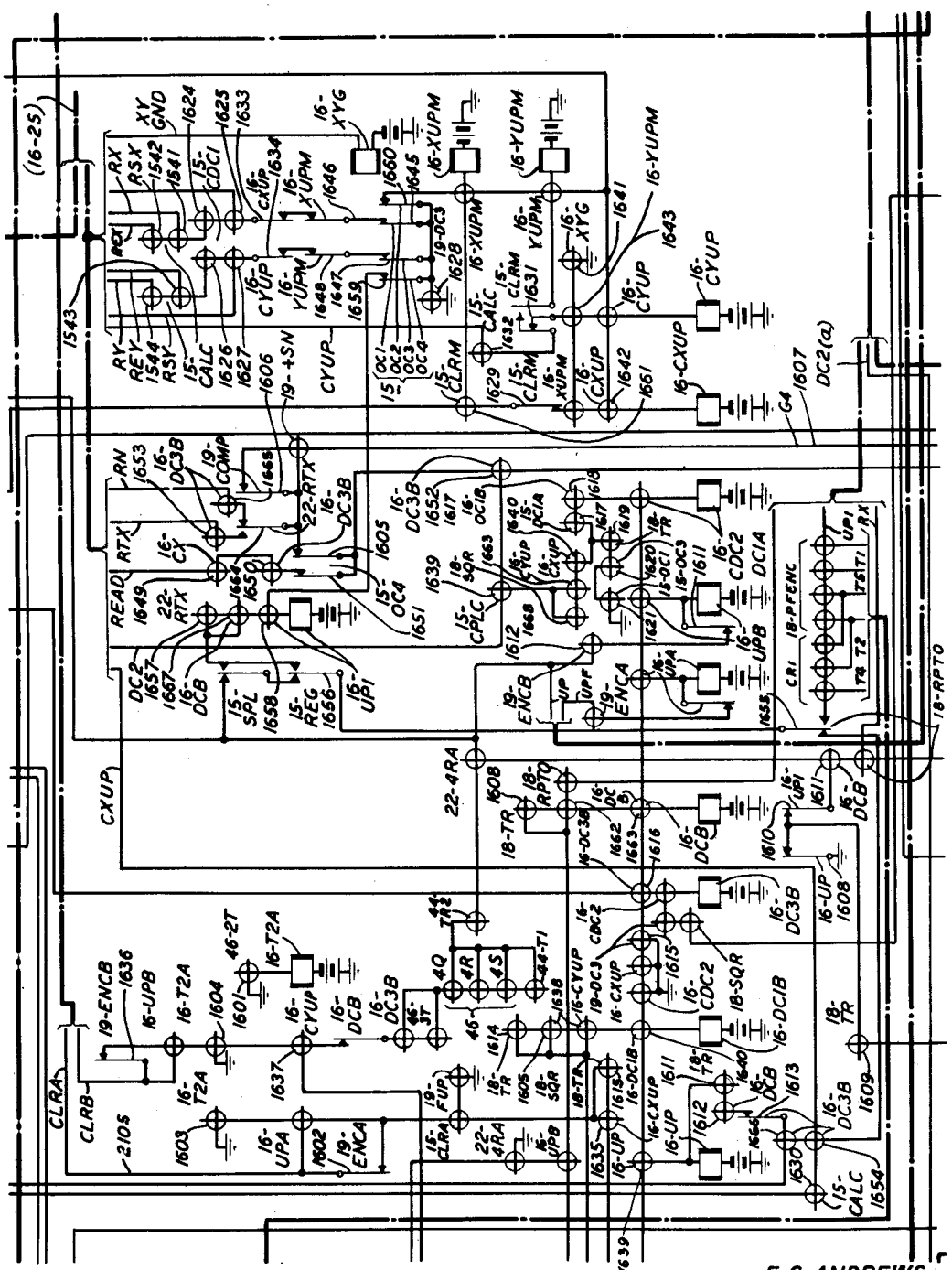

FIG. 16

INVENTORS E. G. ANDREWS
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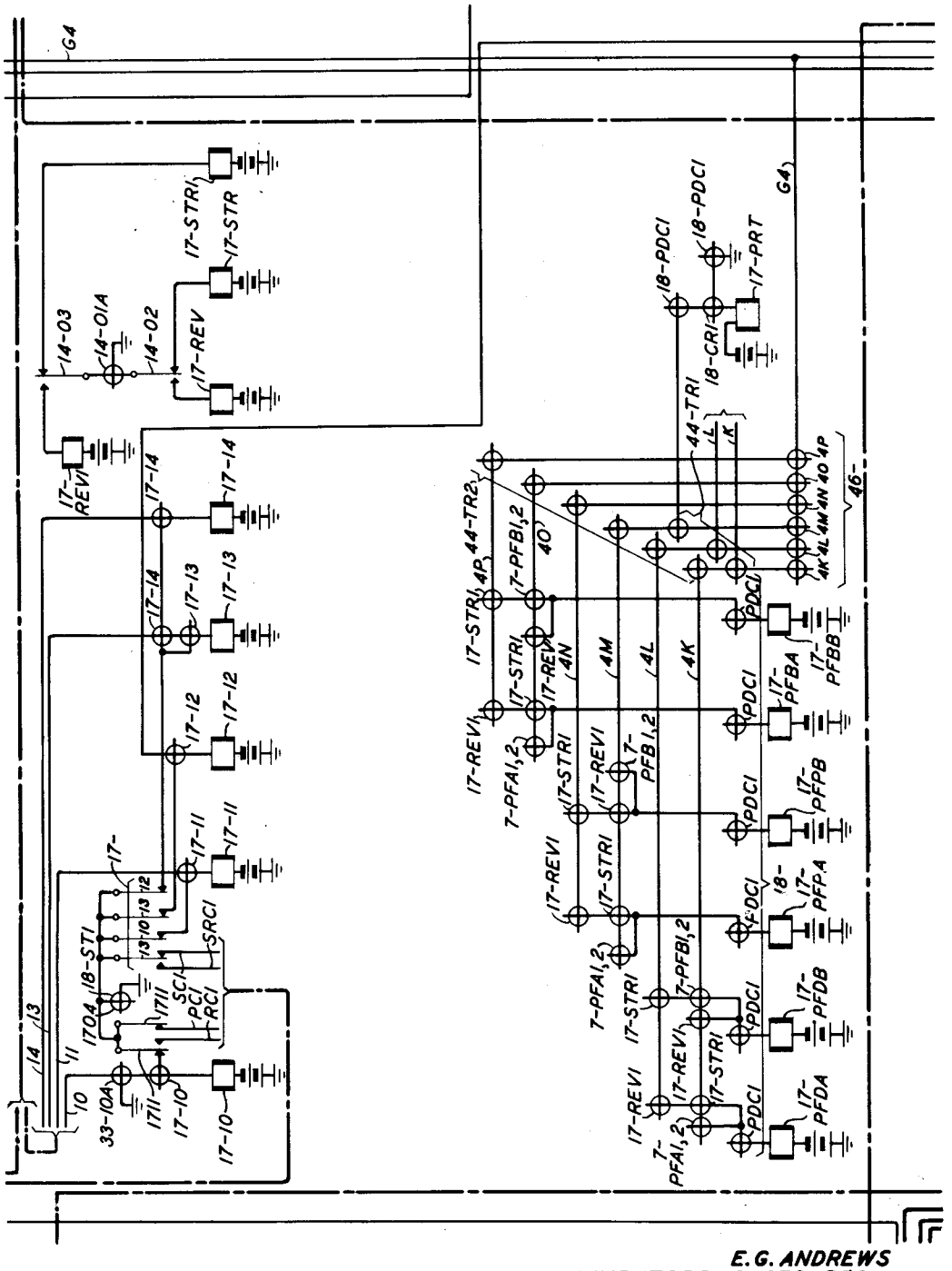

FIG. 17

INVENTORS E. G. ANDREWS
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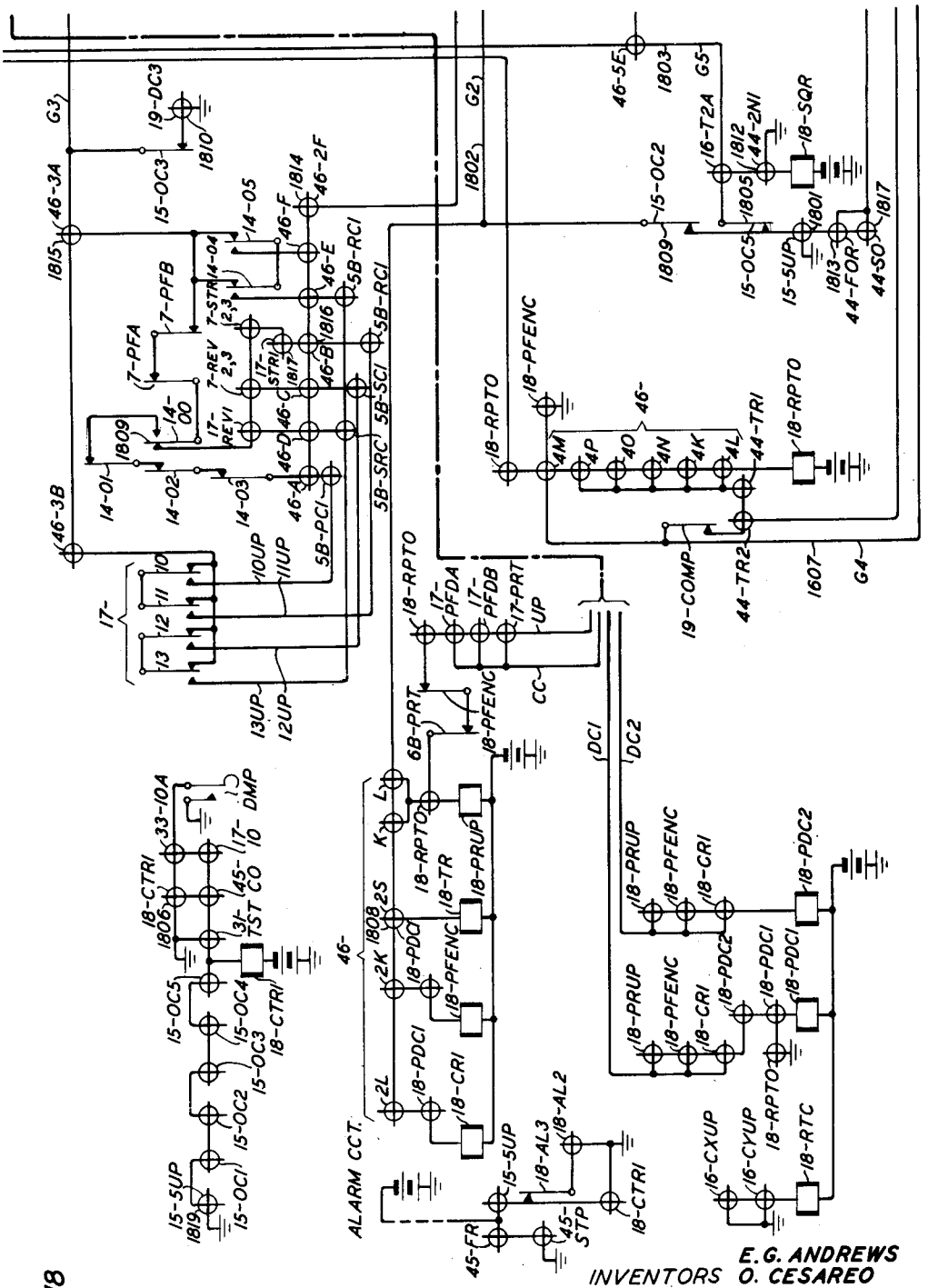

FIG. 18

INVENTORS E. G. ANDREWS
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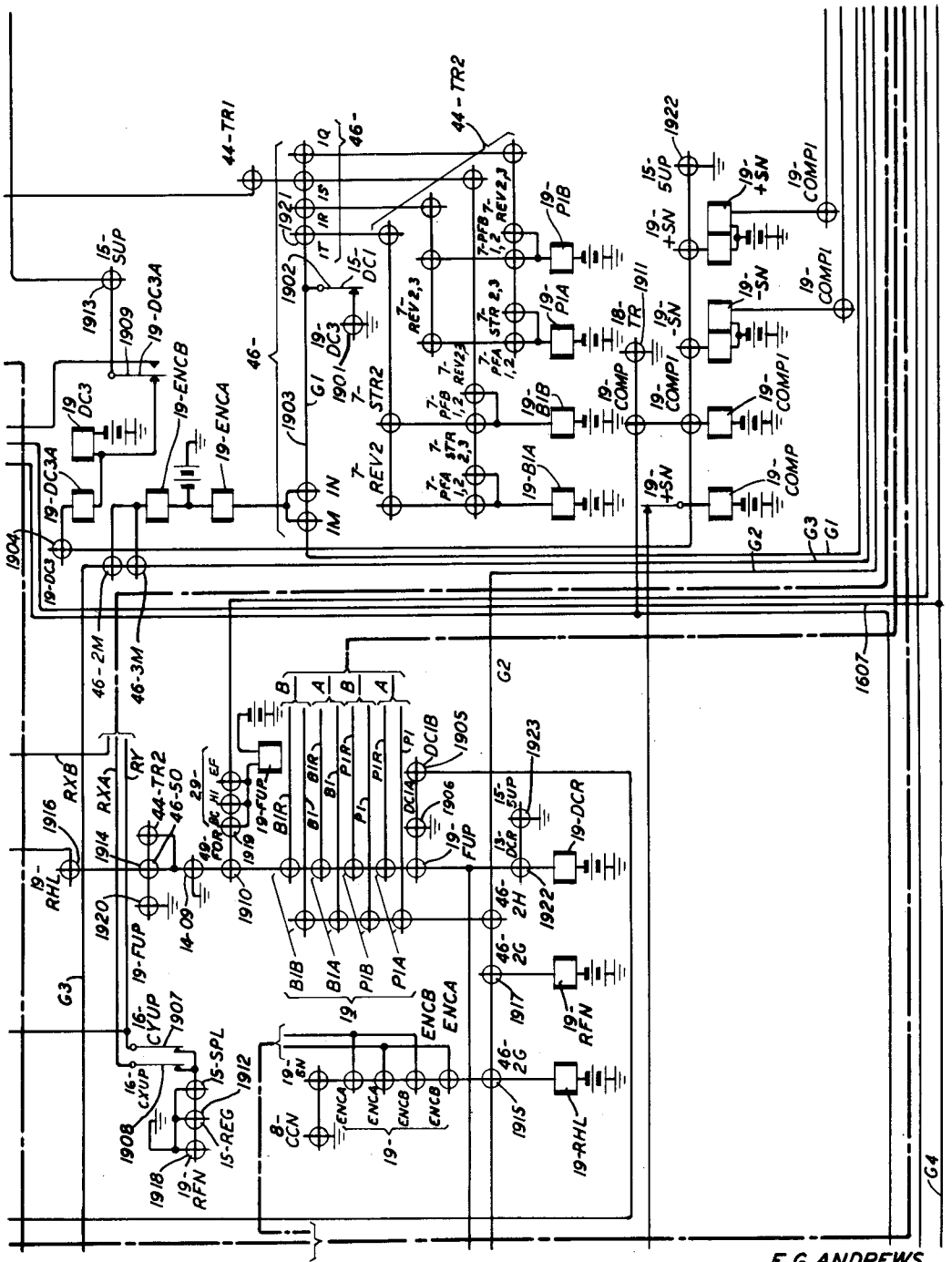

FIG. 19

INVENTORS E. G. ANDREWS
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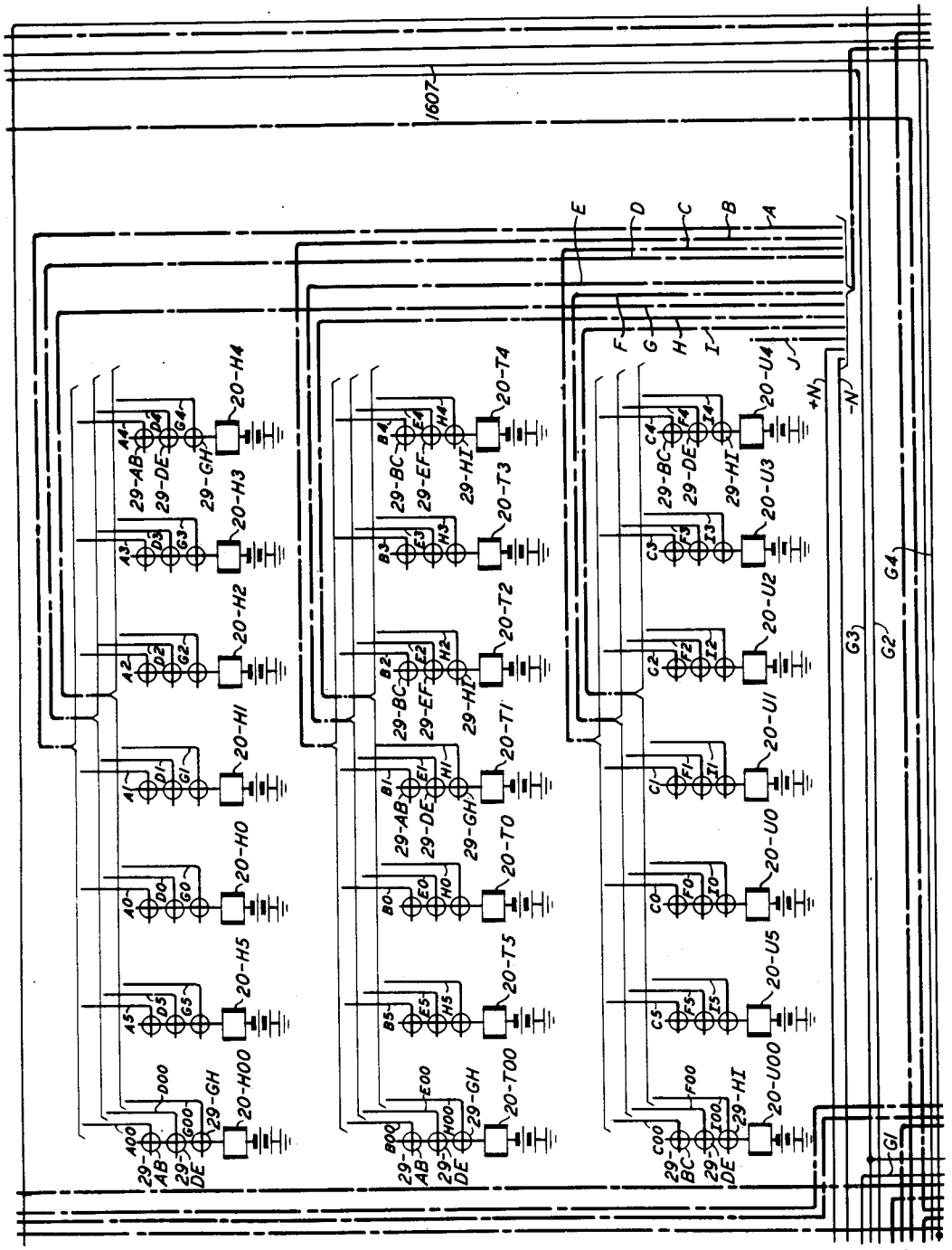

FIG. 20

INVENTORS E. G. ANDREWS
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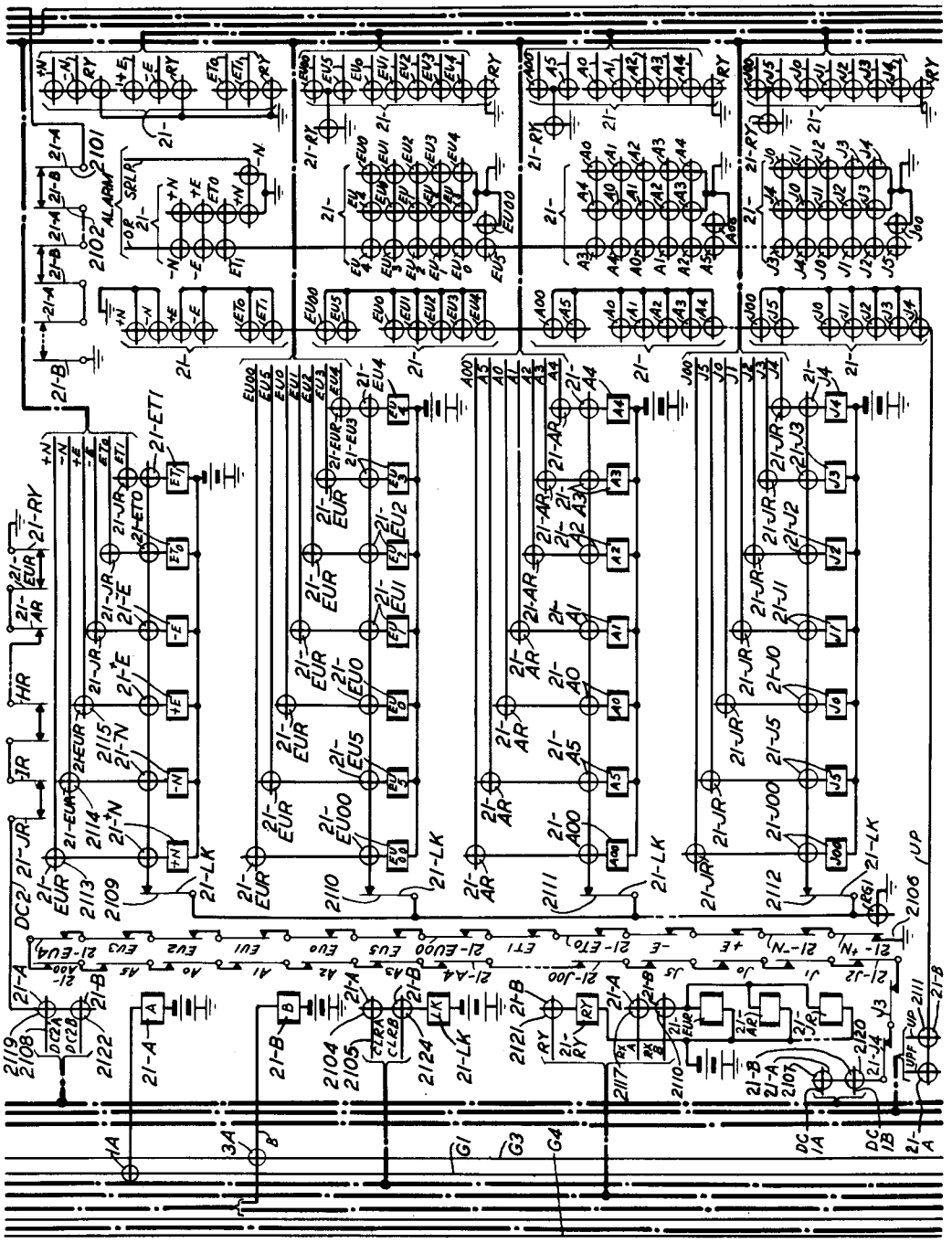

FIG. 21

INVETORS E. G. ANDREWS
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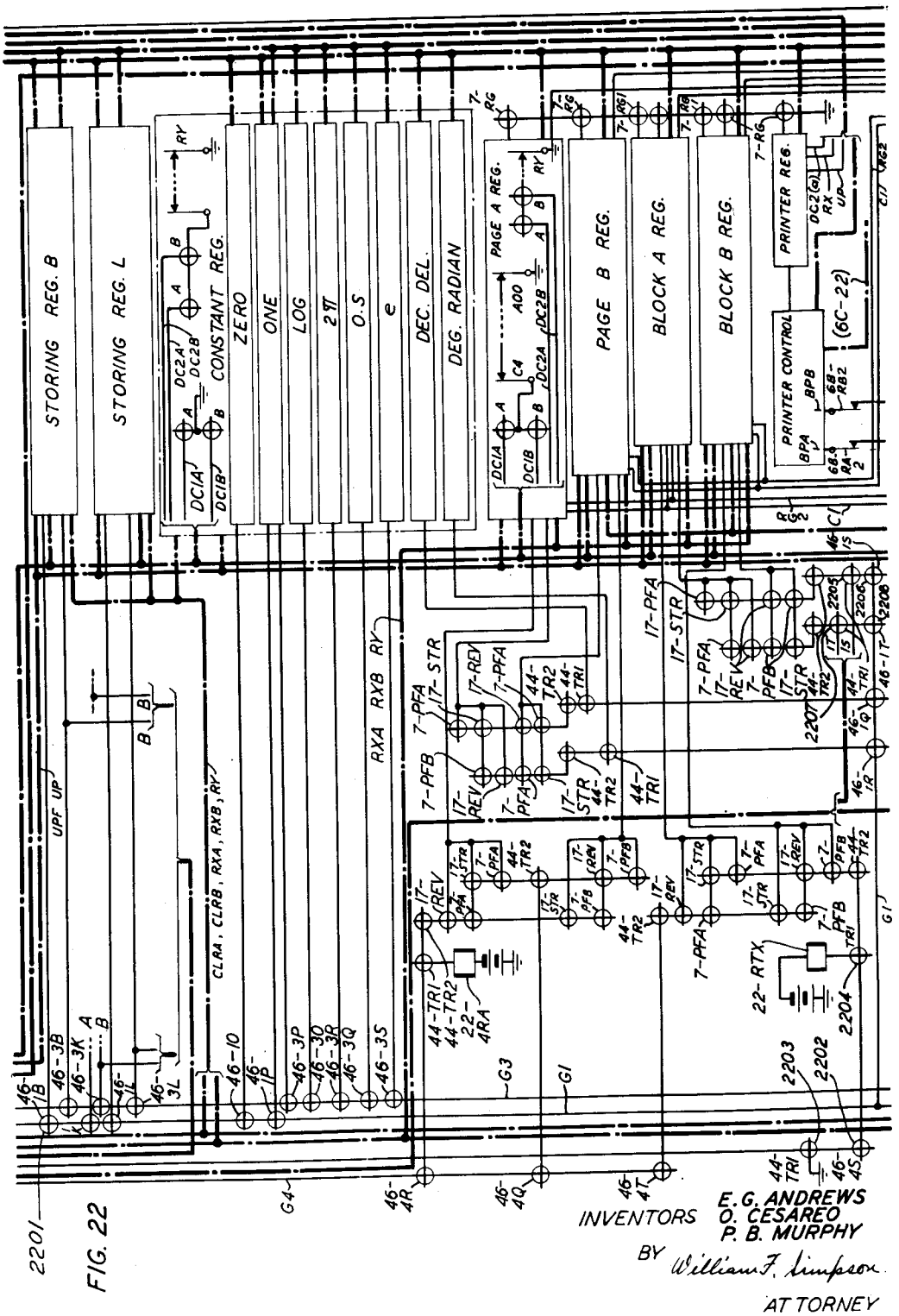

INVENTORS E. G. ANDREWS
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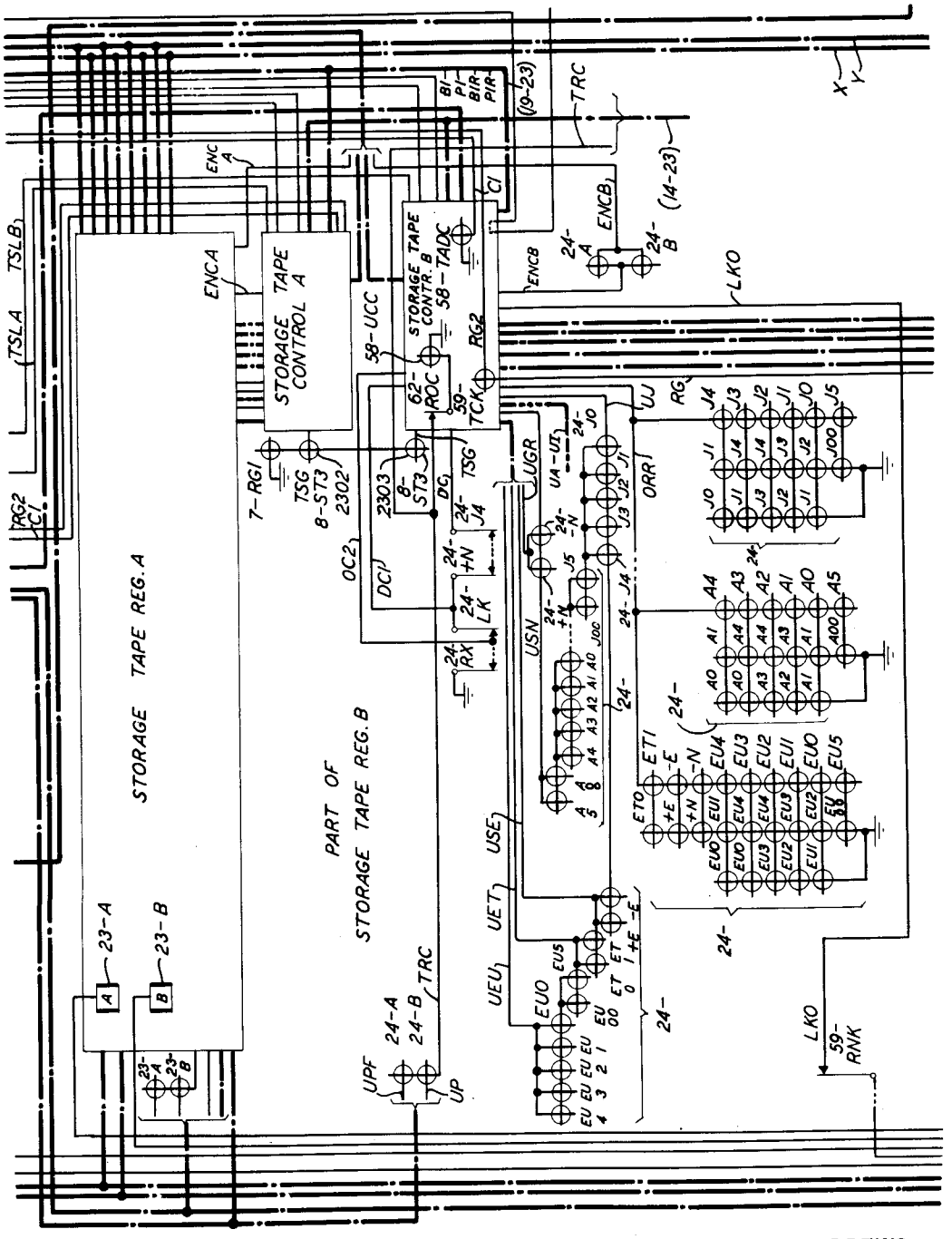

FIG. 23

INVENTORS E G ANDREWS
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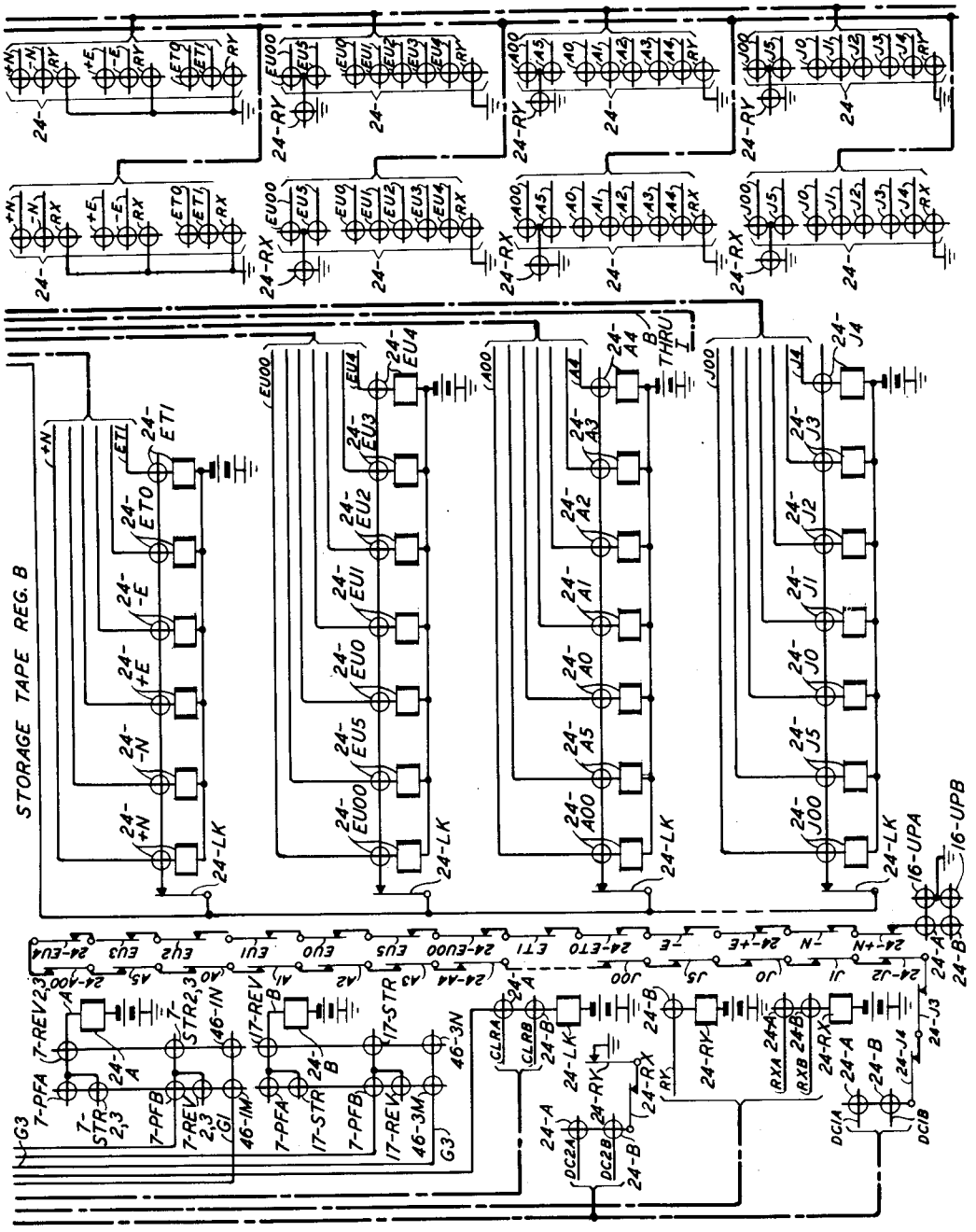

FIG. 24

INVENTORS E. G. ANDREWS
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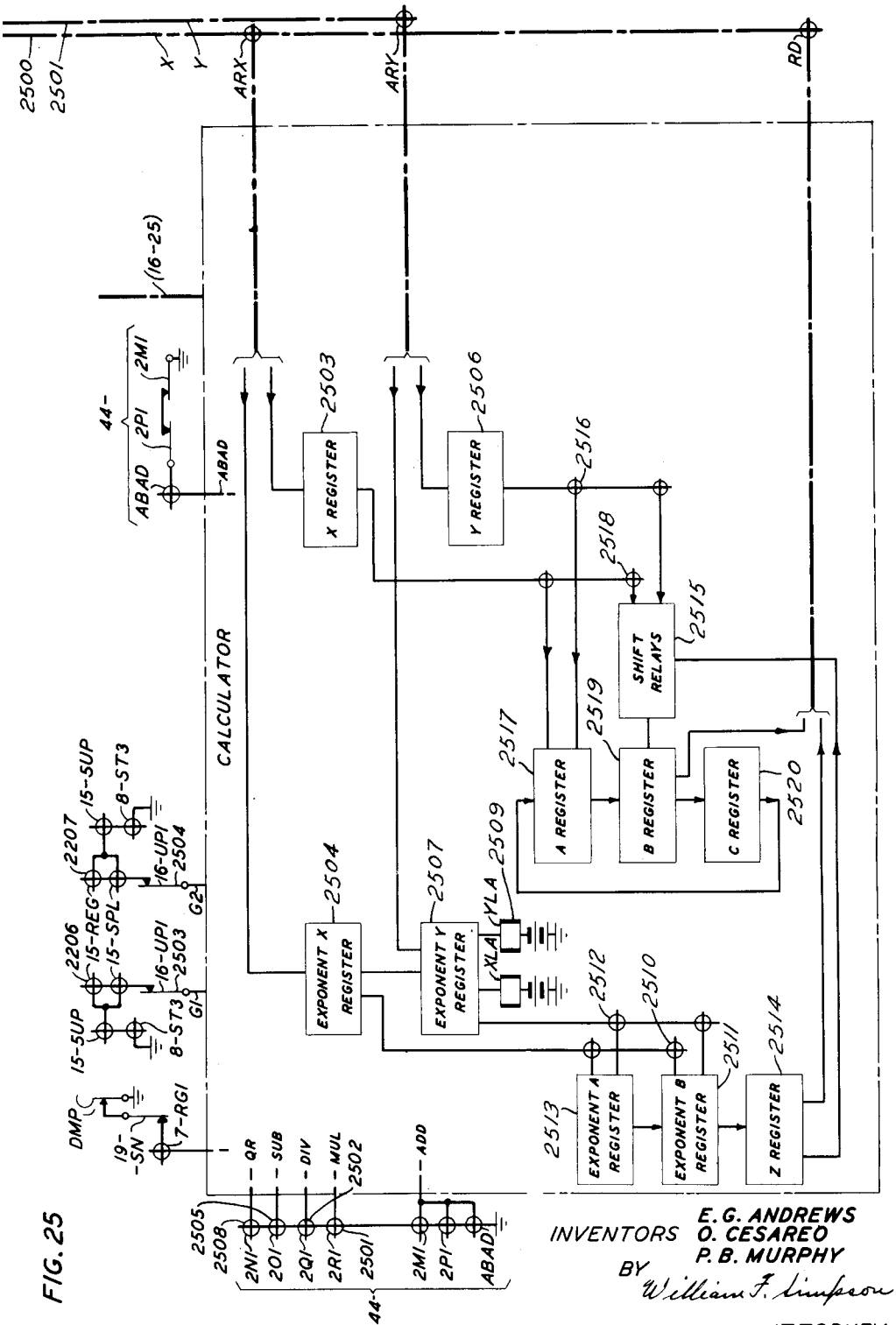

FIG. 25

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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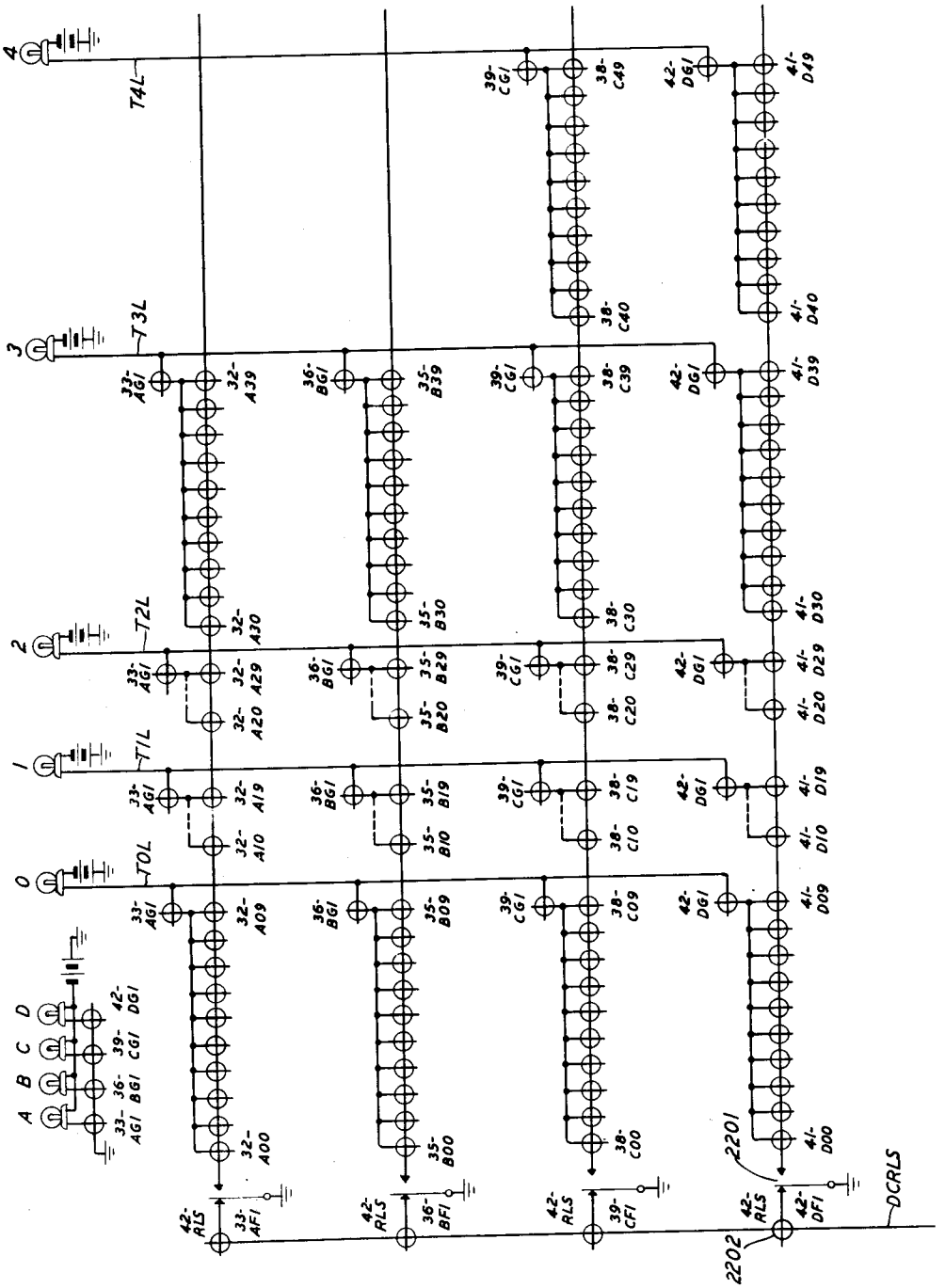

FIG. 26

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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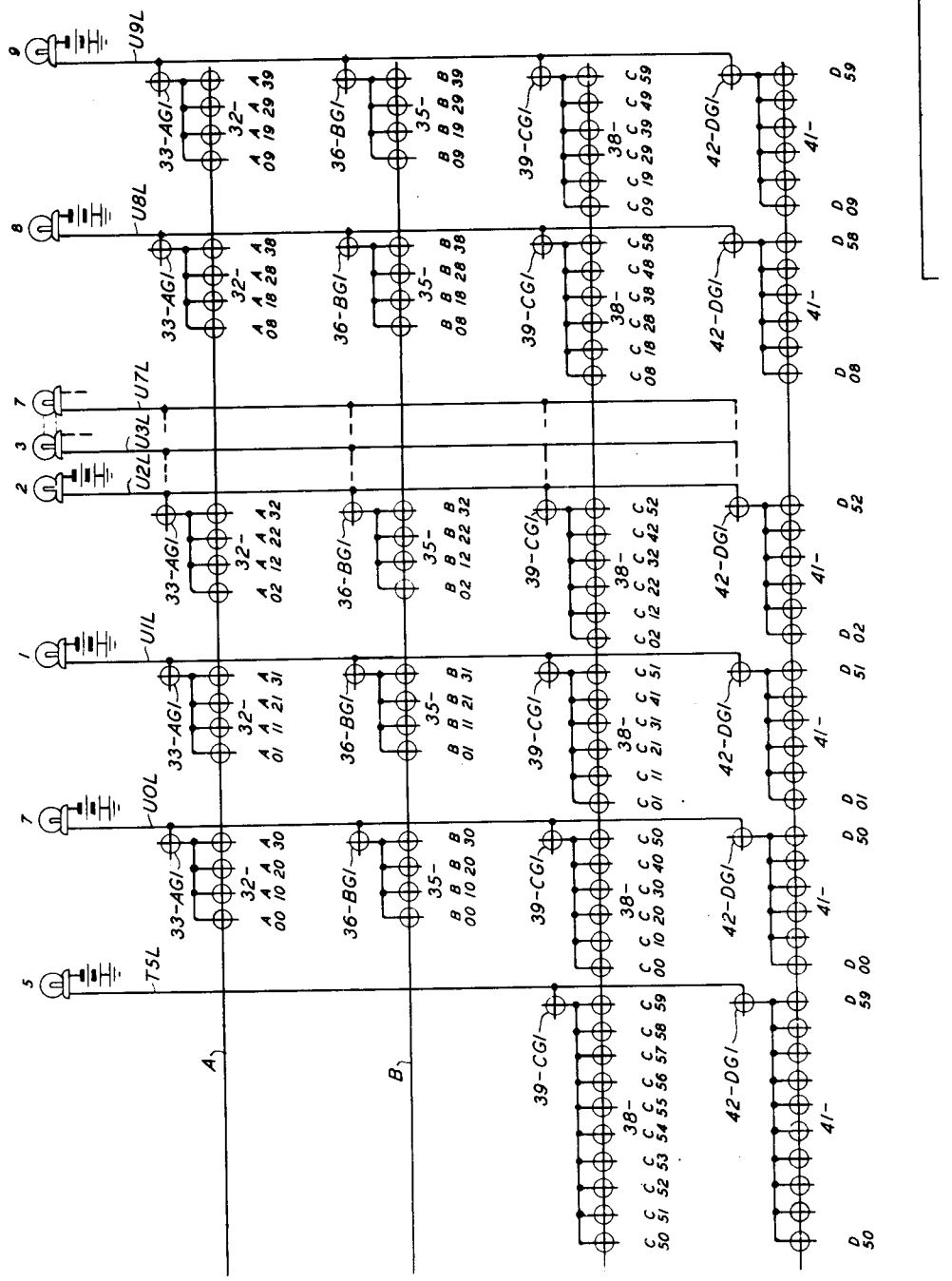

FIG. 27

INVENTORS E. G. ANDREWS
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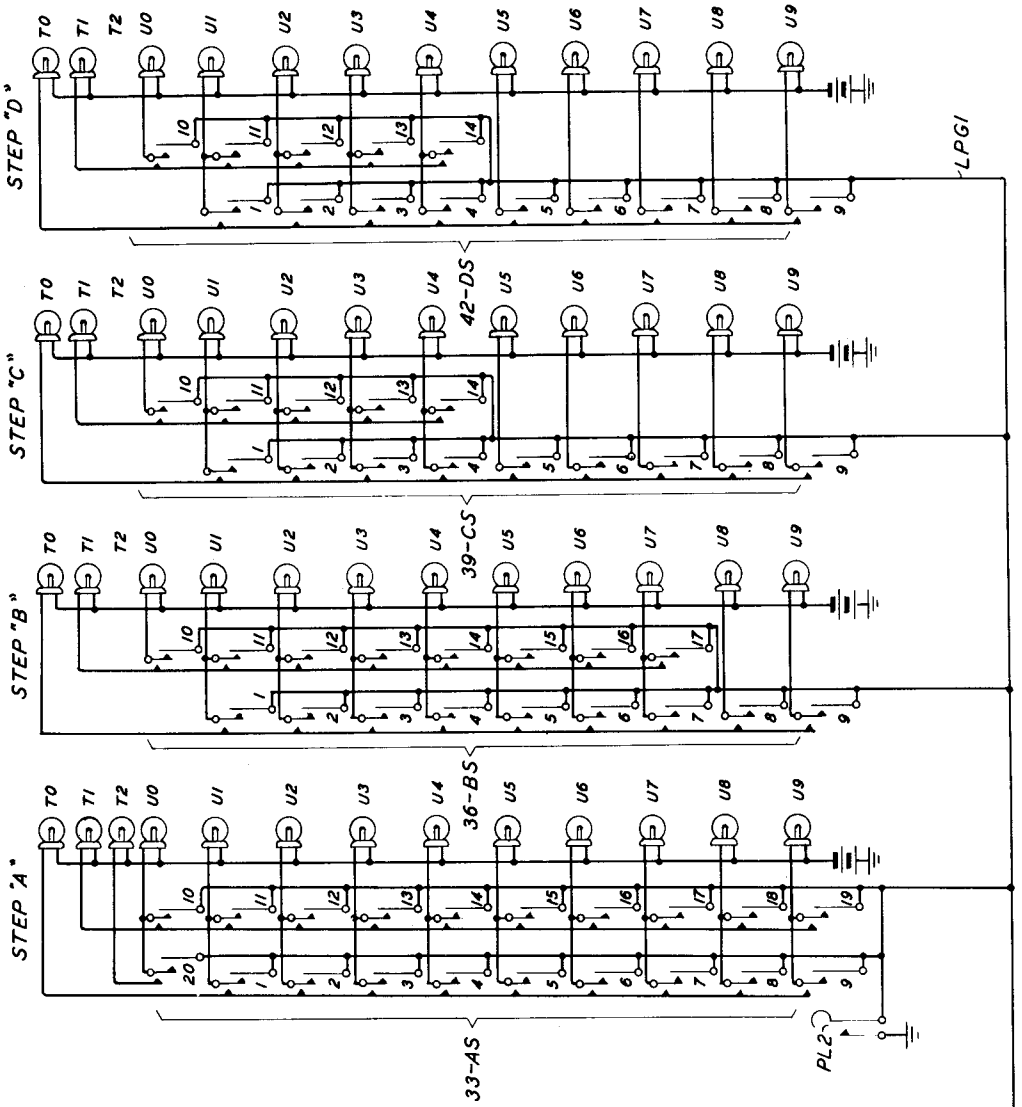

FIG. 28

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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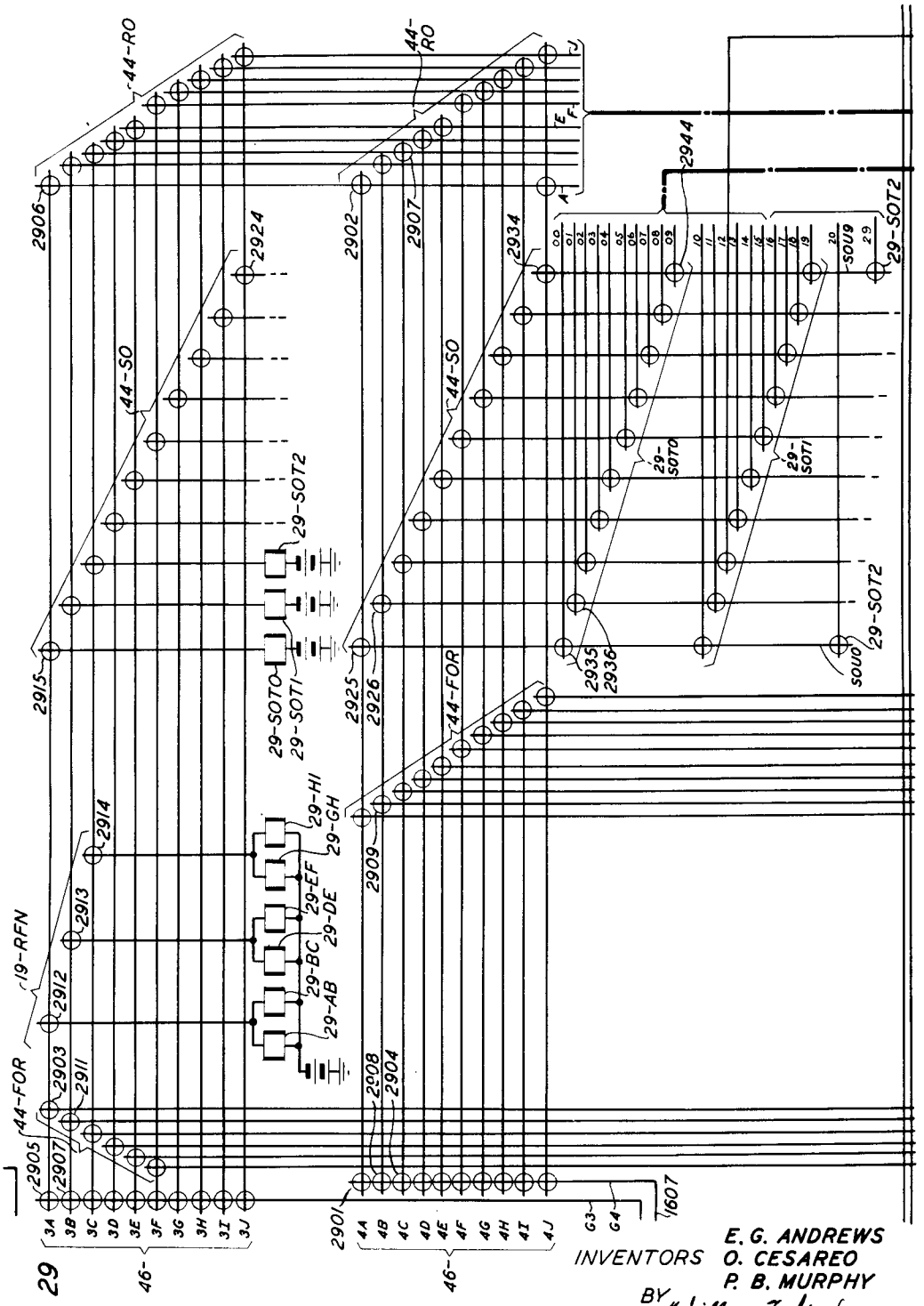

FIG. 29

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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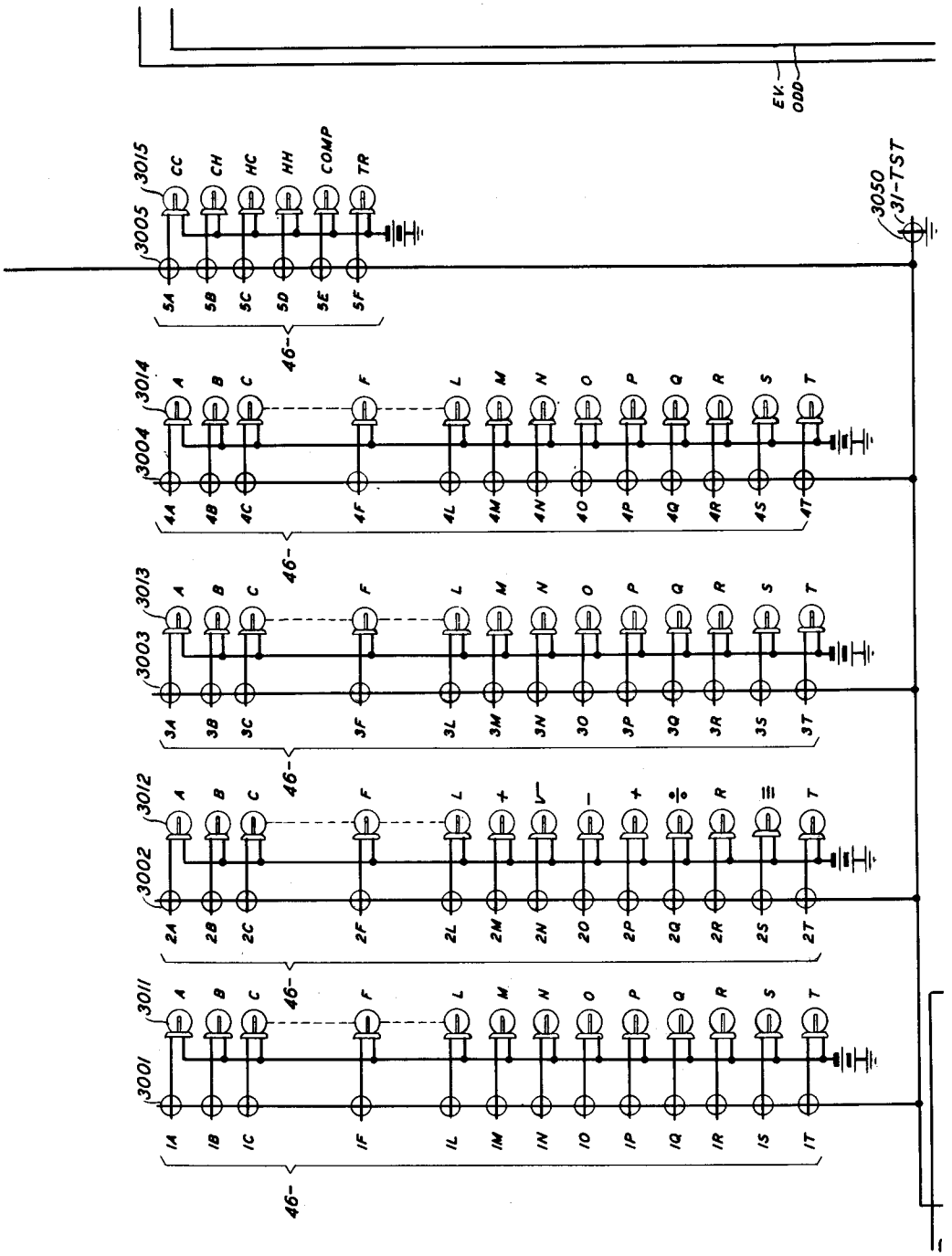

FIG. 30

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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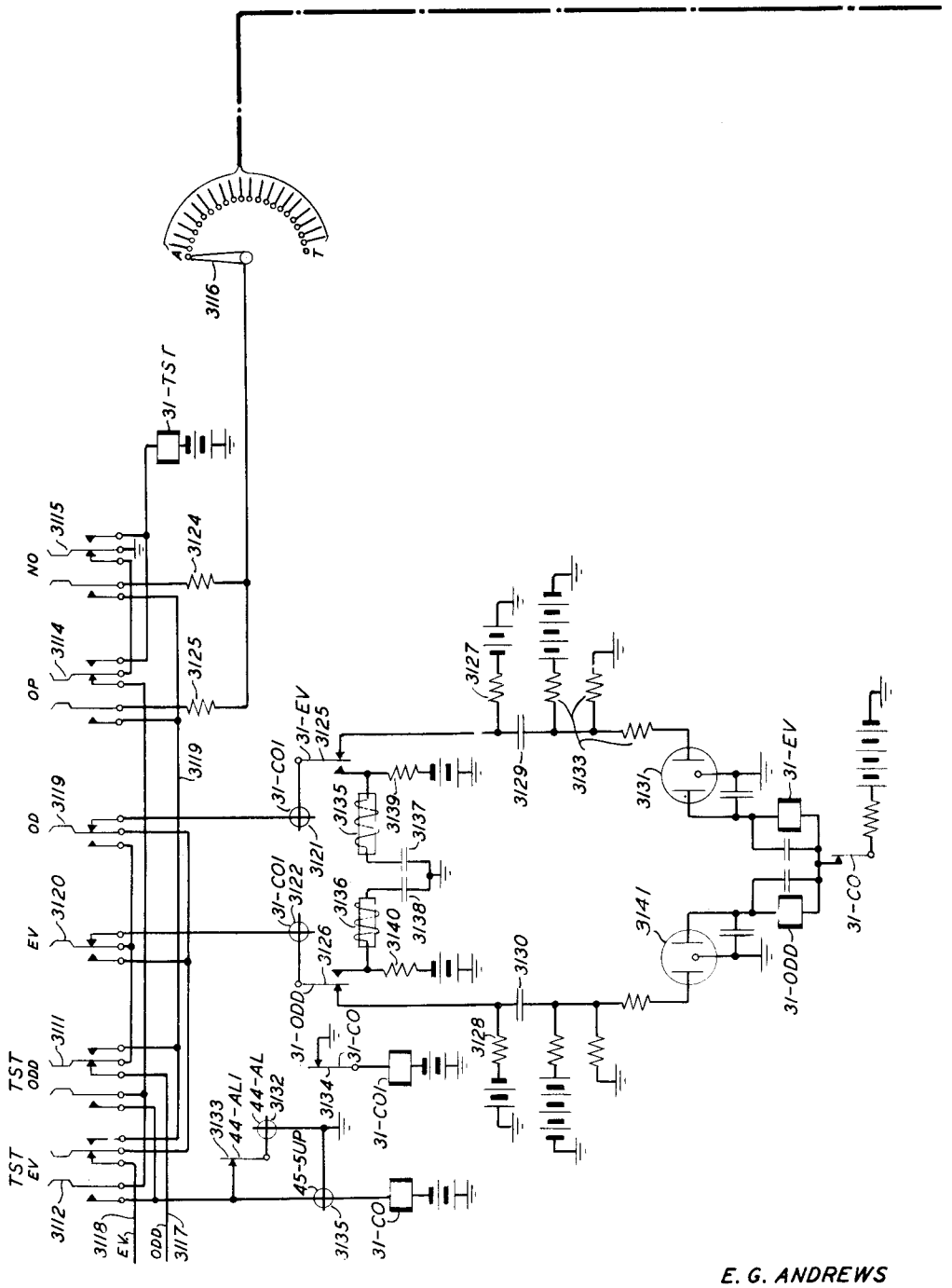

FIG. 31

INVENTORS E. G. ANDREWS
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P. B. MURPHY

BY William F. Simpson.

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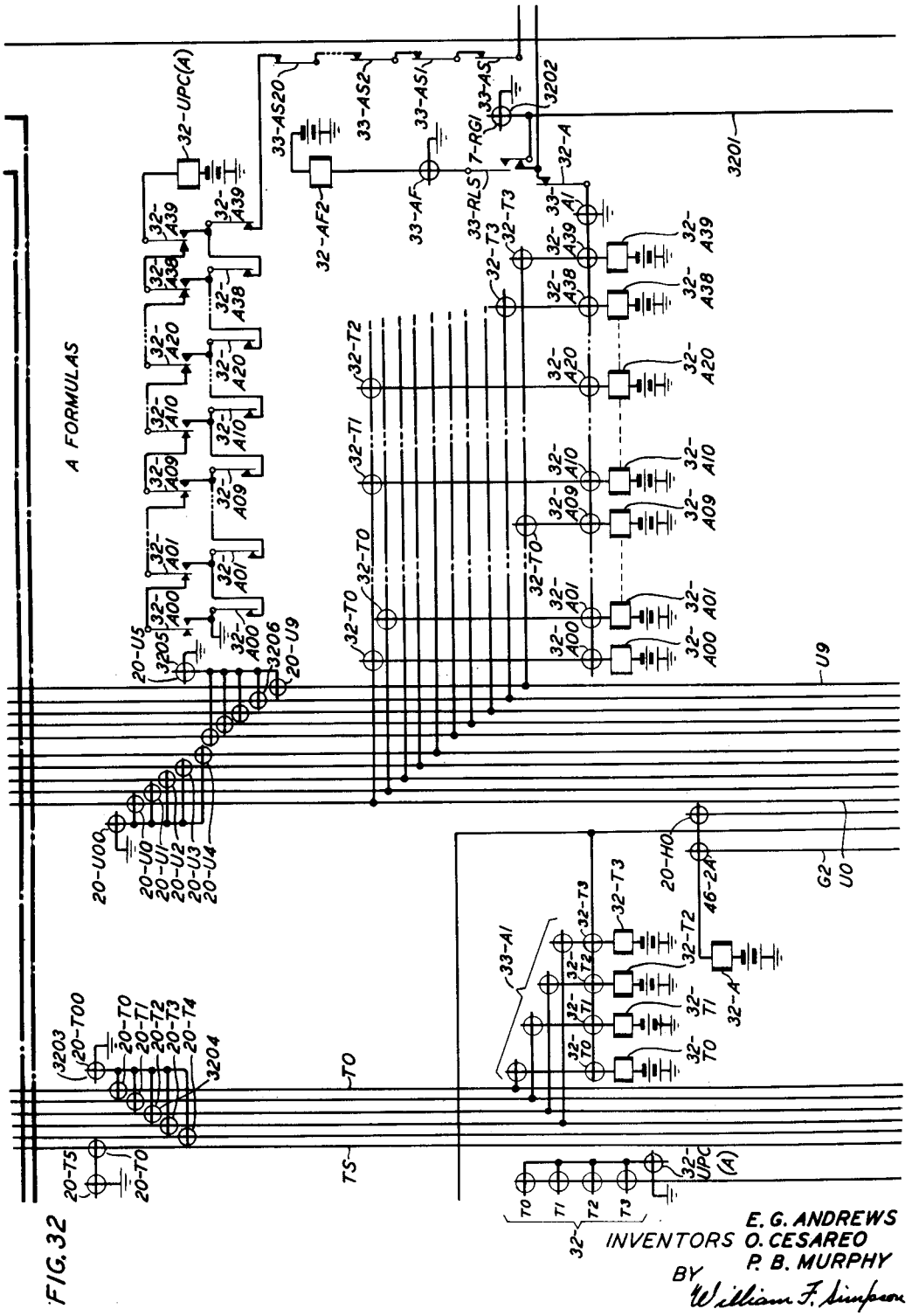

FIG. 32

INVENTORS E. G. ANDREWS
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P. B. MURPHY

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Filed Nov. 8, 1951 75 Sheets-Sheet 38

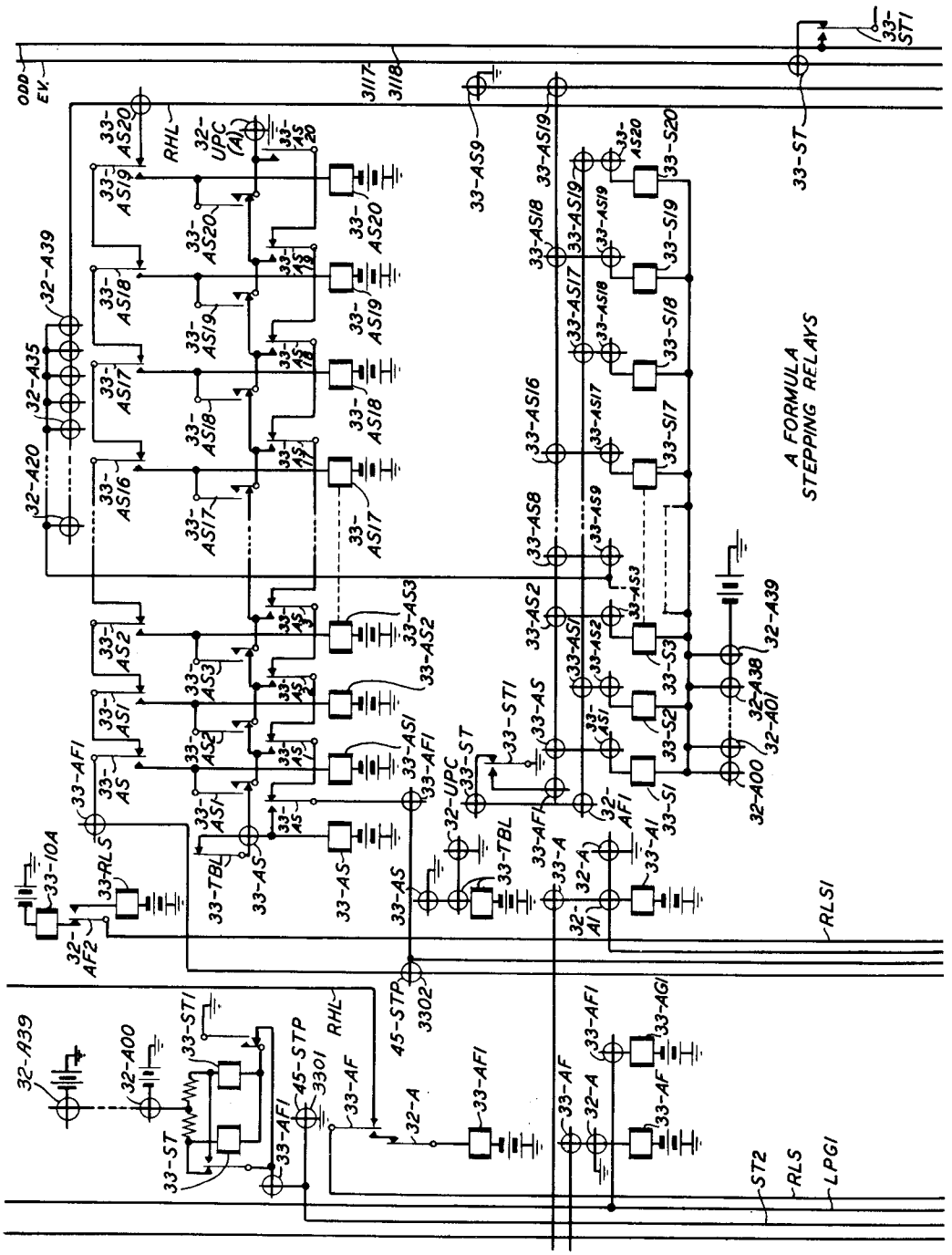

FIG. 33

INVENTORS E. G. ANDREWS
O. CESAREO
P. B. MURPHY

BY William F. Simpson.

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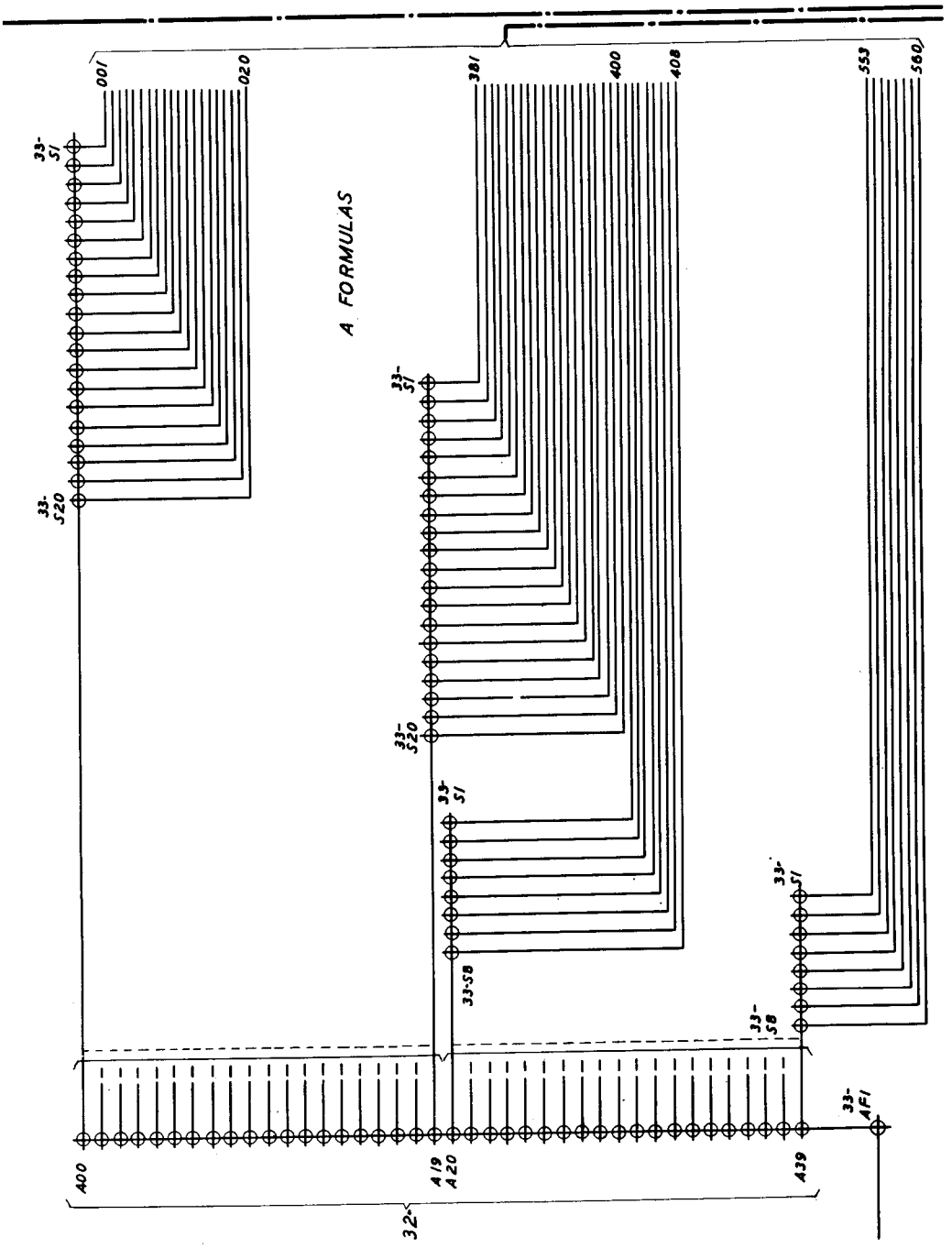

FIG. 34

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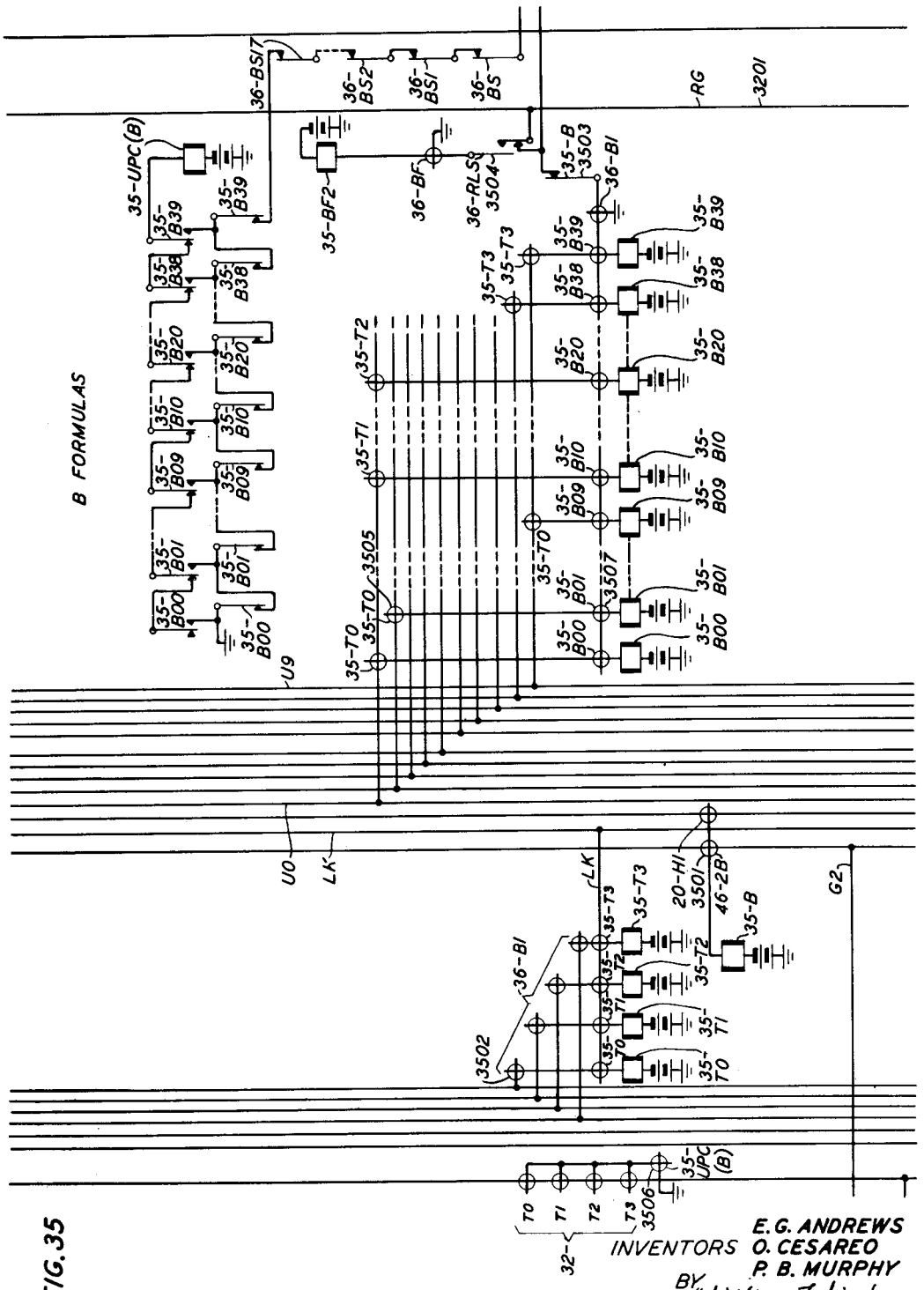

FIG. 35

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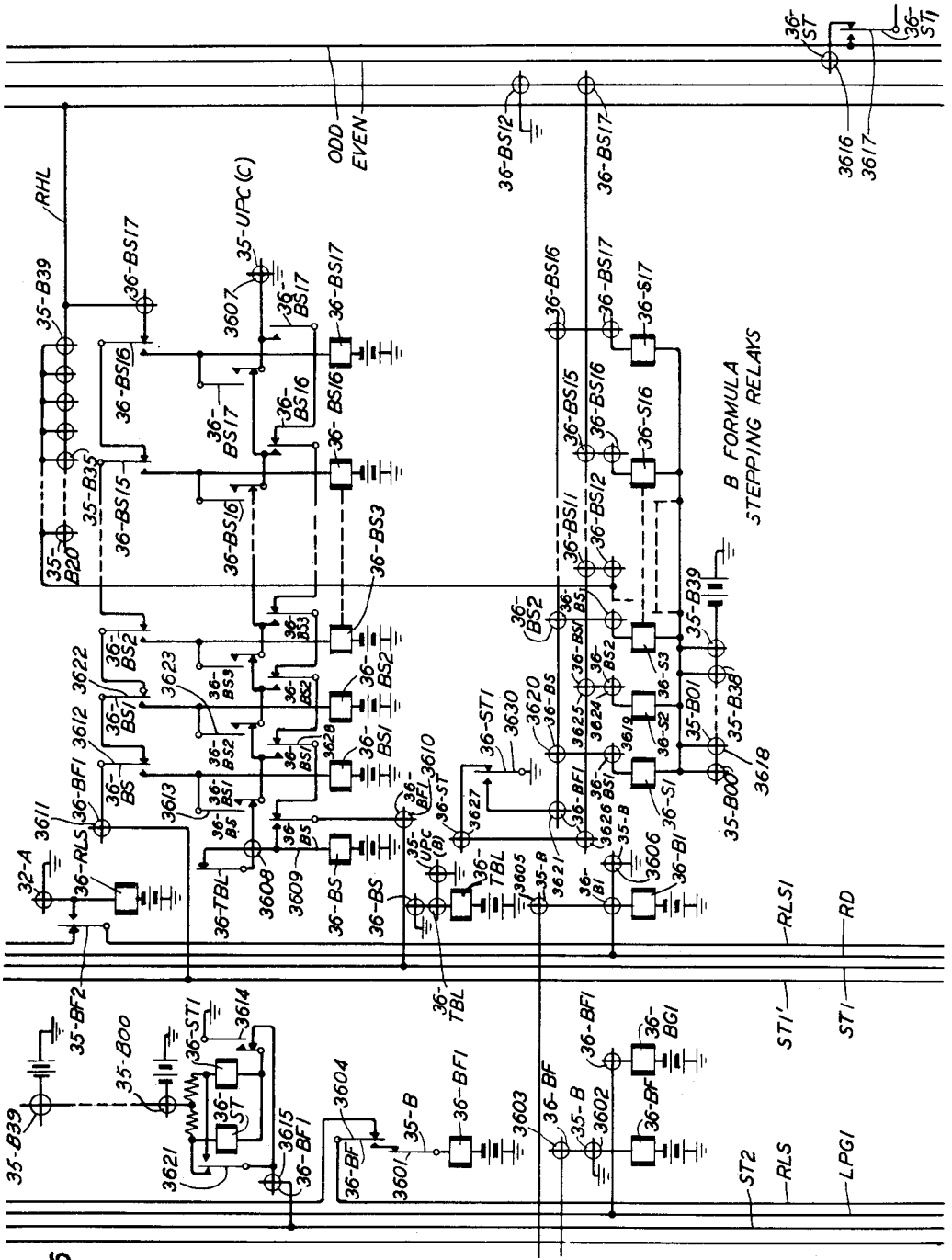

FIG. 36

INVENTORS E.G. ANDREWS
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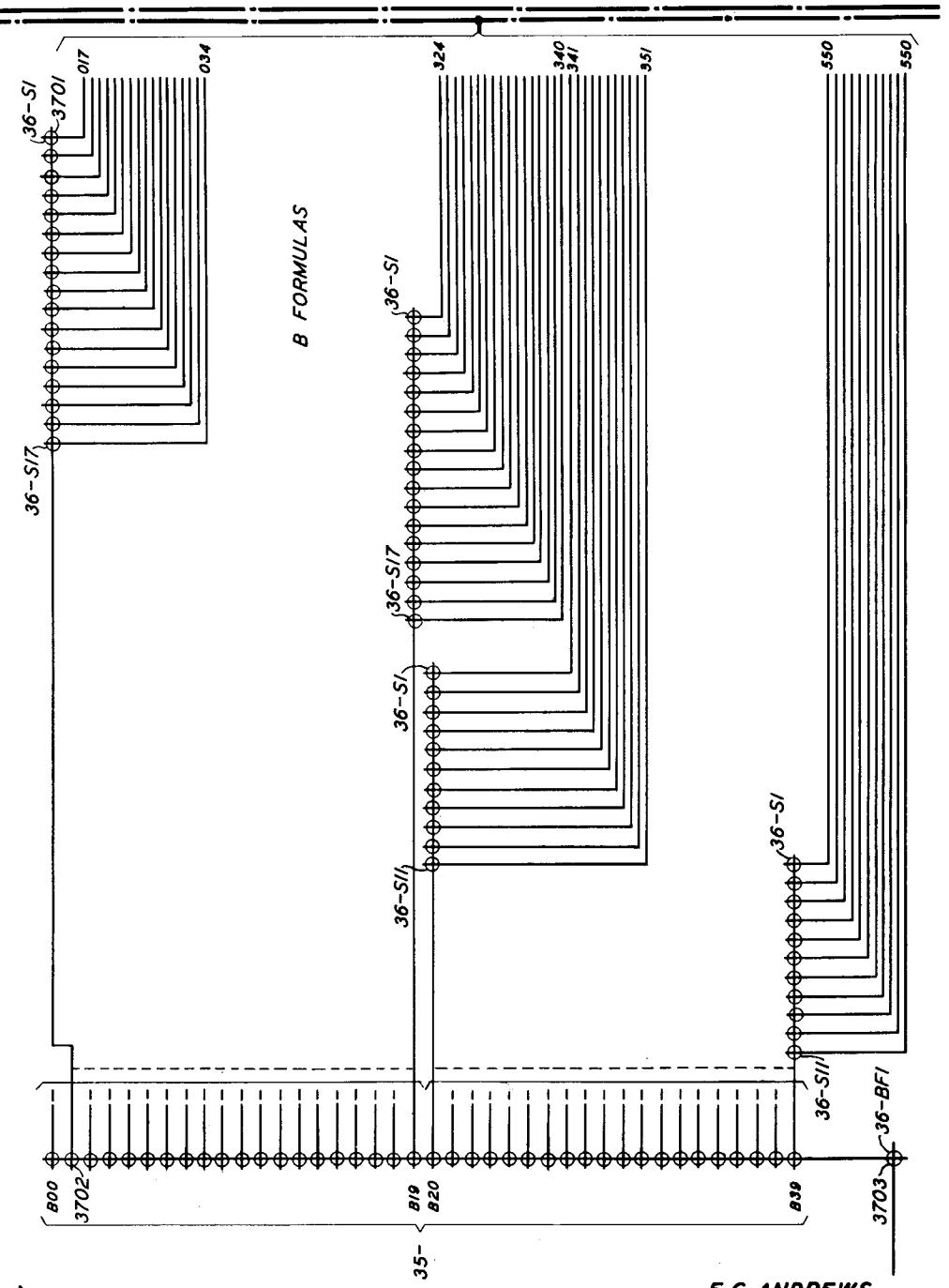

F/G. 37

INVENTORS E. G. ANDREWS
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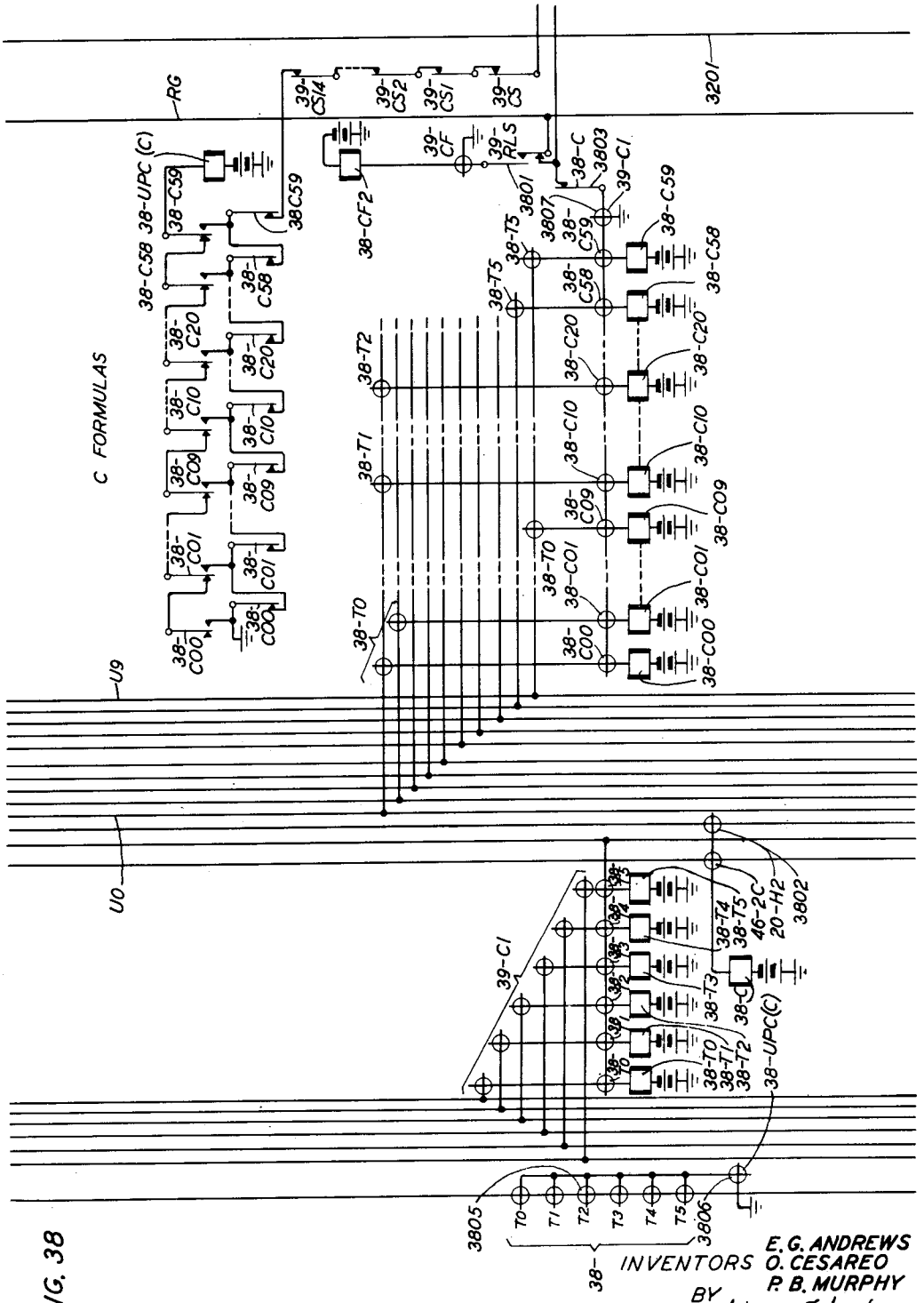

FIG. 38

INVENTORS E. G. ANDREWS
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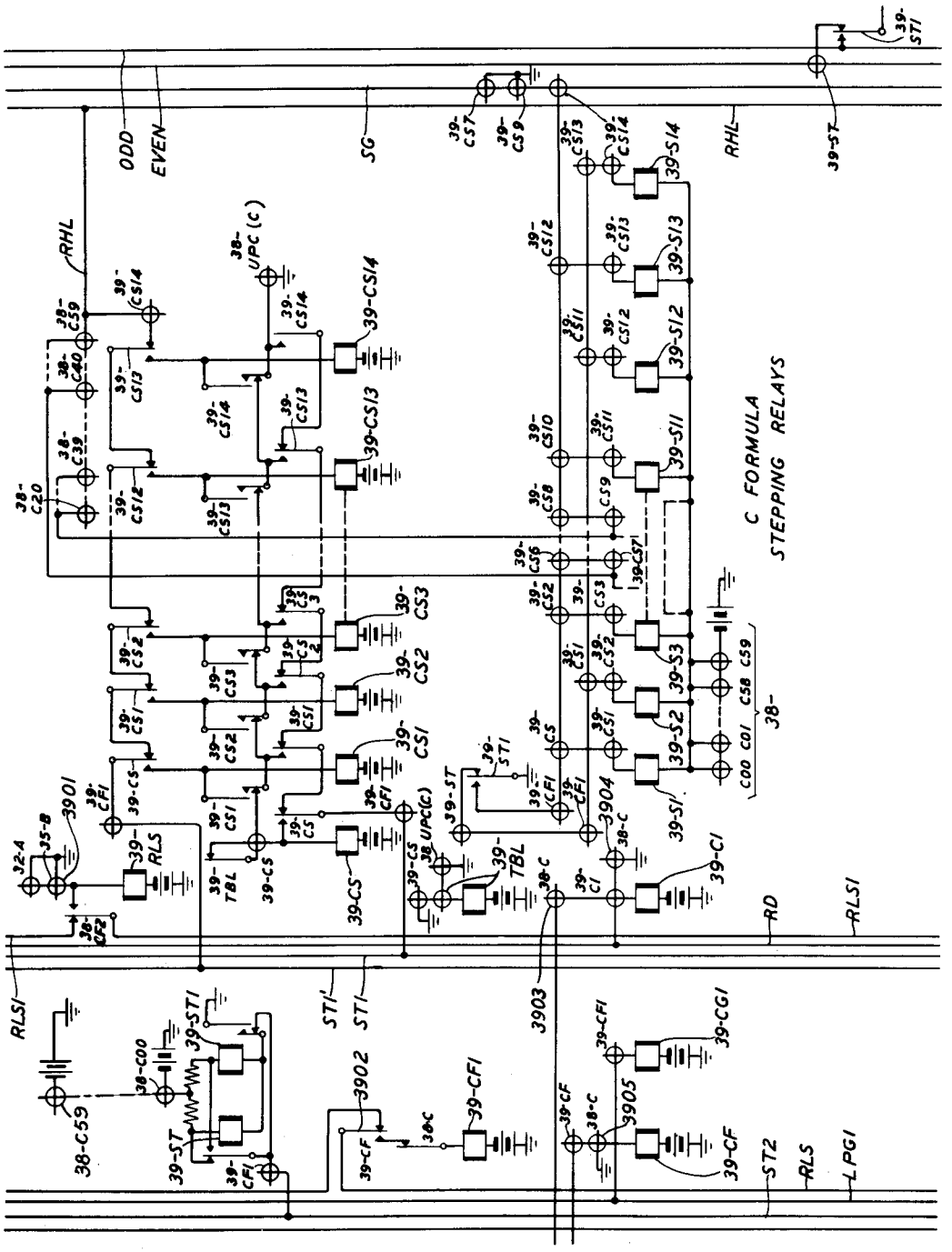

FIG. 39

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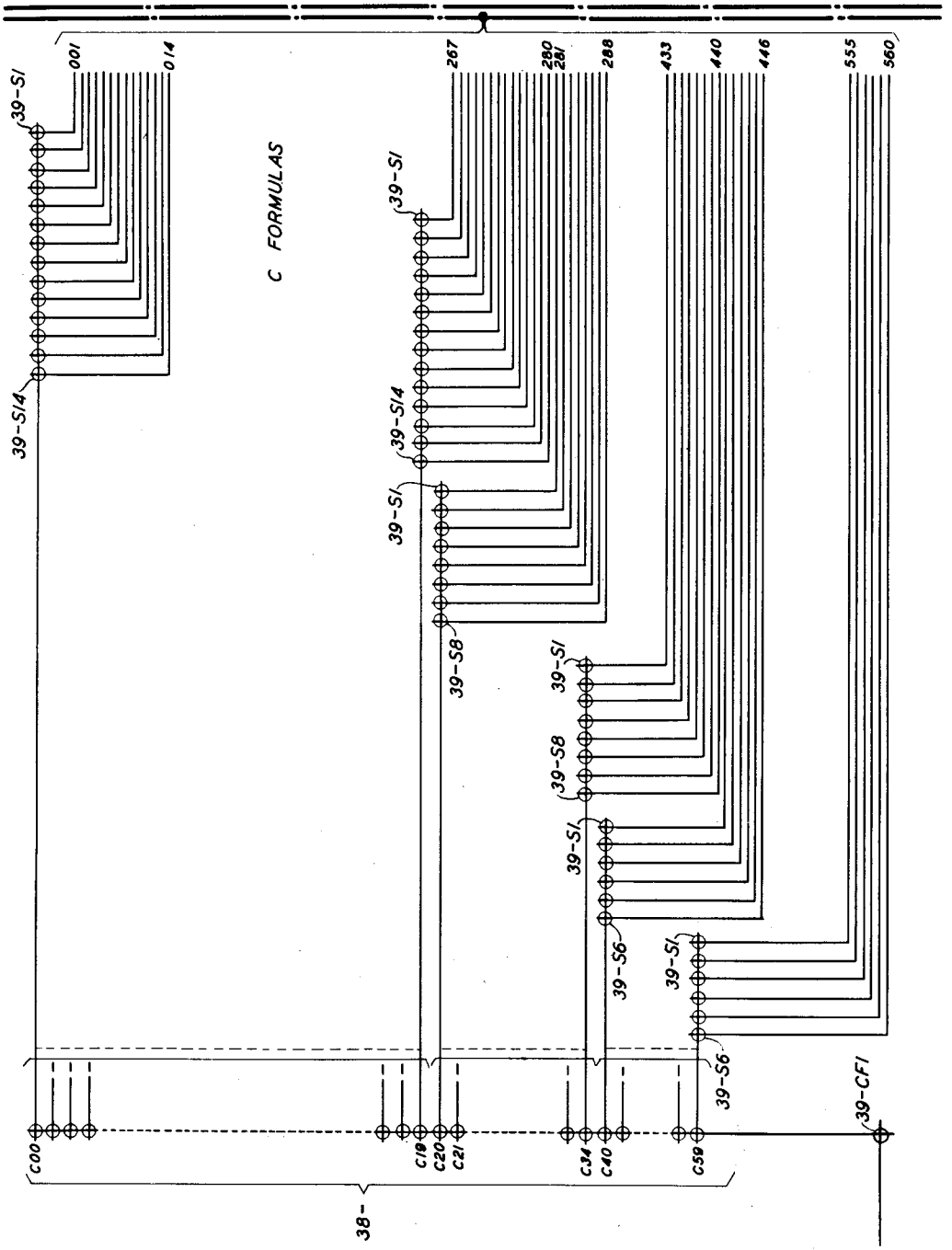

FIG. 40

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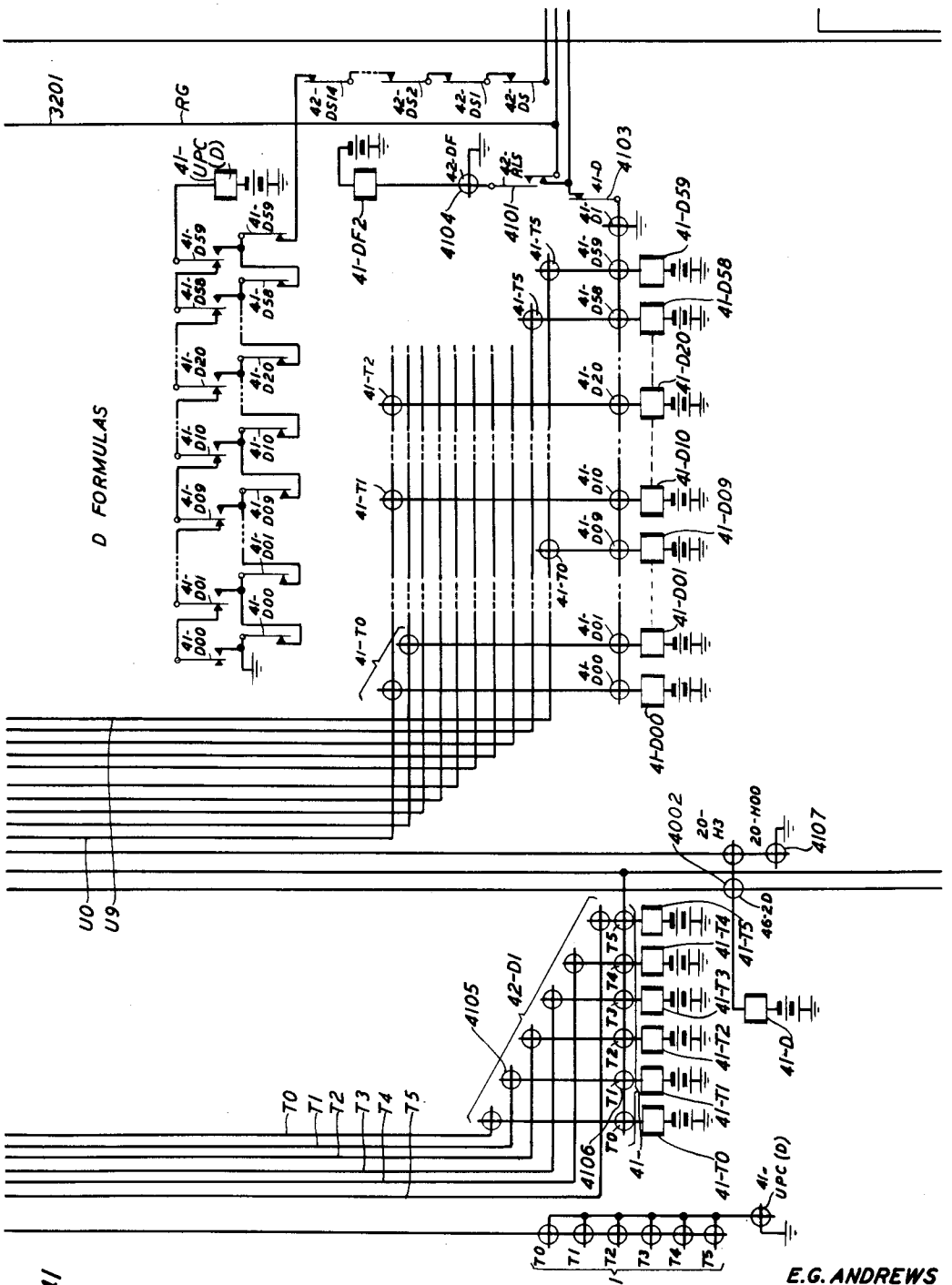

FIG. 41

E.G. ANDREWS
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INVENTORS

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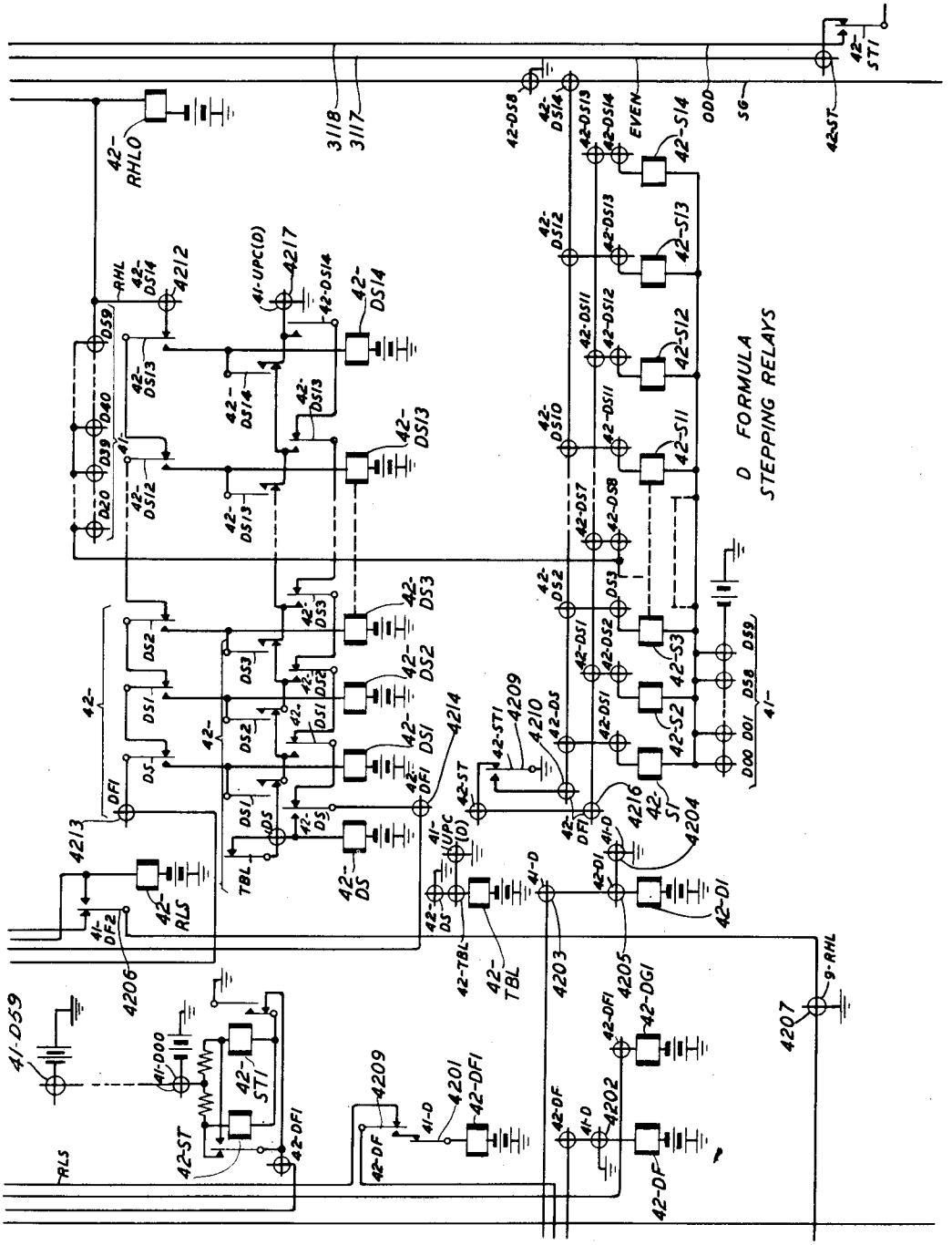

FIG. 42

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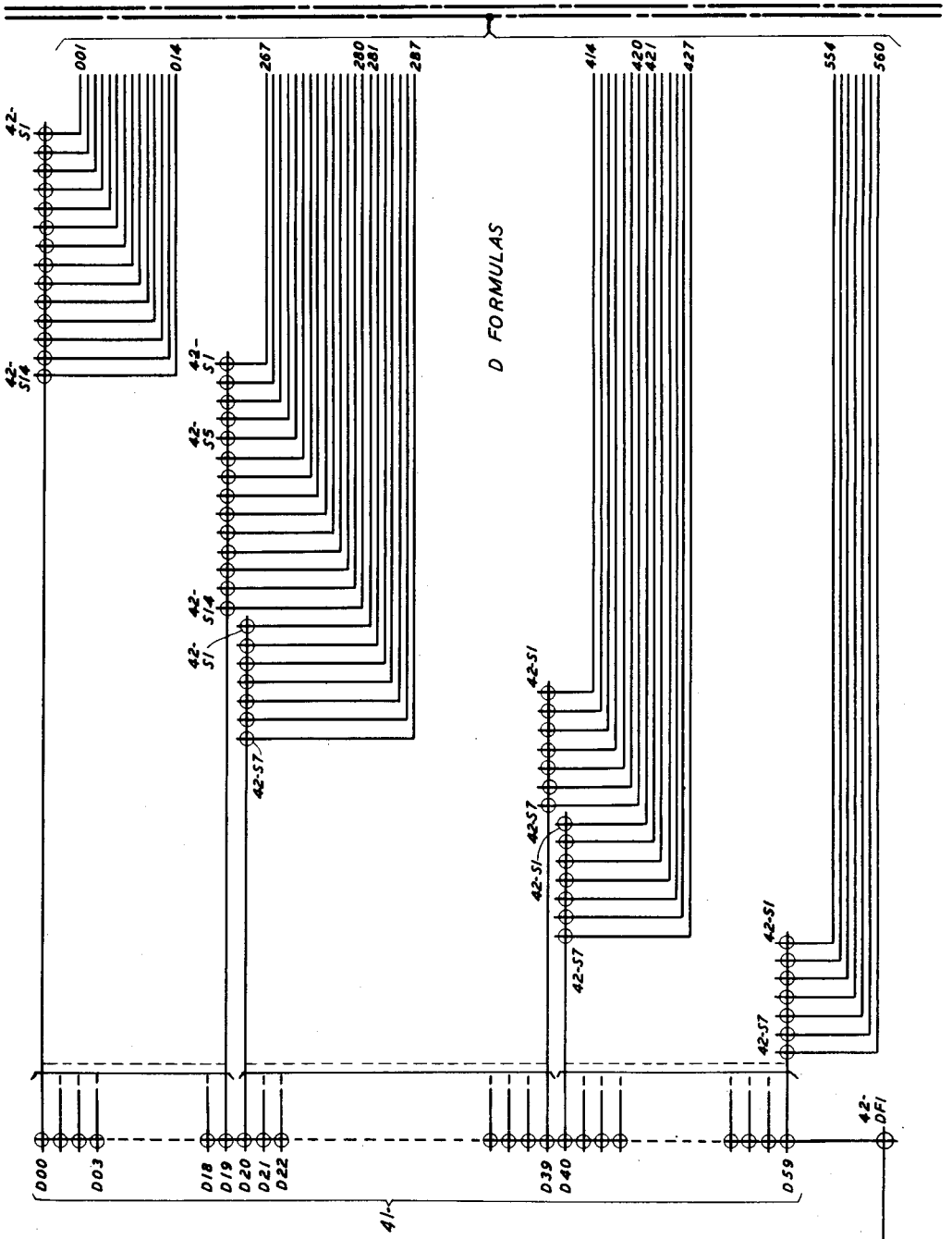

FIG. 43

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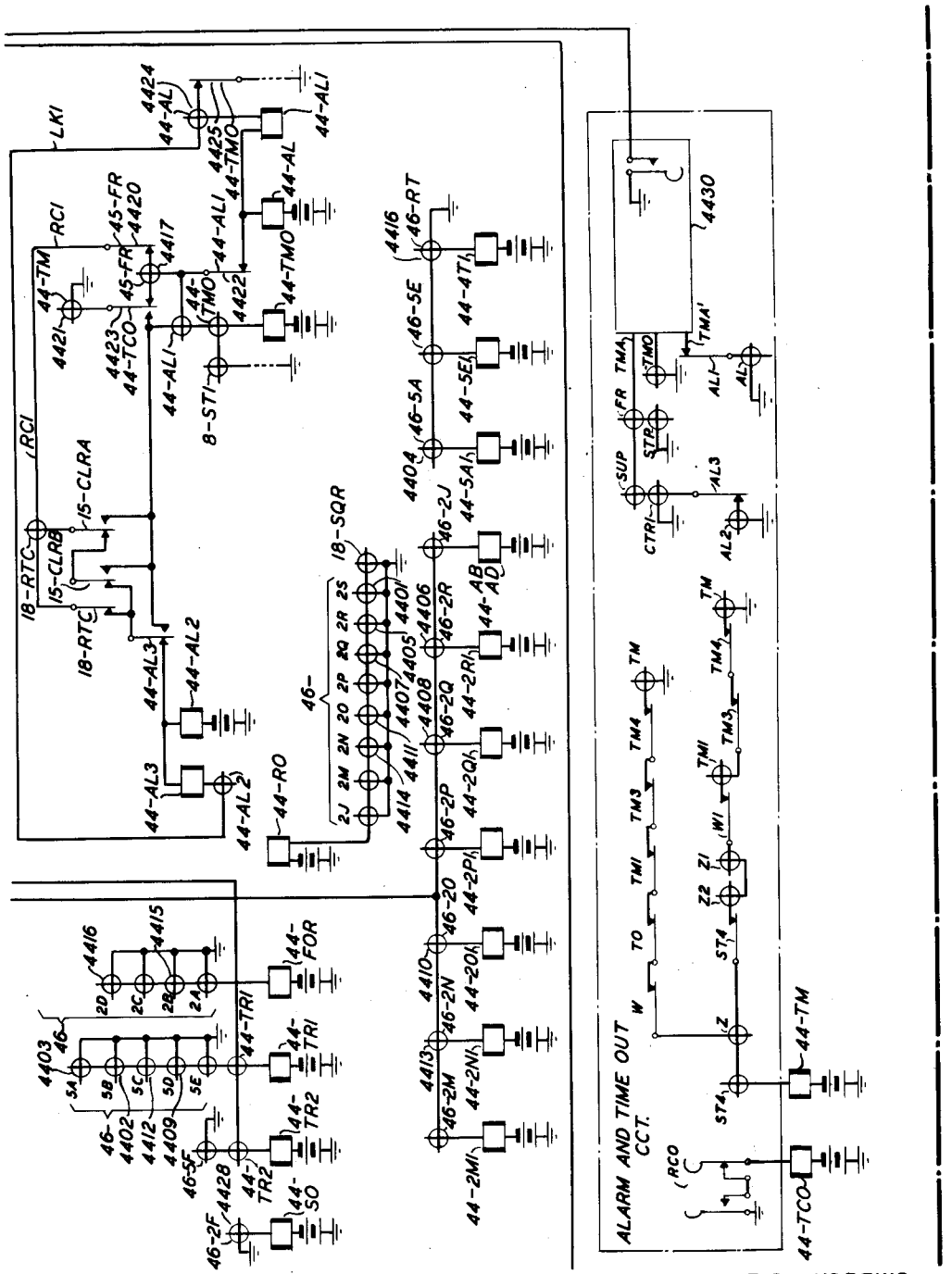

FIG. 44

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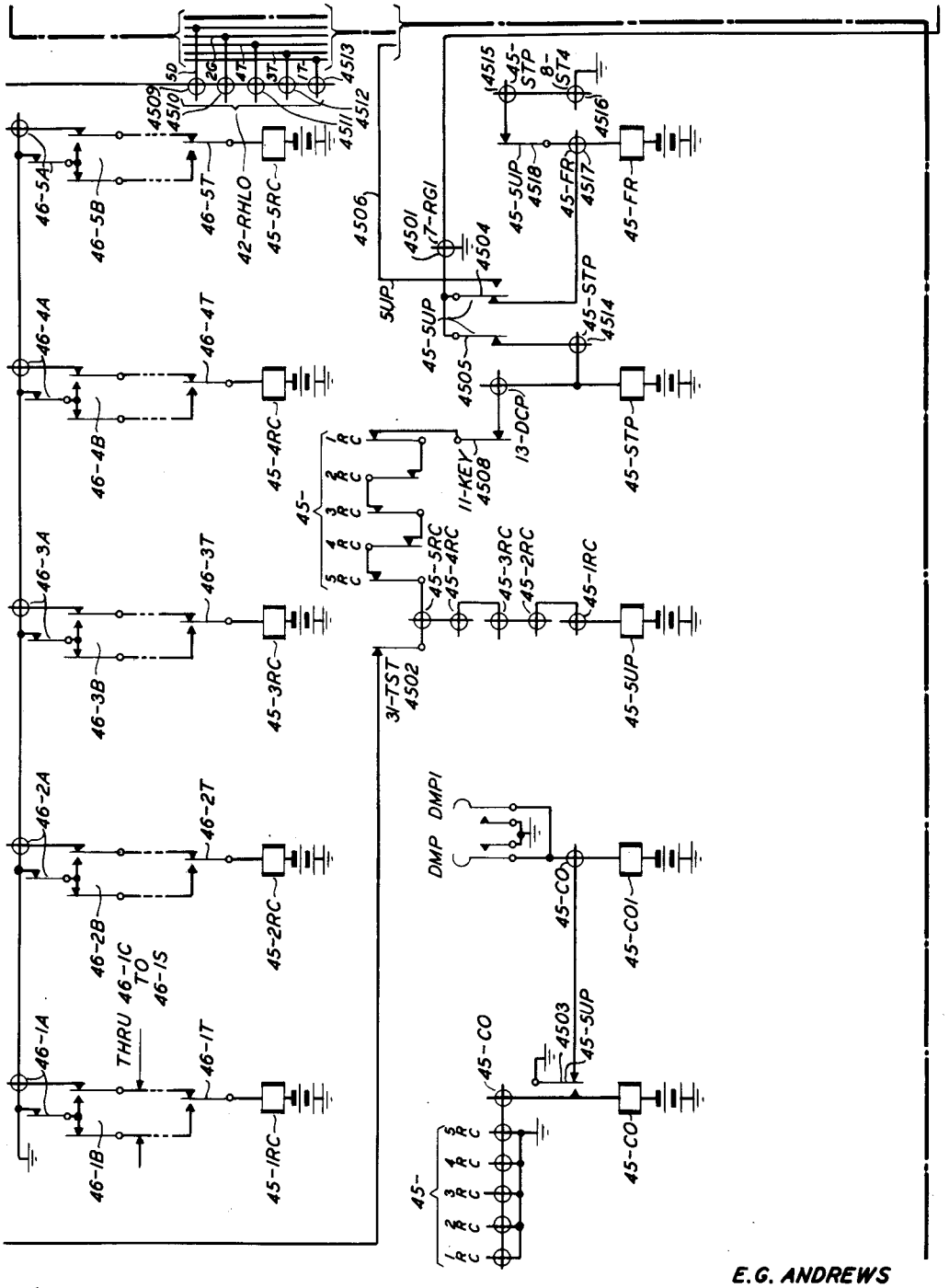

FIG. 45

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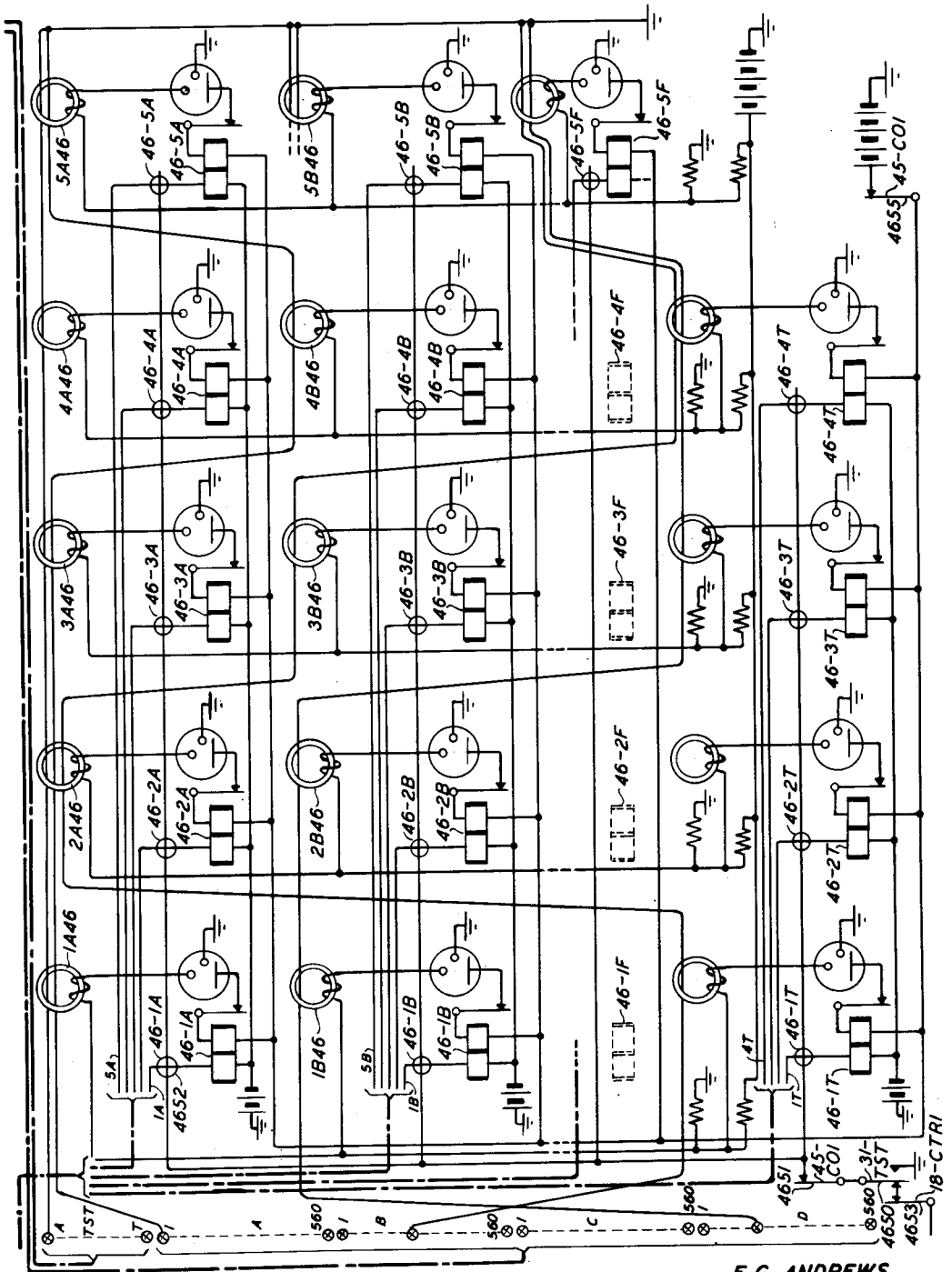

FIG. 46

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CODE CHART — DIGITAL COMPUTER

TAPE CODE COLS 1-4	READ OUT – X MULT. COLUMN 1 DESIG.	ORDER	COL. 1A ORDER	OPERATION COLUMN 2 DESIG.	ORDER	READ OUT–Y MULT. COLUMN 3 DESIG.	ORDER	READ IN – X MULT. COLUMN 4 DESIG.	ORDER	COLUMN 4A	TERMINATION COLUMN 5 DESIG.	ORDER	TAPE CODE COL. 5
123	A	STOR. REG. A		A	A FORM. NO. FOLLOWS	A-0	STOR. REG. A	A-0	STOR. REG. A		CC	CLEAR BOTH 1 & 3	0125
124	B	" " B		B	B " " "	B-1	" " B	B-1	" " B		CH	CLEAR 1, HOLD 3	0124
125	C	" " C		C	C " " "	C-2	" " C	C-2	" " C		HC	HOLD 1, CLEAR 3	1234
134	D	" " D		D	D " " "	D-3	" " D	D-3	" " D		HH	HOLD BOTH 1 & 3	1245
135	E	" " E		E	READ AS FORM. NO.	E-4	" " E	E-4	" " E		CP	COMPARE	0123
145	F	" " F		F	SPEC. ORD. NO. FOLLOWS	F-5	" " F	F-5	" " F		TR	TRANSFER	1345
234	G	" " G		G	RETURN TO HIGHER LEVEL	G-6	" " G	G-6	" " G				
235	H	" " H		H	HUNT PAGE OR BLOCK NO.	H-7	" " H	H-7	" " H				
245	I	" " I		I		I-8	" " I	I-8	" " I				
345	J	" " J		J	ABSOLUTE VALUE ADDITION	J-9	" " J	J-9	" " J				
012	K	" " K		K	PERFORATE ENC.	K	" " K	K	" " K	PERF. DATA ON A			
013	L	" " L		L	CARR. RET. LINE & FIG. SHIFT	L	" " L	L	" " L	" " B			
014	M	TAPE REG. A		M	+ CANCEL R.O. & ZERO SHIFT	M	TAPE REG. A	M	PRINT	" PAGE NO. A			
015	N	" " B		N	✓	N	" " B	N		" " B			
023	O	– 0.00		O	–	O	0.0342944818	O		" BLK. " A			
024	P	1.00		P	+	P	1.00	P		" " B			
025	Q	0 X 10^10	PAGE REG. A	Q	÷	Q	0.500	Q		READ IN PG. REG. A			
034	R	57.2957795I	" " B	R	X	R	6.283185307	R	DUMMY	" " " B			
035	S	"X" REG. OF CALC.	BLK. REG. A	S	≡ (TRANSFER)	S	2.718281828	S	"X" REG. OF CALC.	READ IN BLK. REG. A			
045	T	DUMMY	" " B	T	DUMMY	T	DUMMY	T	DUMMY	" " " B			

FIG. 47

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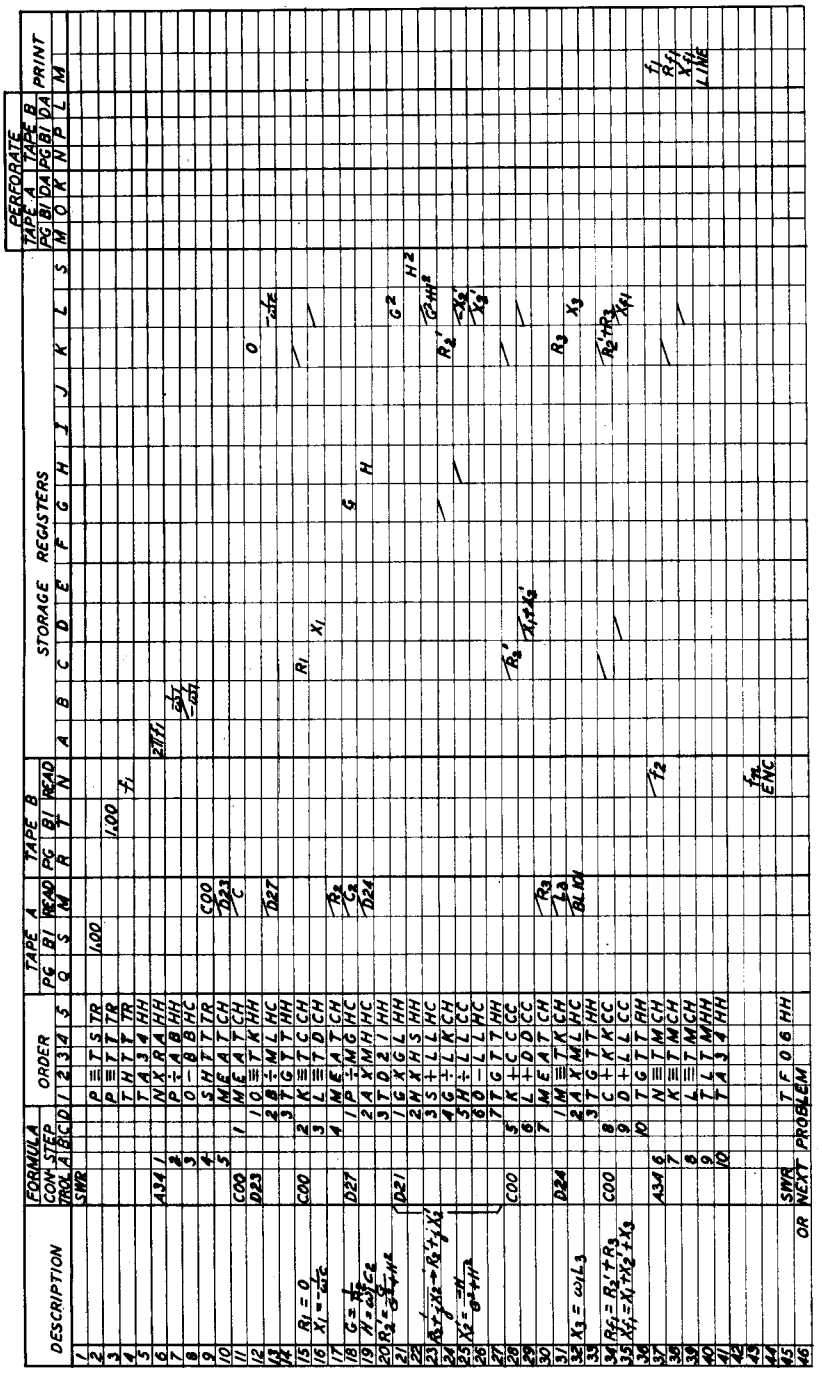

FIG. 49

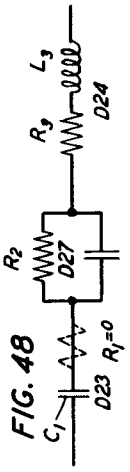

FIG. 48

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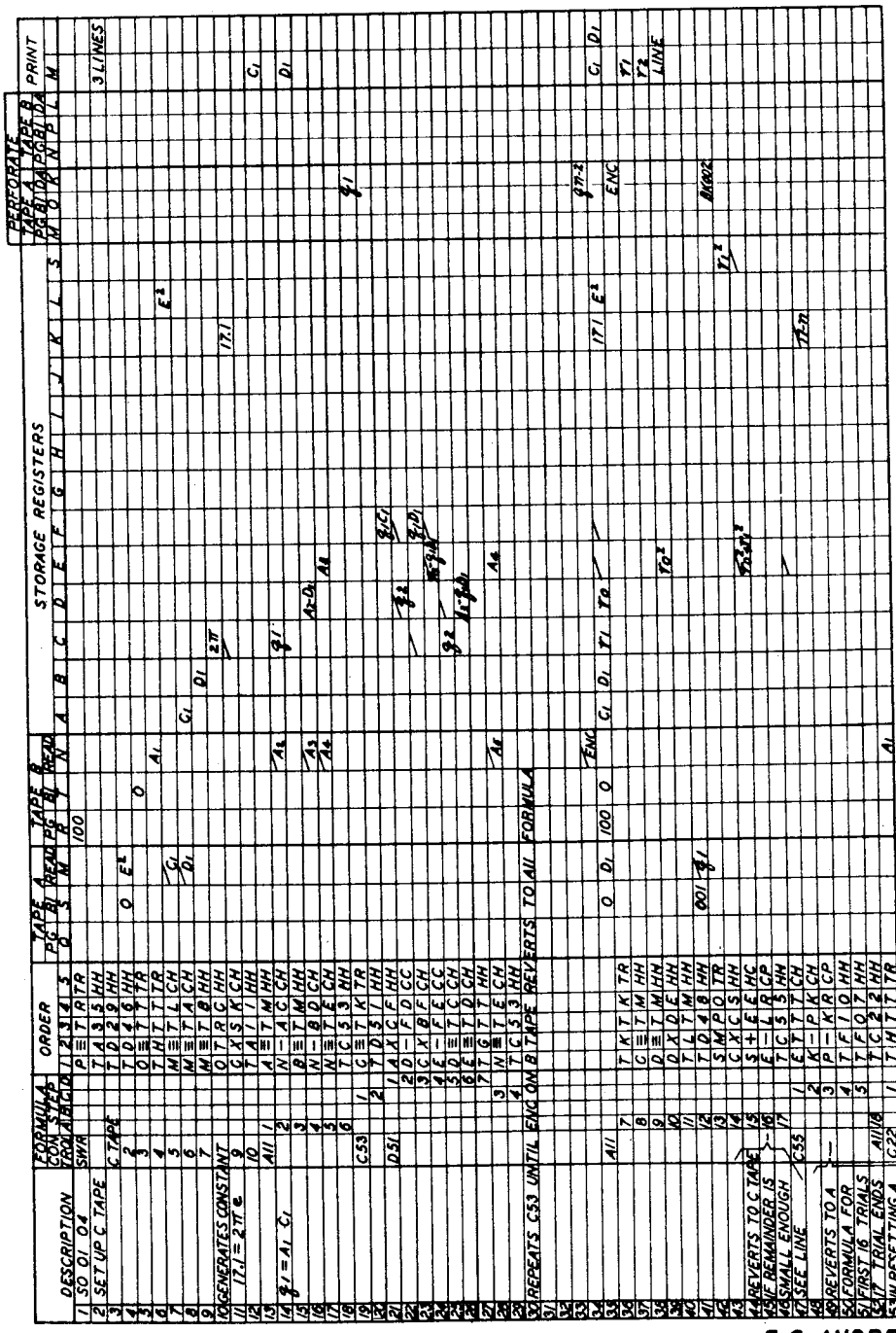

FIG. 50

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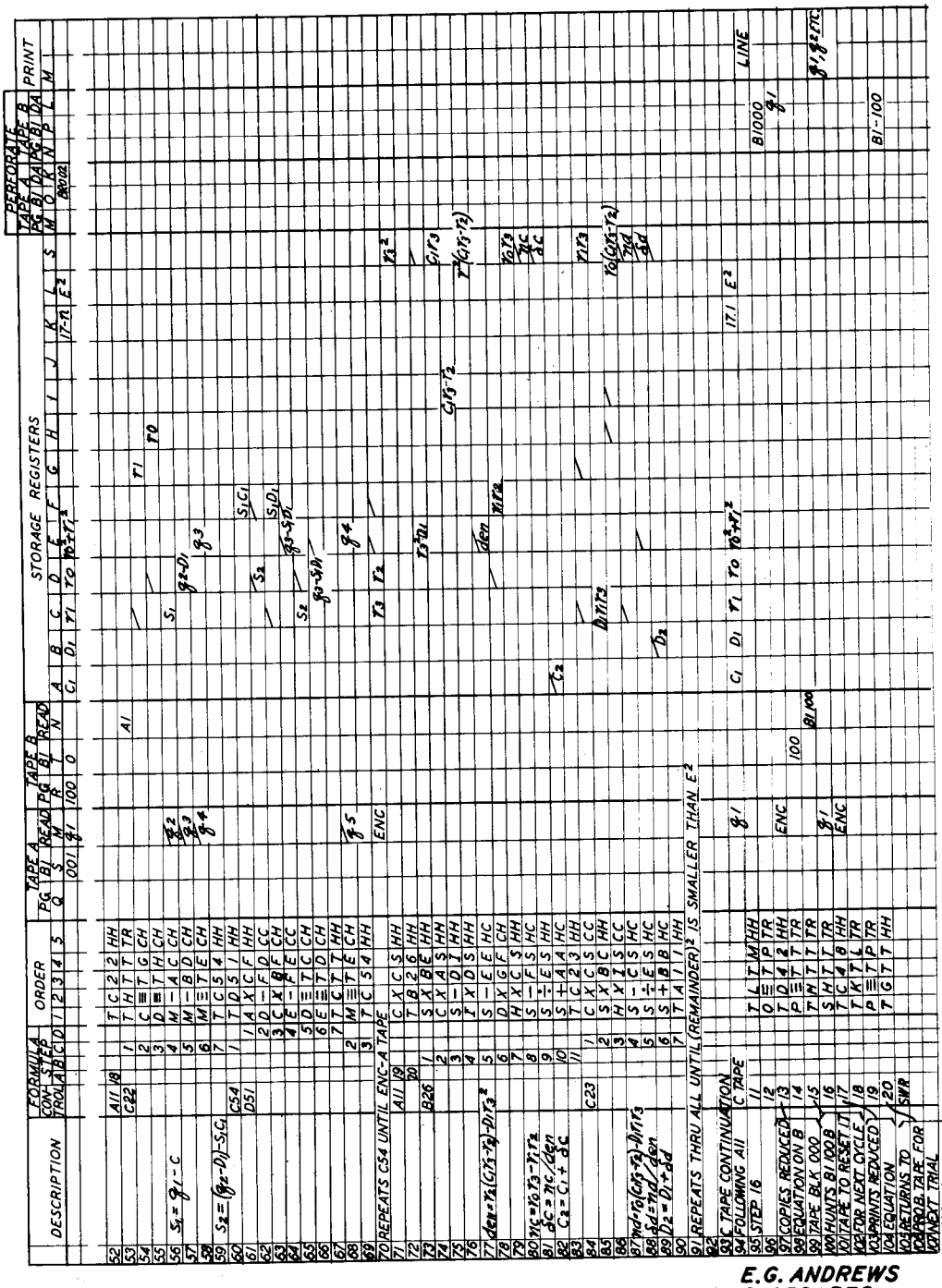

FIG. 51

INVENTORS E.G. ANDREWS
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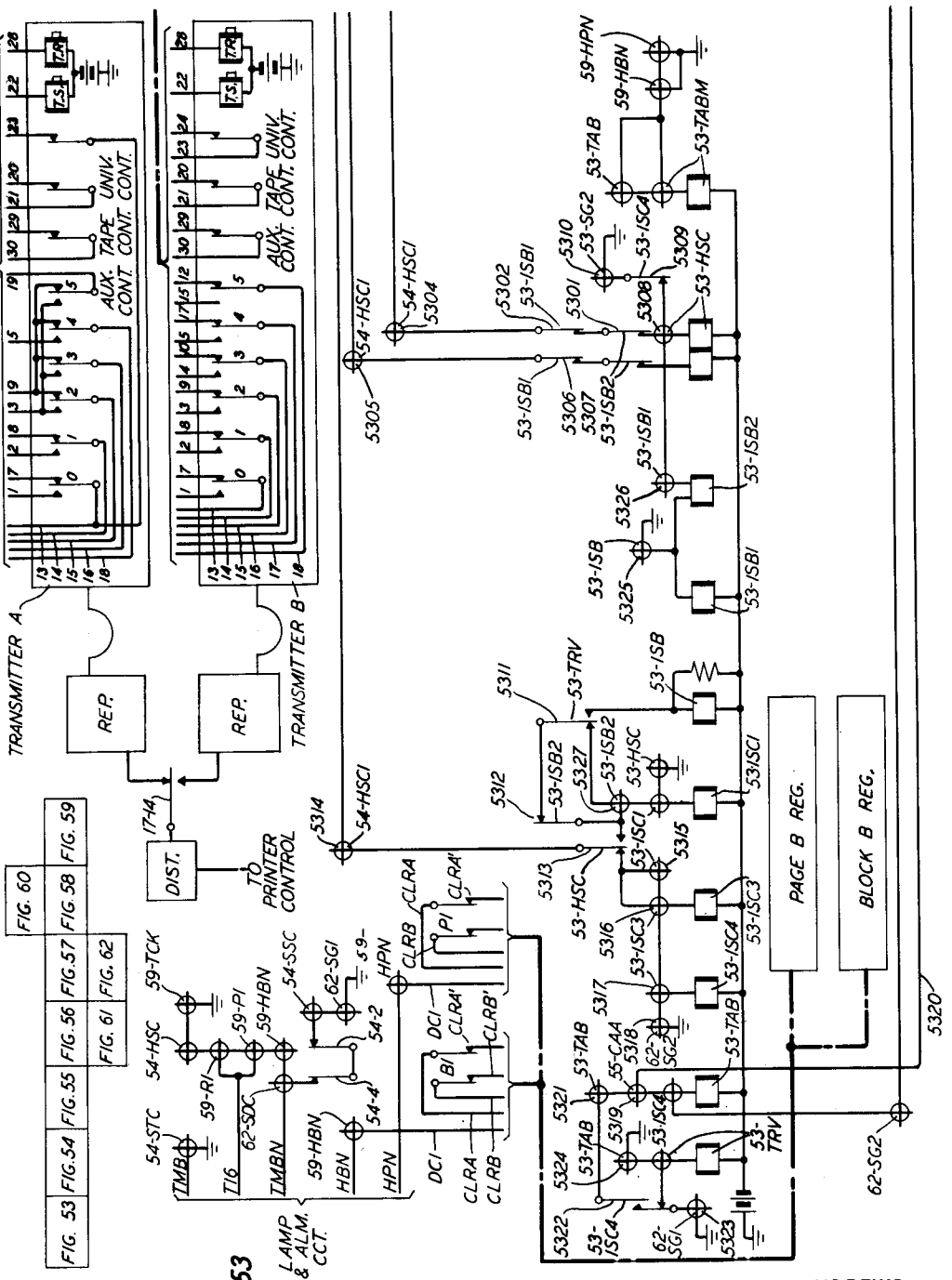

FIG. 52

FIG. 53

INVENTORS
E. G. ANDREWS
O. CESAREO
P. B. MURPHY

BY
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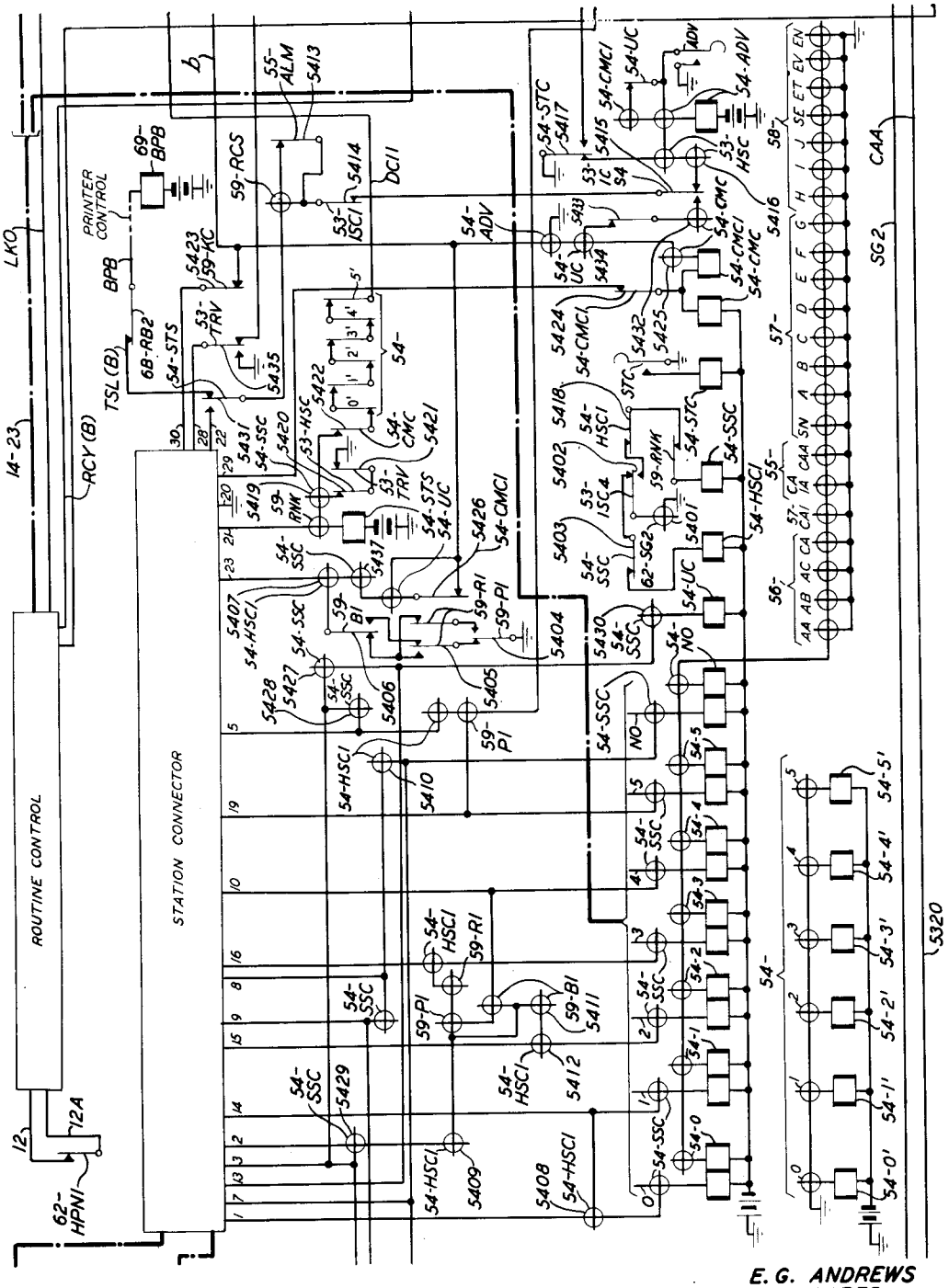

FIG. 54

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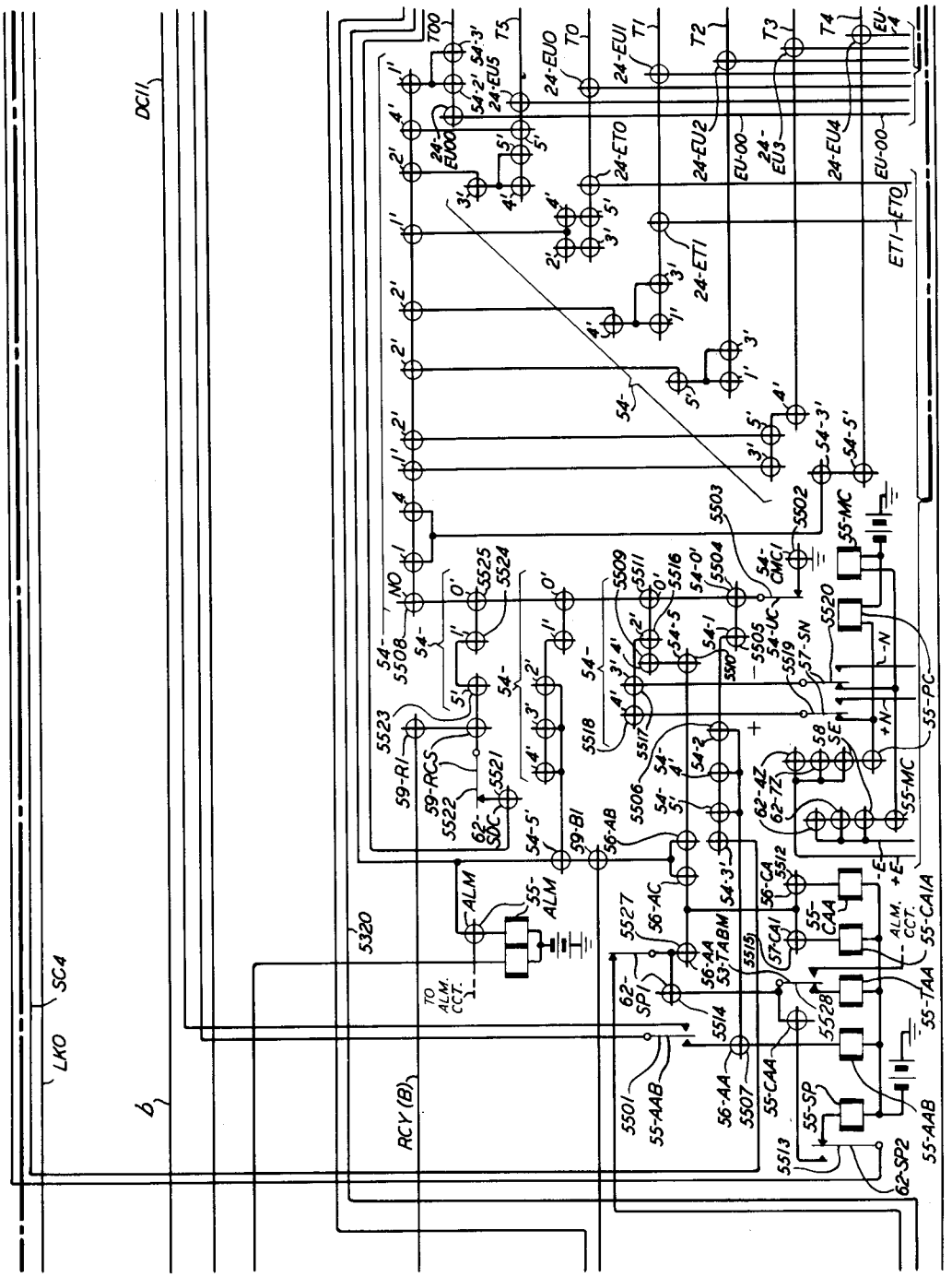

FIG. 55

INVENTORS E. G. ANDREWS
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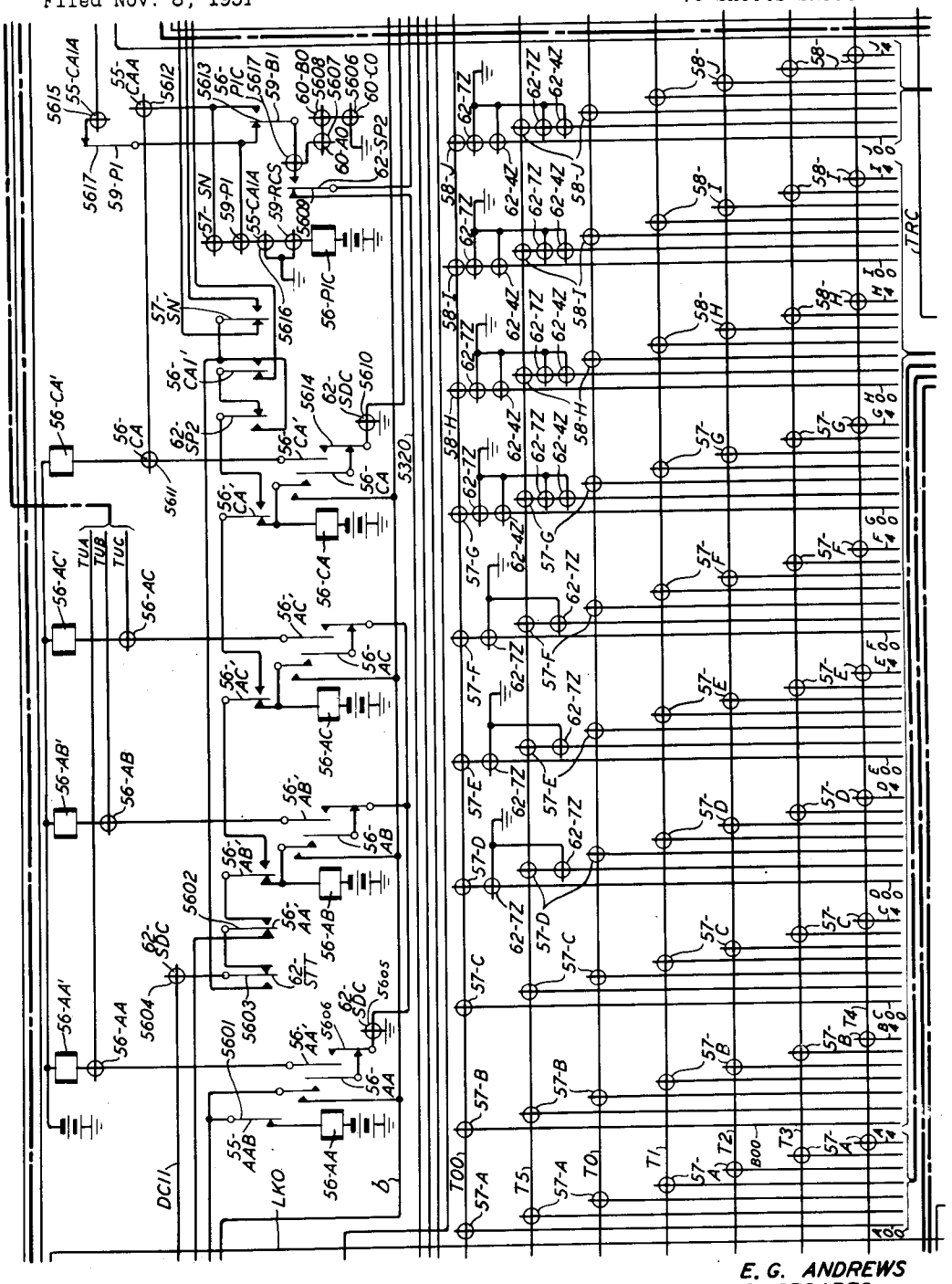

FIG. 56

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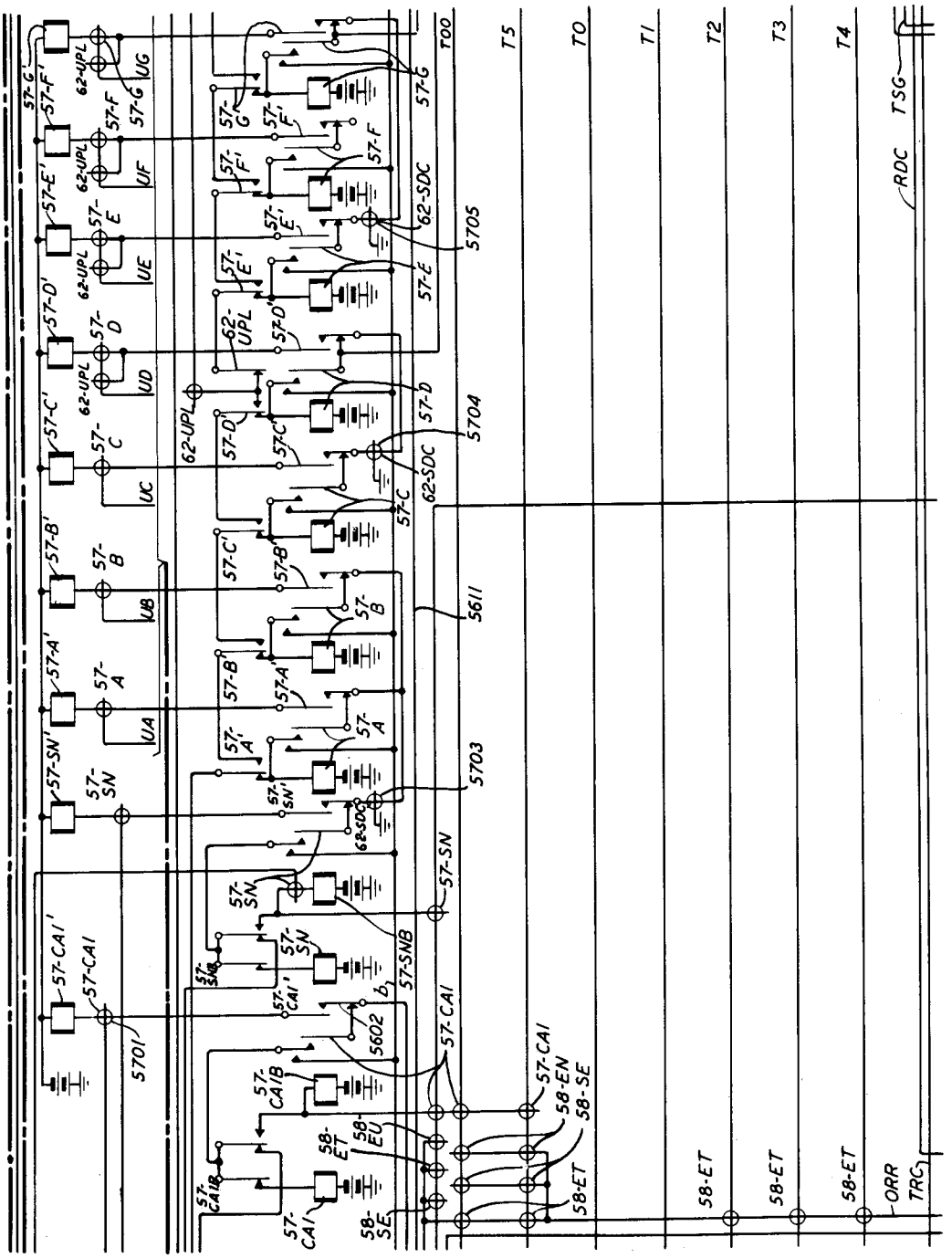

FIG. 57

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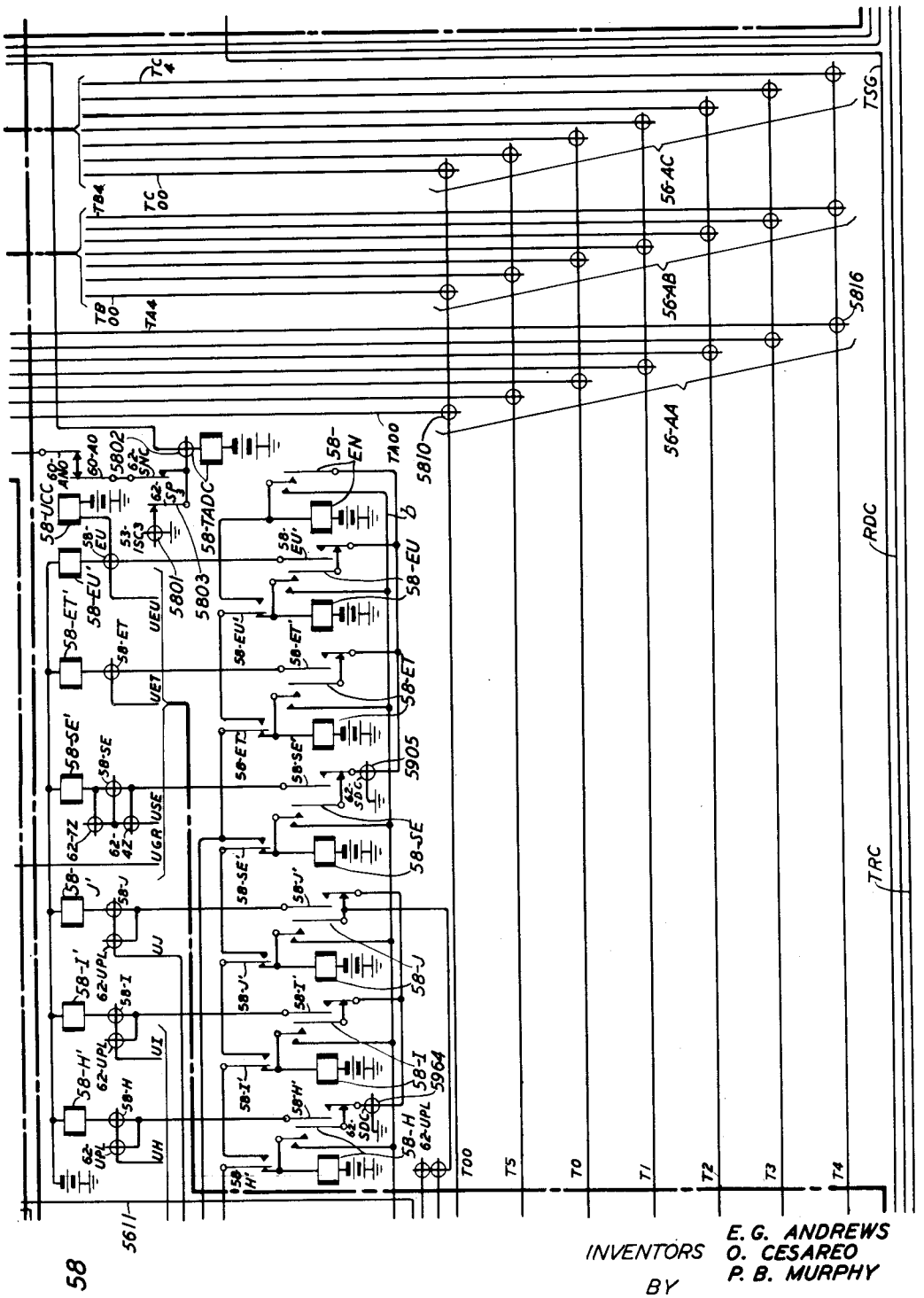

FIG. 58

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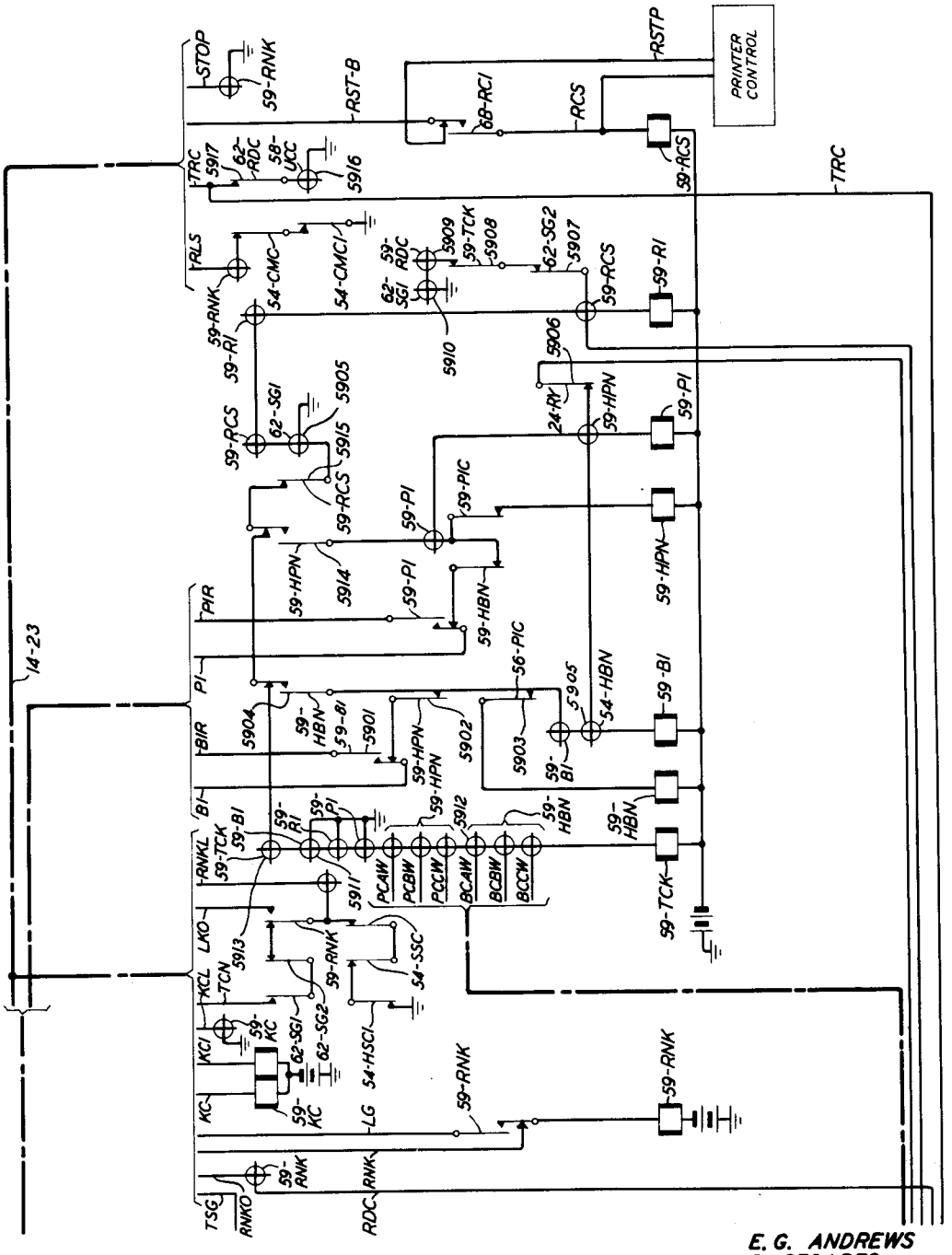

FIG. 59

INVENTORS E. G. ANDREWS
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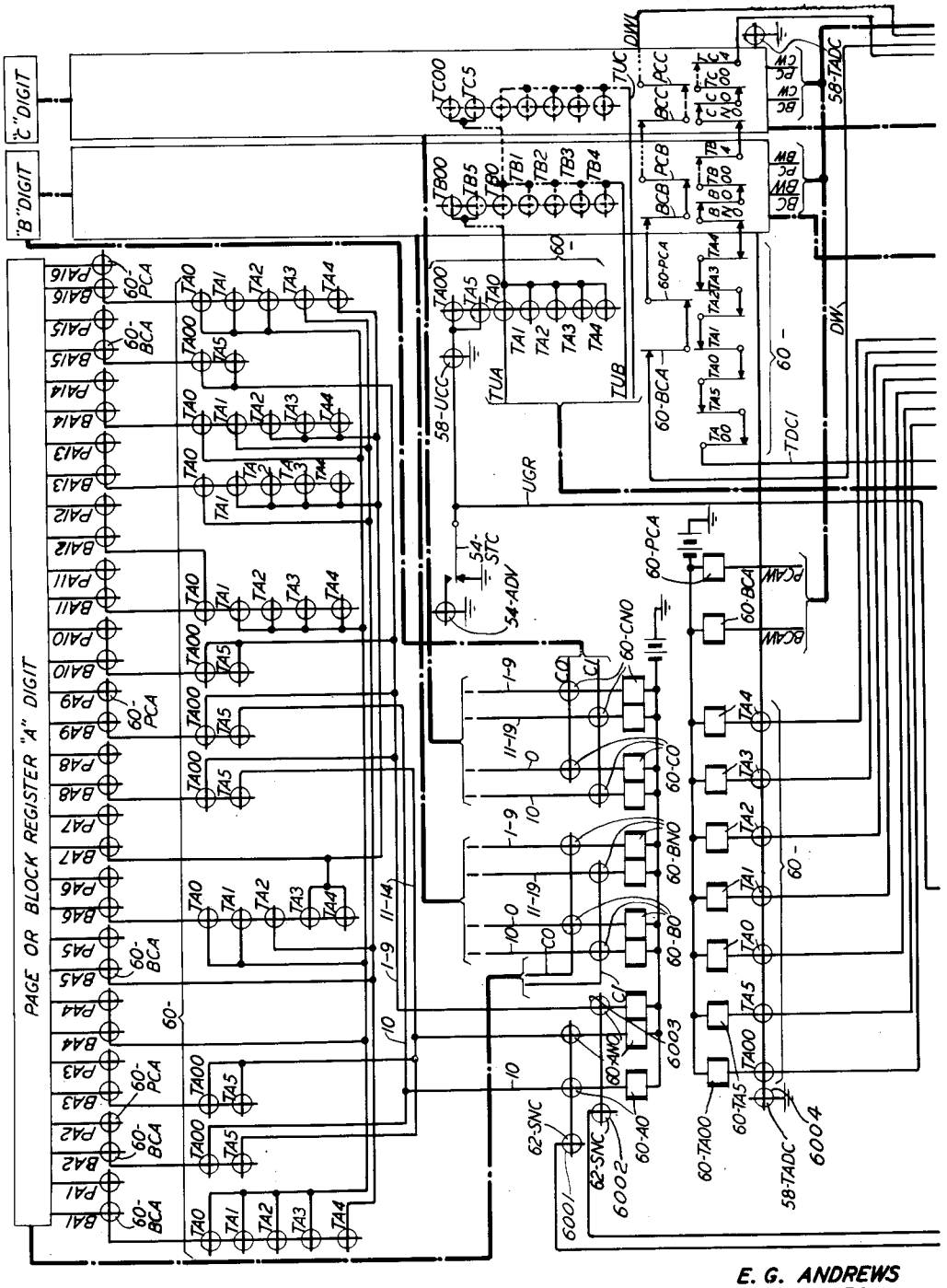

FIG. 60

INVENTORS E. G. ANDREWS
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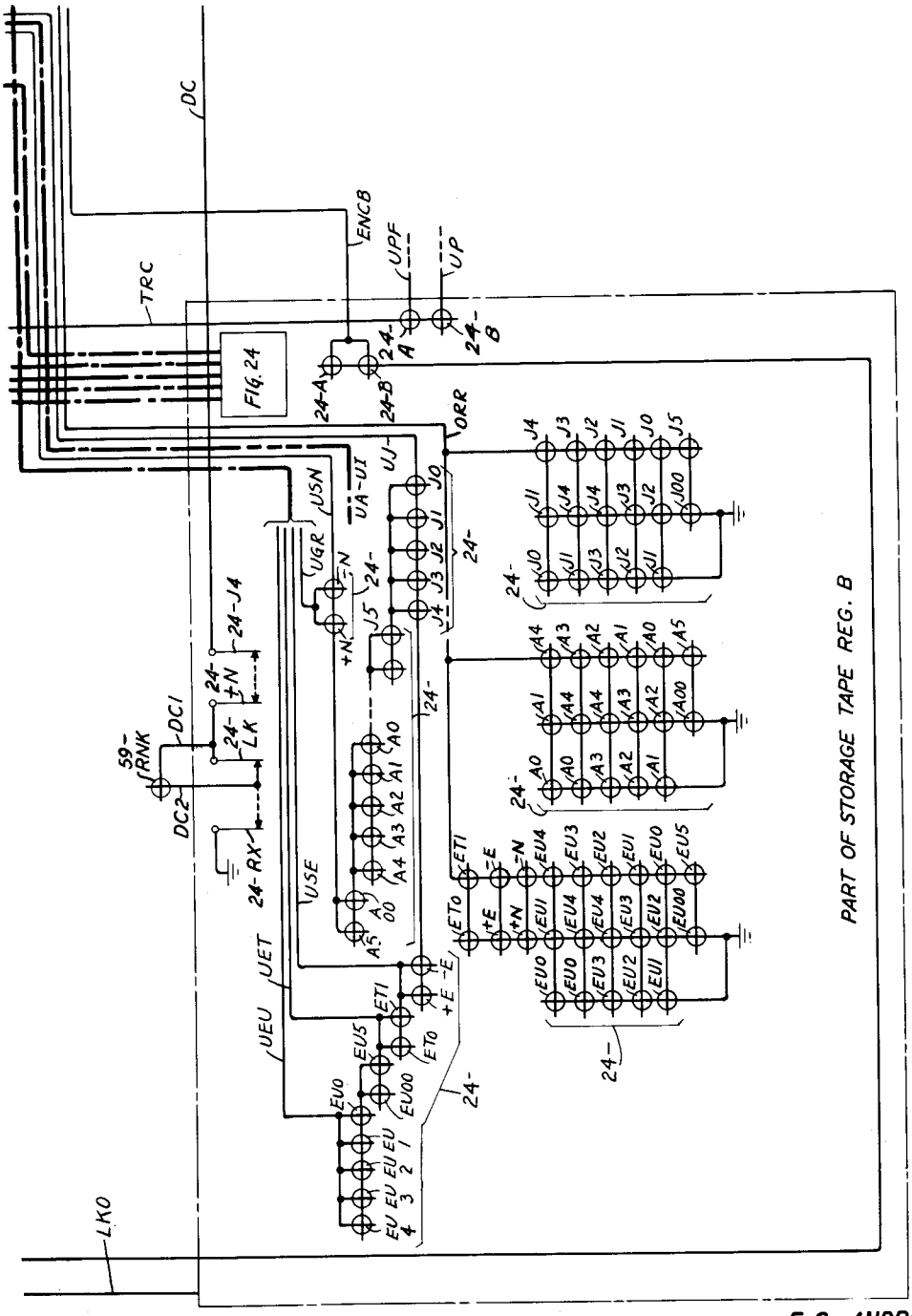

FIG. 61

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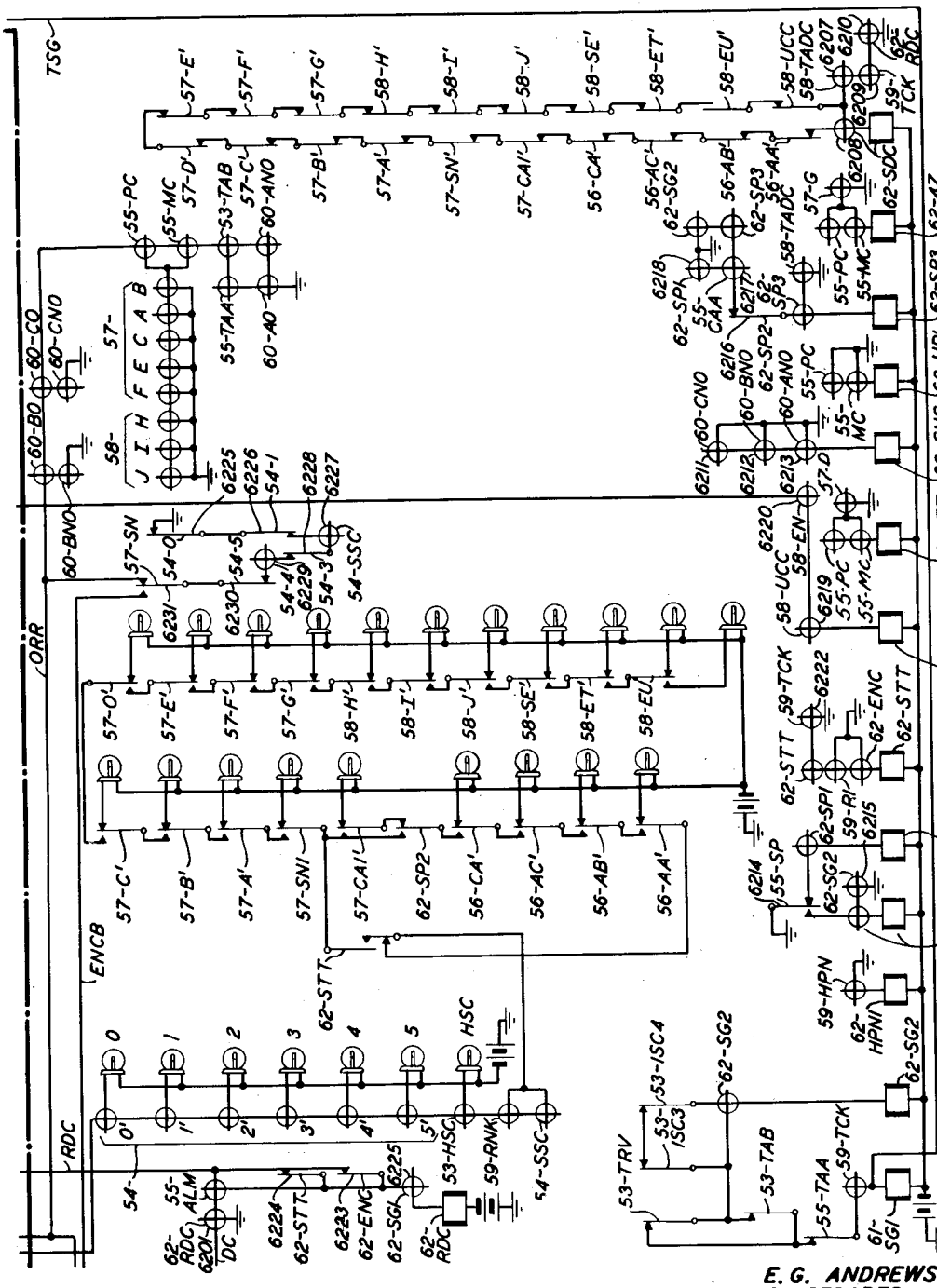

FIG. 62

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FIG. 64	FIG. 65	FIG. 66	FIG. 67	FIG. 73
FIG. 68	FIG. 69	FIG. 70	FIG. 71	FIG. 72

FIG. 63

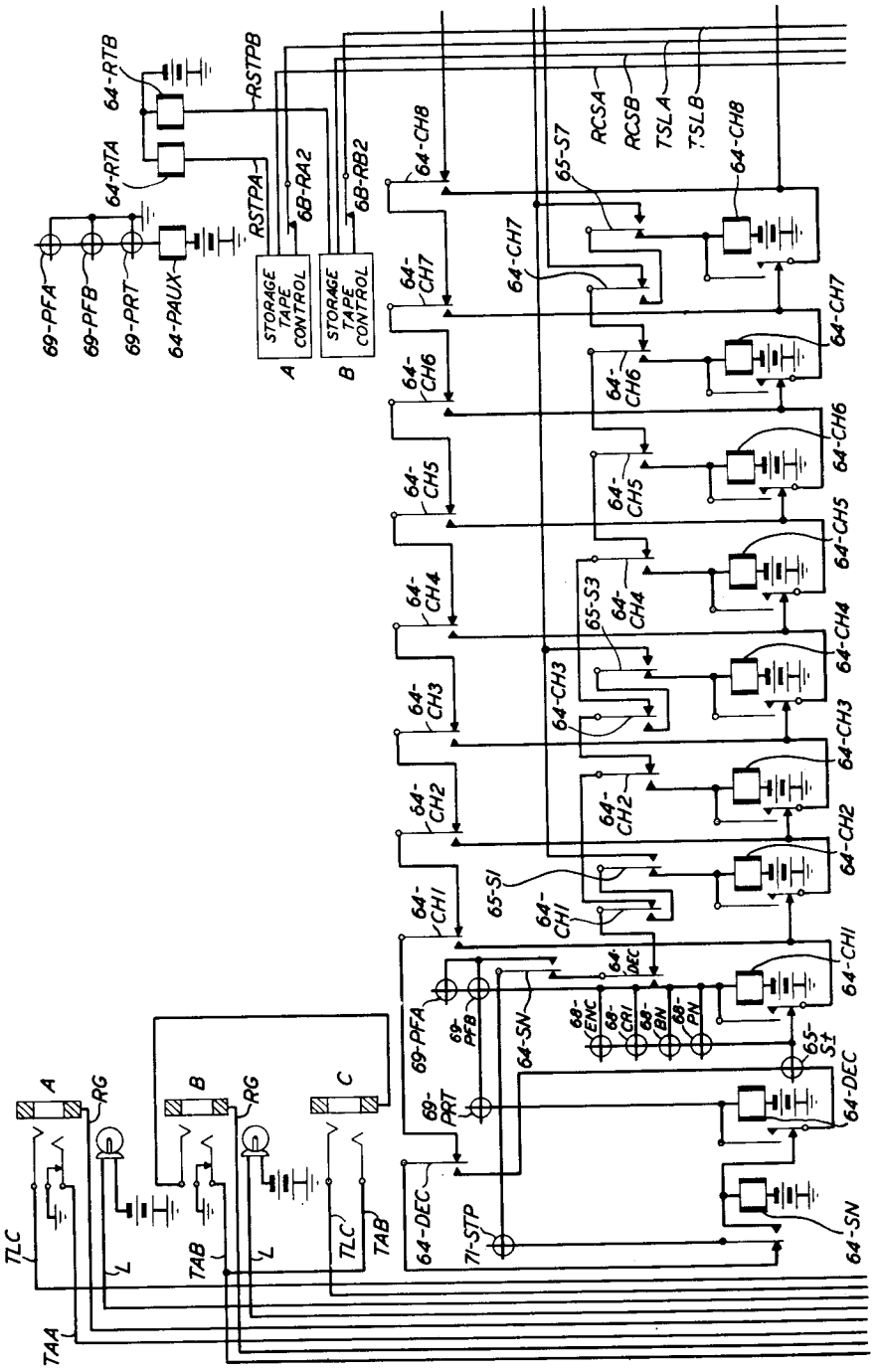

FIG. 64

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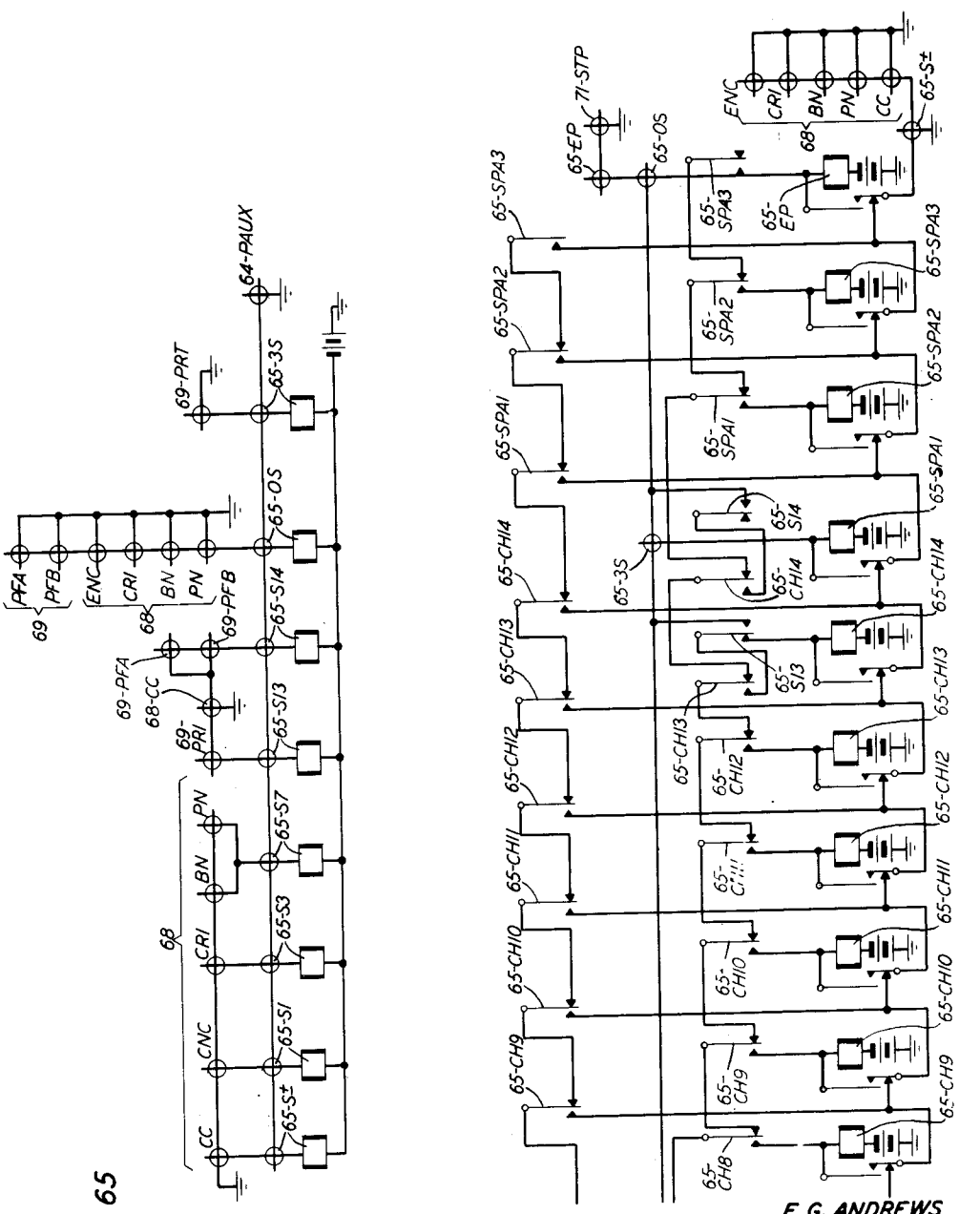

FIG. 65

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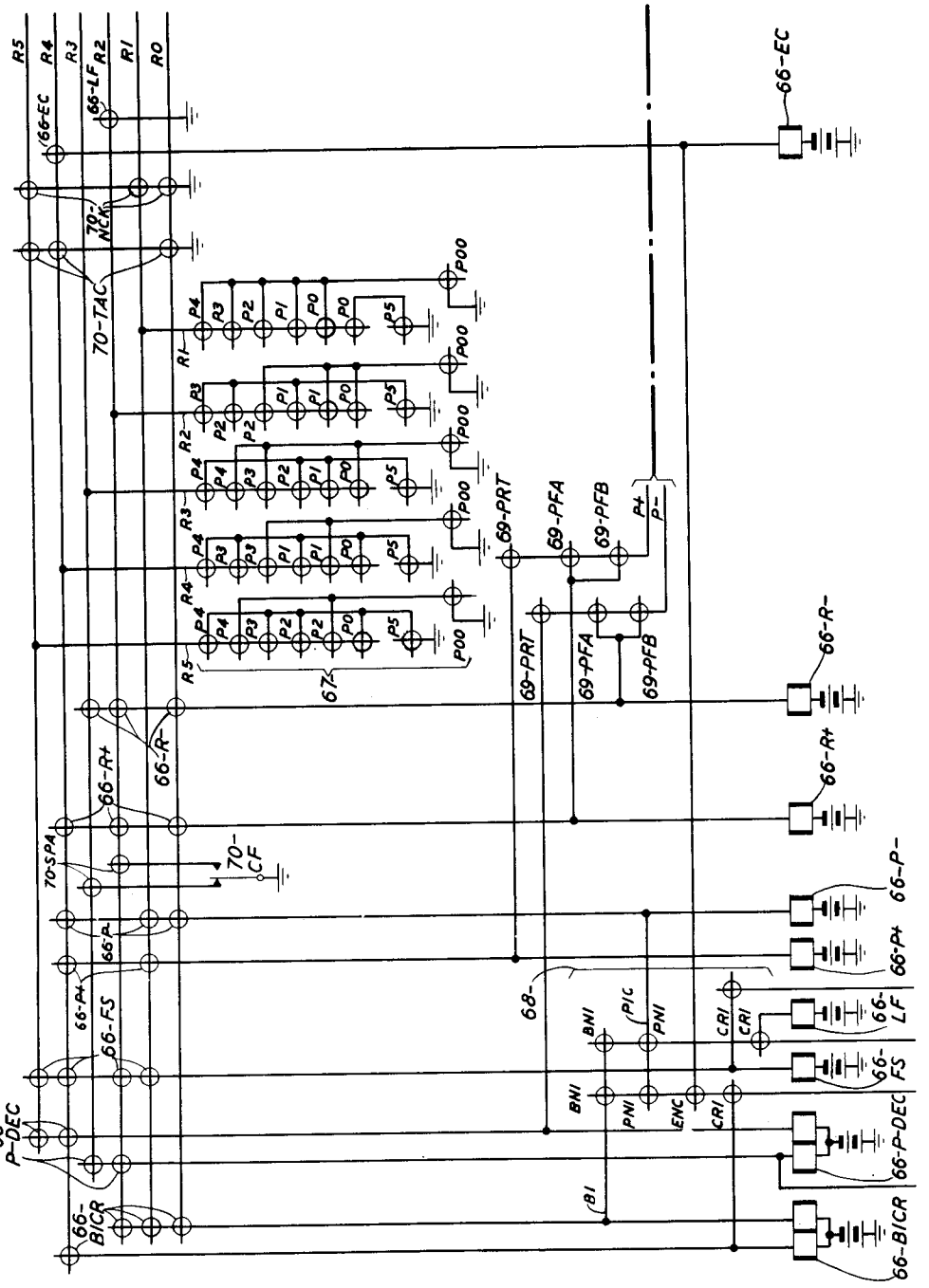

FIG. 66

INVENTORS E. G. ANDREWS
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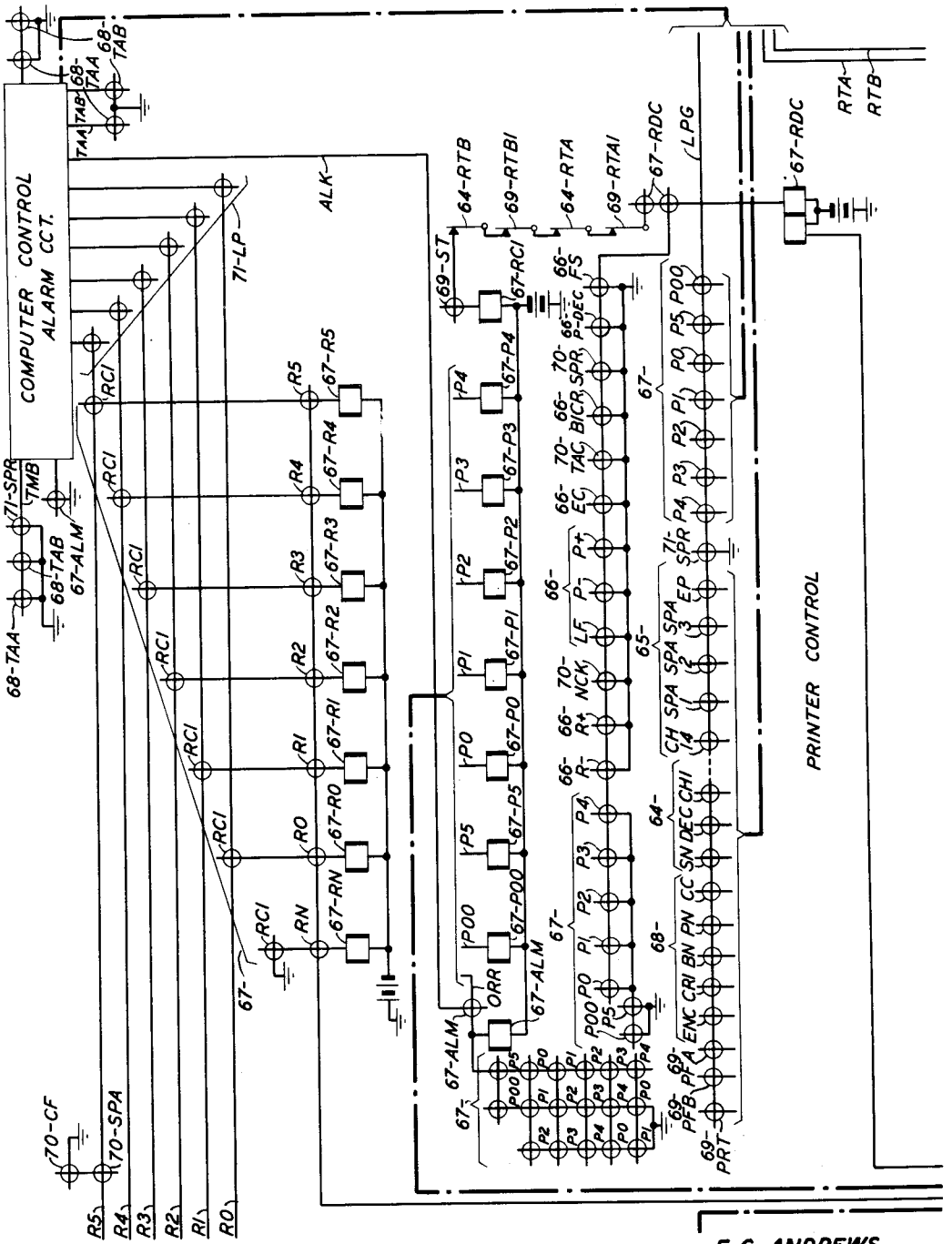

FIG. 67

INVENTORS E. G. ANDREWS
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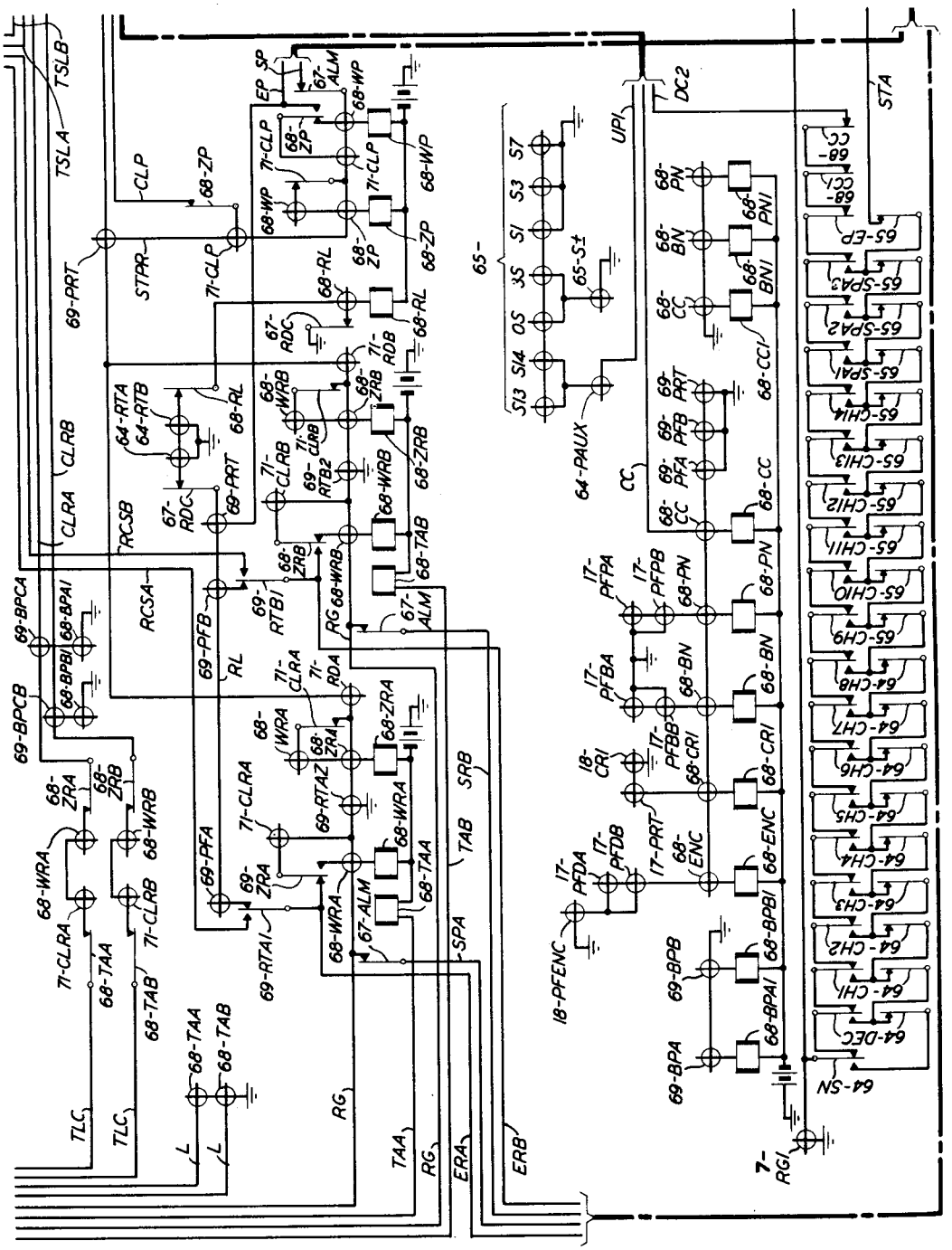

FIG. 68

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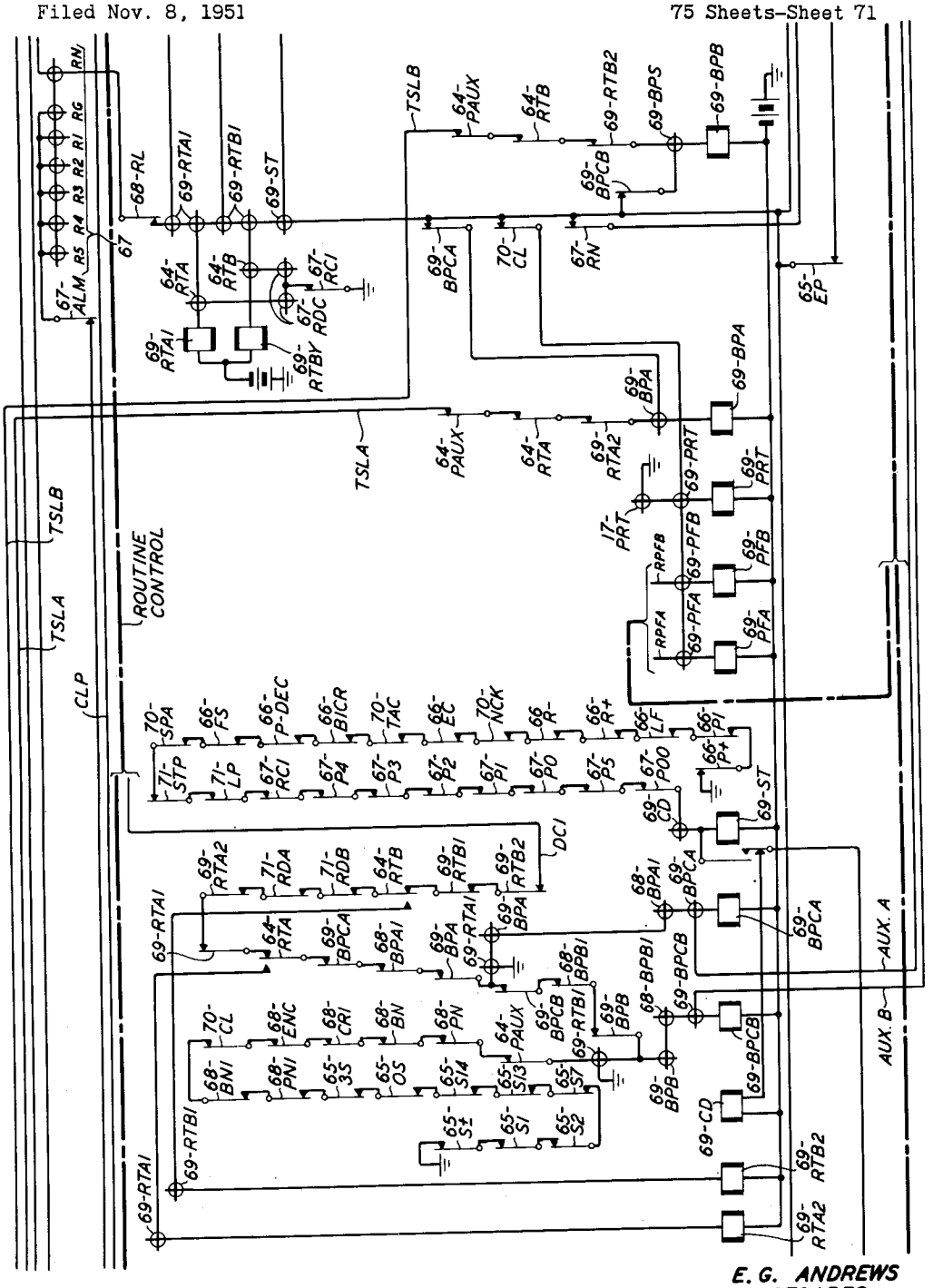

FIG. 69

INVENTORS E. G. ANDREWS
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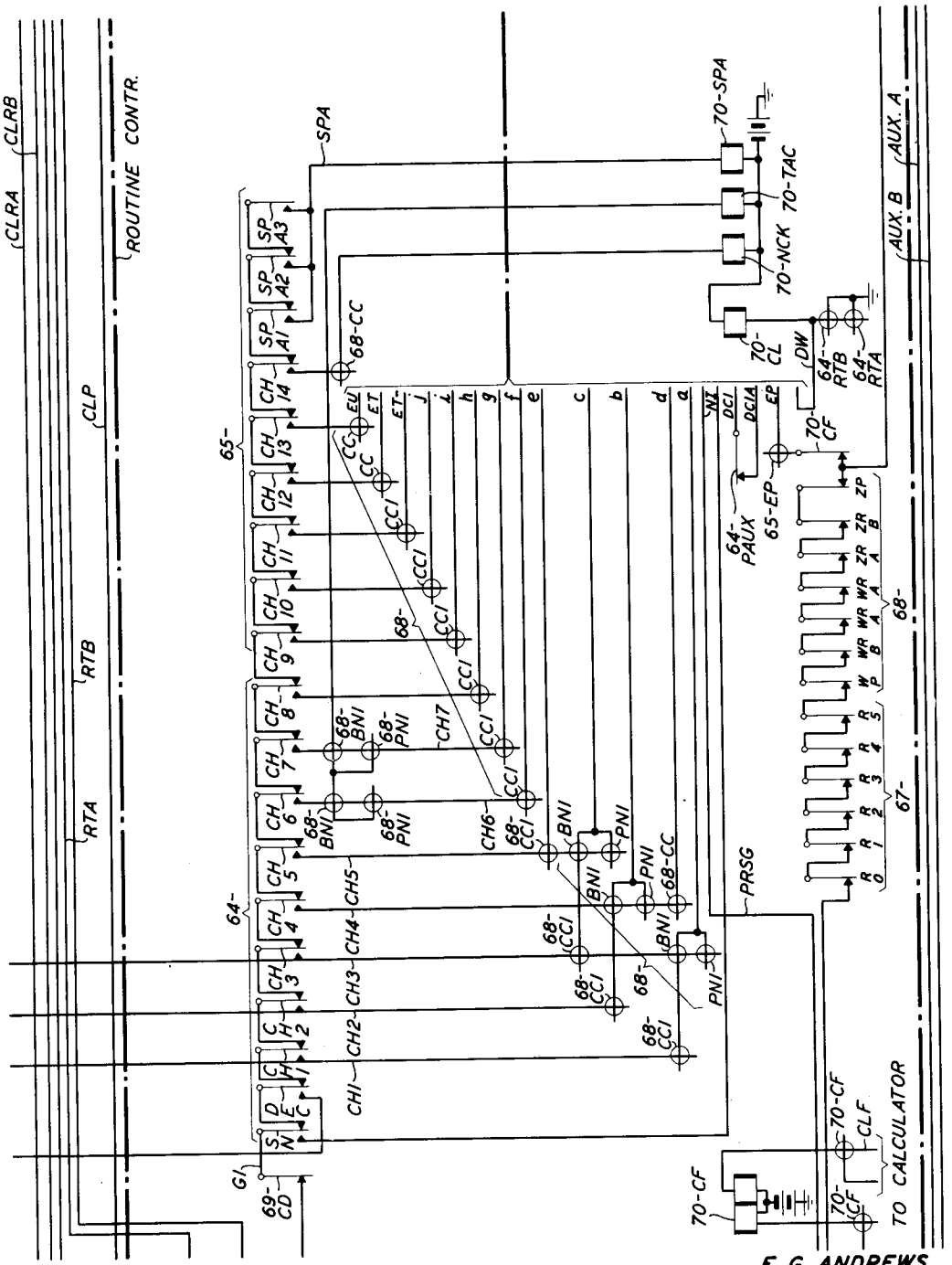

FIG. 70

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BY William F. Simpson.

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July 2, 1957 E. G. ANDREWS ET AL 2,797,862

DIGITAL COMPUTER

Filed Nov. 8, 1951 75 Sheets-Sheet 73

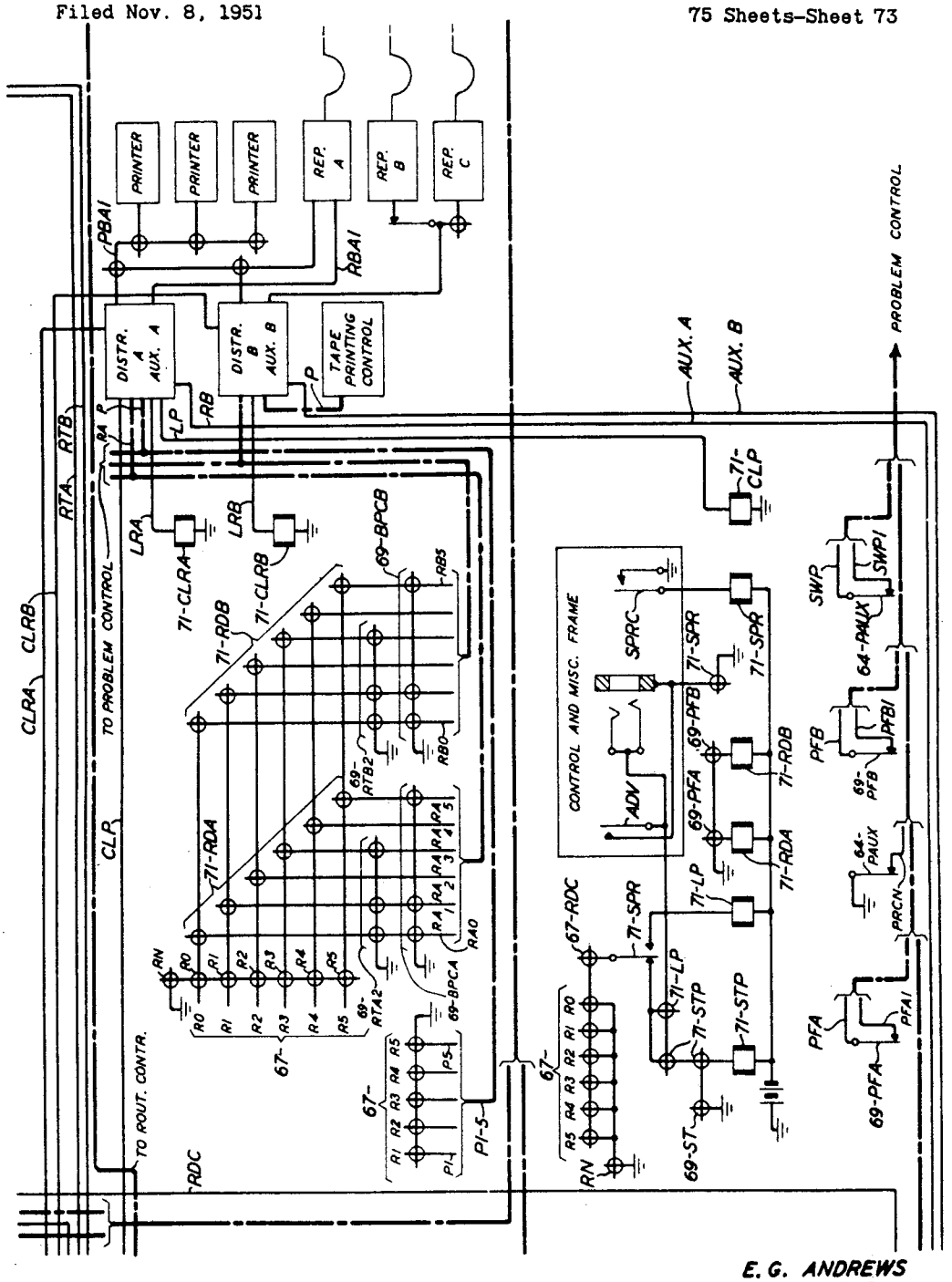

FIG. 71

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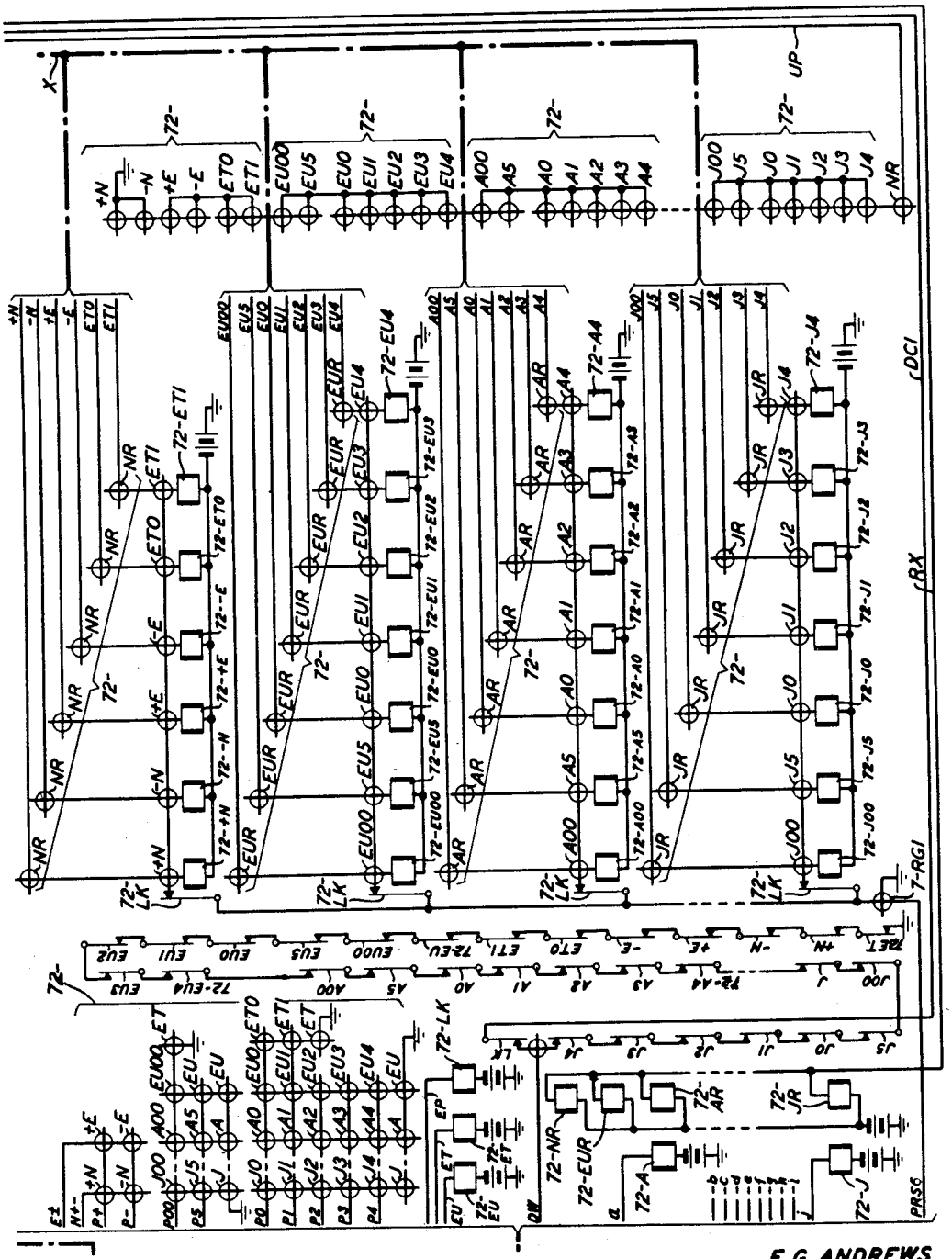

FIG. 72

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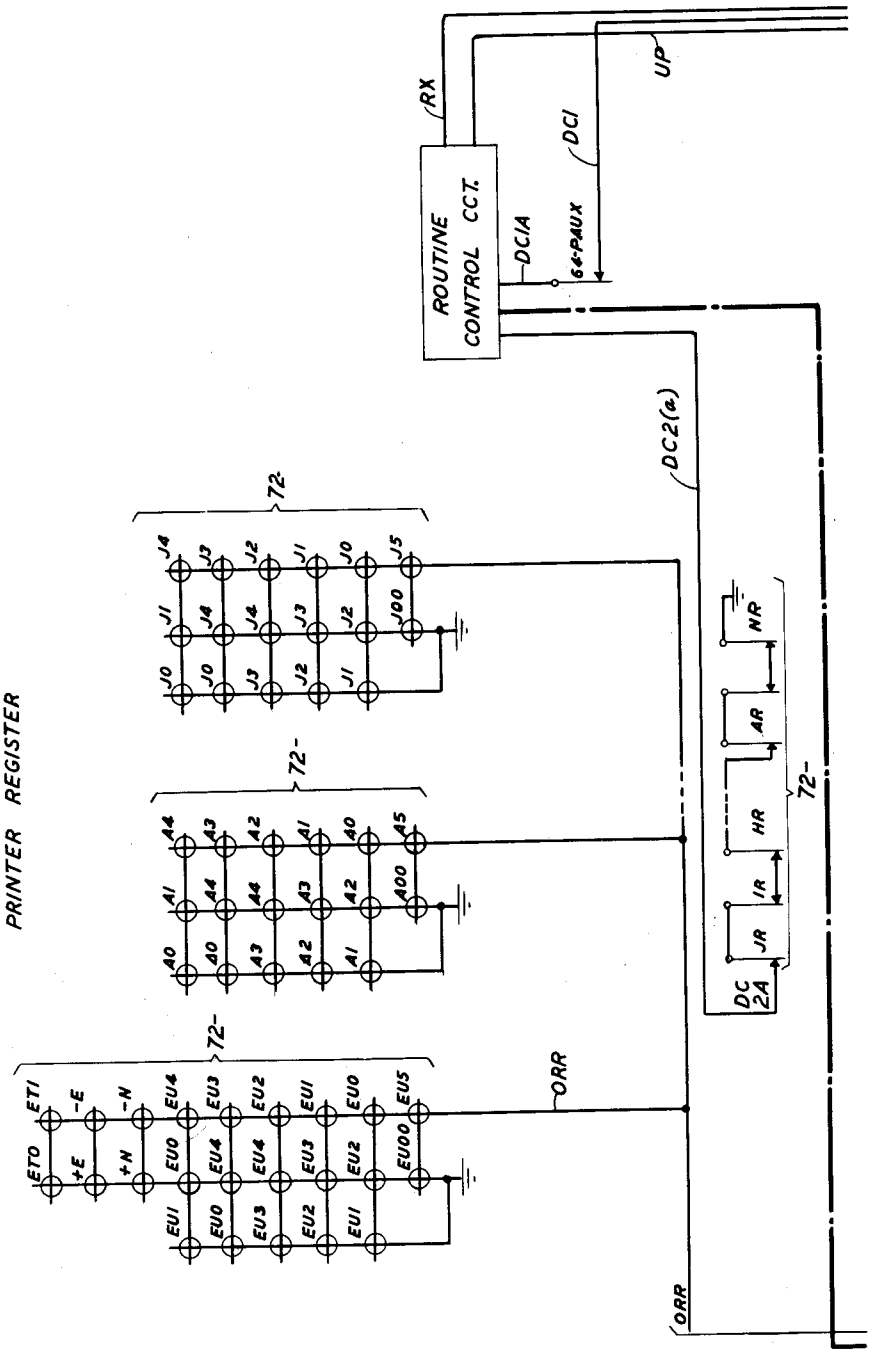

FIG. 73

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DIGITAL COMPUTER

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Application November 8, 1951, Serial No. 255,362

15 Claims. (Cl. 235—61)

This invention relates to computers and more particularly to digital computers.

An object of the invention is to improve the organization of a large scale digital computer by providing improved circuits, apparatus and methods for more reliable and speedier operation, for greater flexibility, and for greater ease and facility in operating and programming.

Large scale computers have been constructed for performing many mathematical operations and for solving numerous types of mathematical problems which open up fields of scientific investigation by taking the drudgery out of computations of problems known to mathematicians but which have been so extensive that it was previously impossible to carry them out. These large scale computers have been of several types. One type employs mechanical apparatus, a second type employs electronic circuits, apparatus and equipment and a third type employs relays and other communication apparatus. Of these types the electronic computer is by far the speediest in operation while many of the relay type computers have been more reliable and more accurate due to the use of self-checking features. United States Patent 2,486,809, issued to G. R. Stibitz, November 1, 1949, shows fundamentals of an exemplary embodiment of a relay type computer. This patent, however, does not disclose suitable entry means whereby operational orders and numerical values may all be entered under control of a tape or other storage means so that it is impossible in this computer to prepare a long series of mathematical operations in a program or routine whereby the computer may be caused to operate unattended over long periods of time.

Computers have been devised subsequently which are suitable for being controlled by a long routine or program of operations which may be devised and placed in the computer on the tape or other storage means and then the computer set into operation to perform the necessary operations to obtain the desired results.

In an effort to simplify and improve the operation, certain of the computers have been arranged and devised so that a routine or program of operations is set forth or recorded in a routine or problem tape and a series of problem arguments set forth in another storage tape. In some cases additional tapes known as table tapes are also provided from which numerical values may be taken as desired when called for by orders on the recorded routine tape or storage apparatus.

An object of the present invention is to arrange the sequencing and control functions of a computer so that the work of programming a computer for any of a wide range of types of problems and any problems in any of these types may be readily arranged. In an exemplary embodiment of this invention the routine of the computer is broken up into a number of sub-routines each of which may be called for or ordered by the master or problem routine and in which each of the sub-routines may in turn call for other sub-routines or for repeating themselves. Thus, the routine or program may consist

of a principal or master routine which may be prepared for each problem or for each of a series of problems and this master routine may call for sub-routines which form a part of the principal control of the mechanism. These sub-routines may be placed in separate tapes so that when in the course of operation the master routine comes to a point where a sub-routine may be used further control of the computer is directed by a sub-routine tape which tape then controls the operation of the computer until the routine recorded on the sub-routine tape is completed. Thereafter, the control is restored to the principal or master routine tape. In this manner many mathematical computations in the form of exponential or power series may be set forth in a routine so that it may be performed an indefinite number of times in accordance with various controlling values known as arguments so that, for instance, a table of sines or other trigonometric functions may be completely produced by such a computer by entering into the computer through a problem tape the various angle values for which the functions are desired.

In accordance with the present invention, in an effort to further simplify the programming of such a computer and the control and sequencing circuits thereof the computer has been arranged to provide for a large plurality of sub-routines called formulas which may be readily wired into the computer on a semipermanent basis. These formulas have been arranged in different groups which are called "levels" herein. These levels or groups are arranged in descending order of complexity. For example, the least complex group of formulas is called the D level formulas, the next group is called the C level formulas, the next the B group and the group having the greatest complexity is designated the A level formulas. Of course, still more complicated routines may be devised and entered in a problem tape for controlling the computer from this problem tape. In addition, provision has been made for use of an additional storage tape or other storage mechanism in which other routines may be entered for controlling the computer. These other routines may be considered to be of a complexity intermediate between the A level formulas and the routine set up in the problem tape or they may have a complexity still greater than the complexity of the routines set up in the problem tape.

A feature of this invention relates to the control of computer formulas which formulas may be called for by the problem tape or by any other of the formulas. Upon the selection of any formula the control of the computer is directed by the formula until the selected formula either selects an additional formula or completes the various operations called for by the selected formula after which time the computer is no longer controlled by the selected formula. Instead, the computer control is returned to the higher level formula which selected the formula in question or to the problem tape as may be desired.

In accordance with the exemplary embodiment of the present invention described herein in detail the computing mechanism is controlled by orders which generally comprise five parts. The routine control information is entered into the computer by means of these orders and then the control of the computations and the printing or indicating of the results of the computations or the further storing of these results are all controlled by the various orders.

A feature of the invention relates to checking and control circuits which prevent the computer from entering and employing a subsequent order before a previously entered order has been fully executed. Other check cir-

cuits are provided to prevent the mechanism from utilizing a fraction of an order thus causing improper operation.

The circuits and apparatus are arranged so that it is necessary to enter a complete order into the mechanism before any portion thereof is executed by the computer mechanism. Upon the satisfactory completion of an order a signal is transmitted to the routine control and sequencing circuits which then causes the next succeeding order to be entered into the control circuits and then executed by the mechanism and so on.

Routine orders in computers heretofore designed comprise a plurality of signals sequentially transmitted. Each of these portions of the order designate or indicate certain information to be acted upon by the control circuits and computing circuits of the computer. For example, such an order may comprise directions to take a value or number from a specified one of a large plurality of registers. The second portion may be employed to condition the calculator to perform any one of the computing functions such as addition, subtraction, multiplication, division or square foot. The third portion of the order may direct the computer to obtain a second number to be entered into the computations from a designated register or source. The fourth portion of the order may be direct disposition of the result of the computations. In order words, this fourth portion of the order may be employed to indicate or designate where the results of the computation are to be stored or transmitted and the last portion of the order may comprise directions to either hold or discard the numbers entering into the computation. Other control functions may also be provided for by different portions of different orders as will appear hereinafter.

In previously constructed computers the various portions of the order have been transmitted sequentially, thus requiring an appreciable time for the execution of these orders.

In accordance with an exemplary embodiment of the present invention the operation of the computer has been materially expedited by simultaneously setting up each of the parts of an order and so far as practical simultaneously executing the various portions of the order. Such an arrangement materially reduces the time required for performing the necessary functions within the computer. By thus speeding the operation of the relay type computer its operating times may be made to compare more favorably with the high speed electronic computation equipment. The simultaneous entering of all of the portions of each order permits a more reliable and speedier check of the operation of the circuits employed in entering the orders in the computer.

A feature of the present invention relates to the means for achieving said more speedier operation of a relay type digital computer, that is, the simultaneous transmission and entering of all of the portions of an order. In the exemplary arrangement set forth herein this means is electronic in nature and comprises a plurality of cold cathode gas discharge tubes. A tube is provided for each different possible instruction of each portion of the order. Each of these tubes has individually associated with it a transformer having a core in the form of a closed loop or configuration such as a toroid. This loop need not be circular as in the case of the toroid but may be elliptical, rectangular or of any other suitable shape. An output winding is wound about the core usually in a distributed manner around the closed loop of the core, although it is not necessarily so wound, and this output winding is employed to control the gas tube. The input circuit comprises a single conductor, which is threaded through the loop of various ones of the cores, and upon the application of an impulse, which in the exemplary embodiment set forth herein is an impulse of alternating current, to this conductor a voltage is induced in the output winding of the cores through which said single conductor is threaded which voltage in turn initiates a discharge through the gas tube individual thereto. The operation of a gas tube operates an order relay which, when a proper number of these relays is operated, causes the routine control circuits to function to execute each of the parts of the order.

A feature of the invention relates to the ease and facility in which the conductor may be threaded through the core loops of the respective cores and then maintained through these cores on a permanent or semipermanent basis or else readily removed and changed.

A feature of the invention comprises circuit arrangements for threading a large plurality of said conductors through the loops of said coils which may be attached to the circuits in a permanent or semipermanent manner and thus the orders may readily be employed to control the computer repeatedly whenever called for.

A feature of this invention relates to formula control equipment which equipment provides for a large number of formulas each of which may select a suitable number and sequence of orders which orders are entered into the computer control circuits and employed to control the operations performed by the computer. Such an arrangement materially reduces the time and effort required to prepare problems for the computer.

A feature of this invention, comprises means for maintaining a large group of said formulas in a mechanism in a permanent or semipermanent basis which formula comprises a library of orders which are repeatedly used and thus checked and known to be accurate. Such an arrangement, therefore, improves the reliability of operation of the computer.

A feature of this invention relates to the control circuits and apparatus for selecting the various formulas.

A feature of these control circuits relates to circuits and apparatus whereby one formula may select a formula of its own level or a formula of another level.

Another feature of this invention relates to control circuits for controlling the selection of the formulas wherein the selection of a formula of a lower level does not cancel the previously selected formula of a higher level.

Another feature of the invention relates to control circuits and equipment interconnected between the various formulas of different levels in which upon the completion of the execution of all the orders of a formula of a lower level the control of the routine circuits of the computer is returned to the formula of a higher level which selected the formula of the lower level and thereafter the execution of the formula of the higher level resumed.

Another feature of this invention relates to the provision of a signal designated herein an $\overline{\text{ENC}}$ signal, which signal is employed to advance the computer mechanism from one phase of the problem to another or from one problem to another. Previously, when it was desired to solve an equation, a series, or some mathematical function for a large plurality of values of the argument, it was necessary to program the computer by indicating the total number of said arguments and then programming the control circuits to count and record or store within itself indicia of the number of computations performed employing the various arguments. Such a programming requires considerable time and effort. This time and effort is greatly reduced in accordance with the exemplary embodiment of the present invention set forth herein because as many different values of the argument may be entered into the mechanism as may be desired and the repetitions of the computations with different values of argument may be repeated an indefinite number of times until the $\overline{\text{ENC}}$ signal is reached at which time the repeated operation of the computer in obtaining computed values of the desired function is interrupted. Such an arrangement in addition to materially reducing the same complexity required to program the computer also permits considerable simplification in the control circuits and other apparatus and equipment required to satisfactorily control the operation of the computer and, as

a result, the reliability of operation of the computer is improved.

A feature of the present invention relates to control and translating equipment for employing a number stored in any of the storage tapes or other storage registers of the computer as one of a large number of different possible formula numbers.

Another feature of this invention is directed to control, time-out and alarm circuits. These circuits together with the routine control circuits are arranged so that if the execution of an order has not progressed beyond a certain point after a predetermined interval of time the routine circuits are all released as well as the calculator circuits and a second attempt is made to execute the order. Inasmuch as many of the difficulties and sources of error in a relay type computer comprise dirty contacts which occur frequently and which tend to clear themselves up a second or subsequent operation of the relay, the use of the second trial feature greatly improves the operation of the computer and renders the results more reliable.

Another feature of this invention relates to the provision of means for executing a plurality of special orders which control various switching and routine circuits whereby the organization of the computer may be readily changed, organized or reorganized for operation upon different types of problems.

Another feature of this invention relates to control circuits for employing two storage tapes to facilitate the solution of certain types of problems.

Another feature of this invention relates to circuits and apparatus and methods controlling the computer from one storage tape and a problem tape.

Another feature of this invention relates to overlap operation when a problem requires the use of only one storage tape whereby a succeeding problem may be entered into the other storage tape while a first storage tape is employed by the computer for the solution of a given problem.

Another feature of this invention relates to control circuits for organizing the routine circuits of the computer in two different manners, one of which causes the problem to be solved in accordance with one set of orders and constituting a program and if a satisfactory solution is not obtained after a predetermined number of operations of the computer mechanism, the computer is arranged to attempt to solve the problem in accordance with another and different set of orders, thus providing alternative solutions. Thus, if one series employed to solve a problem does not converge sufficiently rapidly in one region, an alternative series may be automatically employed by the computer in these regions to obtain a satisfactory answer.

Another feature of the invention relates to a manual control arrangement for causing the operation of the routine control circuits step by step under the control of a plurality of manual keys, thus facilitating the maintenance of the mechanism.

Another feature of the invention relates to means including a manually operable key-set for entering both orders and numbers into the computer.

Another feature of this invention relates to the provision of numerous lamps controlled by the relays of the various circuits of the computer to indicate the progress and position of the various computer circuits at any given time.

A feature of this invention relates to circuits and apparatus for causing the second trial to be made when certain trouble conditions are encountered. When certain operations are started, timing circuits are set into operation. If the operation is not completed within a predetermined time the time-out circuit functions and interrupts certain connections which release the relays of whatever storage they may have progressed to and may operate a message register lamp or other alarm or any or all of such devices and then at a slightly later time close certain other paths for again initiating the operation. If the operation is successfully completed within a predetermined time interval the circuits advance in normal fashion. If the operation is not satisfactorily completed within the predetermined time on the second attempt, then the operation of the equipment is stopped on the problem being solved and the computer advanced to the next problem if another problem is waiting. However, such information as was printed as a result of the previous operation of the computer in solving the problem is available so that the stage at which trouble was encountered may be more readily determined. Inasmuch as many troubles are of transitory nature due perhaps to dirty contacts which troubles clear themselves possibly due to jarring of the relays and relay frames due to the operations of the various relays, the operation of the computer is greatly expedited by such second trial feature.

Another feature of this invention relates to interlocking circuits, apparatus and equipment for controlling the advance of the computer from one stage to another and at the same time permits some overlap in operations. For example, after a number has been read into the printer register the computer is free to execute additional orders and perform other computations while the printer circuit is printing or perforating the number entered into the printing register. However, the second number cannot be entered in the printing register until the printing register has been cleared after a number has been entered therein and recorded by the printer. Similarly, during resetting and hunting operations performed under control of the storage tape control circuits, other orders effecting the hunting circuits cannot be entered or fully executed until the various hunting operations have been completed.

Another feature of this invention relates to control circuits, apparatus and equipment for controlling the calculator section of the computer to condition the calculator section to perform the various types of operations including addition, subtraction, multiplication, division and square root as well as other functions related to recording a number such as round-off operations, shift operations, etc.

Another feature of this invention relates to selective apparatus for responding to switching signals in the problem tape for directing the information entered into the problem tape to the proper elements or circuits of the computer.

Another feature of this invention relates to switching equipment included in the problem tape control circuits for responding to the switching signals and performing the switching operations necessary to direct the orders, numbers and other information entered into the problem tape to the respective component circuits and apparatus of the computer. These switching signals comprise a problem start signal PS, a switch-to-routine signal SWR, a switch-to-printer signal SWP, a perforate A signal PFA, a perforate B signal PFB, a return control signal RC, an end-of-number check signal ENC and an end-of-tape signal ET.

A feature of this invention relates to a third storage tape and related equipment which tape equipment including a perforator and a transmitter thereof may be submitted for at least one of the other storage tapes.

Another feature of this invention relates to a tape storage and transmitting equipment which may be substituted for the problem tape.

Another feature of this invention relates to a tape storage apparatus equipment and control circuits which may be substituted either for another storage tape or for a routine or problem control tape.

Another feature of this invention relates to a storage tape and apparatus which may be employed as a routine control tape and then reset to its initial position or any other predetermined position and again employed as a problem tape for solving the same problem with the same

or different arguments under control of orders entered into the problem tape, formula entered into the computer or orders entered into the special storage tape itself.

Another feature of this invention relates to circuit apparatus and equipment in the computer responsive to special orders for switching a special tape storage apparatus and equipment.

The foregoing and other objects and features of this invention may be more readily understood from the following description of an exemplary embodiment thereof when read with reference to the attached drawings and in which:

Figs. 1 and 2, when arranged with Fig. 2 to the right of Fig. 1, illustrate in symbolic form the various components of an exemplary computer and the manners in which these components cooperate with one another;

Fig. 3 shows the manner in which Figs. 4A, 4B, 5A through 5C, 6A through 6C and 7 through 46 are arranged adjacent one another;

Figs. 4A, 4B, 5A through 5C, 6A through 6C and 7 through 46, when arranged as shown in Fig. 3, show in detail the control circuits of an exemplary computer embodying the present invention;

Fig. 47 shows a table of the symbols and the functions represented thereby of the component parts of orders;

Fig. 48 shows a simple network, the impedance of which it is desired to compute;

Fig. 49 shows the table of the various orders and the response thereto of the computer in computing the impedance of the network shown in Fig. 48 for one frequency and shows the manner of causing the computations to be repeated for each additional frequency desired and printing the results of the computations and finally the advance to another problem when the impedance of the network of Fig. 48 has been obtained for each of the desired frequencies;

Figs. 50 and 51 show the orders and the response of the computer to such orders for solving a high order polynomial equation in one variable;

Fig. 52 shows the manner in which Figs. 53 through 62 are arranged adjacent one another;

Figs. 53 through 62 when arranged as shown in Fig. 52 show detail circuit apparatus and equipment of a typical storage tape control circuit;

Fig. 63 shows the manner in which Figs. 64 through 71 are arranged adjacent each other; and

Figs. 64 through 71 when arranged as shown in Fig. 63 show circuit details and apparatus of the printer control circuit.

As set forth herein the exemplary computer embodying the present invention employs a calculator section of the type disclosed in United States Patent 2,538,636, granted to S. B. Williams, January 16, 1951. In conformity with the showing in that patent and in an effort to simplify the drawing and facilitate understanding of the operation of the exemplary computer described herein the relay windings and the contacts controlled thereby have been separated. In addition each of the make contacts is illustrated by a circle superimposed upon the intersection of two lines representing wires or conductors which are connected together by the operation of the contacts. All other relay contacts are shown in their more conventional form although separated from the relay windings.

In order to further facilitate the reading of the following description, locating equipment on the drawing and understanding the operation of the computer and the component portions of the circuits thereof each of the relays has been given a compound designation, the first portion of which designates the figure number where the relay winding is shown followed by a hyphen which is in turn followed by letters, numbers or combinations of letters and numbers designating a particular relay which designation usually is symbolic of the function or time of operation of the relay.

Relay contacts likewise have been similarly designated with a hyphenated designation of a figure number and a group of letters, numbers or combinations of letters and numbers. These designations are the same as the winding of the relay which causes the contacts so designated to be actuated. Furthermore, since many of the relays have numerous contacts when a circuit is traced through these contacts an additional designation has been applied to them to indicate the specific contacts in question. The first two numerals of this designation will likewise represent the figure number where the contacts appear and the last two numerals will designate the particular contacts of their figure number.

Reference will be made herein to up-check and down-check circuits. A full explanation of said circuits particularly useful in computers will be found in United States Patent 2,486,809, issued November 1, 1949, to G. R. Stibitz. An up-check circuit generally is a series circuit including contacts of every relay involved in the up-check which contacts are closed when each of the respective relays operate. Thus, when the up-check circuit is completed each and every one of the relays included therein must be operated. In the biquinary system used herein the up-check circuit proves that one relay in each binary and one relay in each quinary part of each decimal denomination order has been operated. A down-check circuit likewise is a series circuit involving break and back contacts on each of the relays in the down-check circuit. When this circuit is closed each of the relays involved therein must be released. Consequently, the circuit checks the released or down-check condition of each of the relays involved therein.

As a general principle of operation the computer system works on a checking and interchecking basis. Each component operation must be completed before the control circuits advance to the next step. Furthermore, before any of the register circuits can be employed they are checked to insure that no numbers are recorded in them and a check is often made to insure that when a number is read into any of the register circuits that the number is fully recorded by these register circuits.

General description

The various components of an exemplary computer embodying the present invention is shown in outline form in Figs. 1 and 2 with Fig. 2 positioned to the left of Fig. 1. So many computing stations may be included in exemplary computers in accordance with the present invention as may be required to supply computing problems to be solved by the mechanism.

The exemplary computer described herein embodying the present invention is a general purpose computer which may be employed to solve a wide range of different types of problems. In general purpose computers of the prior art in order to achieve the desired flexibility for solving many different types of problems, it has been necessary to complicate the programming required since substantially all of the operations had to be directed by means of the program or problem information supplied to the computer. Furthermore, each problem of each different type of problem had to be individually programmed, thus requiring a large degree of exacting work by skilled programming experts in order to effectively utilize the capabilities of the computer.

The exemplary computer set forth herein wherein the programming is broken down into many formulas which may be repeated and selected at will greatly simplifies the programming required for any one problem and for any and all different types of problems. This simplification of programming has been achieved in the exemplary embodiment set forth herein without restricting the range of types of problems or complexity of the problem within any type which may be solved with the aid of the computer. By employing the improved control circuits, means, methods and apparatus set forth herein in the ex-

emplary computer, said computer becomes substantially as easy to control, program and manipulate as numerous specific purpose computers in solving the specific problem for which the computer has been designed.

In the following description of an exemplary general purpose computer embodying the present invention, only typical operations are described and the solution of only two limited types of problems is set forth in detail. It, however, should be obvious that a large variety of problems of the two types described herein may be solved with the aid of this computer as well as large varieties of problems of other types.

Thus, network problems of substantially any desired degree of complexity and type may be solved including filter problems, transmission problems, equalizer problems, insertion problems, phase shift or time delay problems and many other types of network problems. As described herein, only one problem involving the solution of a polynomial of high order is described. Many other types of a similar equation may be solved of both high and lower order and described herein, the only difference being the time required to reach a satisfactory solution. Furthermore, the computer is arranged to provide alternate solutions for different portions of a problem or for the entire problem as pointed out with respect to the solution of the polynomial of high order. While only two alternative solutions are programmed for this problem, it is to be understood that any suitable number of different problems providing any alternative methods of solutions may be programmed and the computer arranged to automatically select the various alternate methods in a predetermined order until a satisfactory solution is obtained, all under control of the computer circuits. In other words, for each different set of arguments the computer will attempt to arrive at a solution and if one method fails to give a satisfactory solution in a predetermined time or after a predetermined number of attempts, then the next method is automatically employed without the attention of any attendant or operator. If this solution appears unsatisfactory after a predetermined time or a number of attempts, another alternative method may be automatically employed by the computer, etc.

Likewise, many other types of problems may be solved by the aid of the computer which types of problems comprise matrix equations and problems, continued fractions, power series expansions, power series problems, exponential and logarithmic series expansions and problems computing numerous tables of various mathematical functions including trigonometric functions, logarithms, etc. Continued fraction problems may be solved by the computer as well as any interpolation problems in which the interpolation may be arranged in accordance with any desired formula or formulas. As described herein the computer is arranged to solve many problems employing so-called complex quantities, complex mathematics, complex arithmetic which types of computations are frequently encountered in physical problems. The computer in accordance with this invention may be arranged to compute tables of any or all of the transcendental problems. In solving network problems it has been found advantageous to employ subroutines to consider branches of the network of different types and then other routines to combine the results obtained from the computations of the various branches into a more complicated network. In addition to computing values of sine, cosine tangents, values of the inverse function may be included as well as hyperbolic tangents, inverse hyperbolic tangents and other hyperbolic functions and inverse hyperbolic functions and numerous Bessel functions and the solution of other differential equations.

Two stations **110** and **120** are shown in Fig. 1 with an indication in the station connector circuit **130** of connections for a third station. Of course, additional stations may be provided as may be desired. These computer stations are connected to a station connector circuit **130** which permits only one station to be connected to the computer at one time. Station **110** is shown connected to the station connector circuit by line **111** and station **120** by line **121**. While a single line is shown interconnecting the stations with a station connector circuit, it is to be understood that this line represents numerous individual conductors which conductors may be arranged in one or more cables. The single lines interconnecting other components of the computer as shown in Figs. 1 and 2 likewise represent one or more individual conductors.

The station **120** comprises a printer **122** and a problem tape transmitter **123**. Station **110** likewise comprises a printer **112** and a problem tape transmitter **113**. The printers **112** and **122** are connected over the respective cables of conductors **114** and **124** to the station connector circuit. In addition to the printer stations **110** and **120** and the station connector circuit **130**, the exemplary computer described herein includes a routine control circuit **210**, a formula director circuit **220**, a problem tape control circuit **230**, a printer control circuit **231**, an A tape transmitter **160**, a B tape transmitter **161**, and a C tape transmitter **162**, a storage tape control A circuit **232** and a storage tape control B circuit **233**, a reperforator A designated **150**, a reperforator B designated **151** and a reperforator C designated **152**. The transmitters **160, 161, 162**; the reperforators **150, 151** and **152**; and the storage tape control A circuit and the storage tape control B circuit are provided for perforating information in tapes A, B or C when it is desired to store information in these tapes for a longer period of time than is convenient in various storage registers provided. The reperforators **150, 151** and **152** store information in paper tapes by perforating or punching the tape and the tape is then conveyed or threaded through corresponding tape transmitters **160, 161** and **162**. These tape transmitters are then employed in combination with the tape storage control circuits A and B and the tape storage registers A, **267**, and B, **268**, as described herein.

The printers **112** and **122** in an exemplary embodiment of this invention comprise printing telegraph mechanisms of a known type such as disclosed in United States Patent 1,904,164, granted to S. Morton et al. on April 18, 1933. Likewise, the tape transmitters **113, 123, 160, 161** and **162** may be telegraph transmitters of any suitable type. However, transmitters **160, 161** and **162** have been arranged to move the tape both forward and backward in a manner similar to that set forth in the patent application of O. Cesareo et al., Serial No. 716,754, filed December 17, 1946. The reperforators **150, 151** and **152** likewise are printing telegraph reperforators of any suitable known type such as disclosed in Patent 2,042,788, H. L. Krum, June 2, 1936.

The printers **112, 122** and the reperforators **150, 151** and **152** being telegraph instruments are arranged to be controlled over a single pair of wires. Consequently, it is necessary to provide a transmitter-distributor arrangement for receiving information from the computer and translating this information into series of serially transmitted pulses of the type suitable for operating of printing telegraph mechanisms. The distributor **105** is provided for transmitting information to the printers **112** and **122** of stations **110** and **120** and is connected through the station connector circuit **130** to the appropriate printer. A reperforator transmitter-distributor **106** is provided for transmitting suitable signals to reperforator A, **150**, while a similar distributor **107** is provided for transmitting signals either to reperforator **151** or reperforator **152** under control of a special order switching circuit **131** of the station connector circuit. The special order switching circuit **131** is controlled from a special order circuit **212** of the routine control circuit.

In order to facilitate the checking correcting, editing,

etc., of the problem and other tapes, it has been found desirable at times to print a record of the information in a problem tape and for this purpose a copy printer **170** is provided. The distributor **171** is provided to transmit suitable signals to the printer **170** and the printer-distributor **171** is in turn controlled by a tape control circuit **172**.

The routine control circuit **210** comprises problem keys and control circuits and a start circuit **211**, a progress circuit and a progress order circuit **213**, a special order circuit **212**, a second trial circuit and a second trial equipment **214**. In addition, a computer control and alarm circuit **229** is provided for in part controlling the second trial operation equipment. A formula director **220** is provided which includes selecting and control circuits **221**, impulse generators **222**, a group of formula A circuits **223**, a group of formula B circuits **224**, a group of formula C circuits **225**, a group of formula D circuits **226** and an order relay and code coil translator circuit **227**.

Furthermore, the computer comprises a calculator section **2521** shown at the bottom of Fig. 2 and also in Fig. 25. Furthermore, a designated "Read Formula No." circuit **250** is provided for translating numbers or portions thereof into orders for selecting any desired one of the formulas. Furthermore, a group of storage register circuits A through L is provided of which the storage register circuit A, **251**, and storage register circuit B, **252**, and storage register circuit L, **253**, are indicated in Fig. 2. The storage register circuits between B and L are merely indicated in Fig. 2. These circuits nevertheless are provided in a completely equipped computer. While twelve storage register circuits, A to L, are indicated and provided in an exemplary embodiment of this invention described herein, any suitable number may be provided as may be required by the complexity of the problems to be solved by the mechanism. When desired, a lesser number of storage registers may be provided. On the other hand, for more complicated problems it may be desirable to add additional storage register circuits in similar register circuits shown and described herein.

In addition to the storage register circuits A through L referred to above, a number of fixed register circuits is provided for storing the value of various quantities normally encountered in solving problems. These constant register circuits include a zero storage register **254**, a storage register for storing 1.000 . . . , **255**, a storage register for storing the conversion factor between natural or Napierian logarithms and the logarithm to the base **10** designated **256**, a storage register for storing the value of 2π, **257**, a storage register for storing 0.5 designated **258**, a storage register **259** for storing the value of e, the base of the natural or Napierian logarithms, a storage register **260** for use in computing logarithms for controlling or determining the value of various components of a logarithm, a storage register **261** for storing the conversion factor between the degrees and radian measure, a register **262** for storing page numbers for the A storage tape, a register **263** for storing page numbers for the B storage tape, a block register **264** for storing block numbers for the A tape, a block register **265** for storing block numbers on a B tape, a printer register **266**, a tape storage register A, **267**, and a tape storage register B, **268**.

Briefly, in employing the exemplary computer in accordance with the invention set forth herein the operator or attendant will first prepare a problem tape which is divided into a number of different sections. It is frequently desirable to store information relative to a group of problems in one tape. In order to indicate and recognize the beginning of each problem and the termination of the succeeding problem, problem start signals are entered in the problem tape between problems. In addition to the problem start signal placed in the tape between different problems, various orders are entered in the problem tape to condition the computer for solution of the problem. In another section of the tape, information is entered which information is to be stored in the A tape. Information is entered in another section of the problem tape which information is to be stored in the B tape. This information operates to control the operations of the computer and also the values of the numbers or arguments in the numerous equations, values of physical constants of problems, etc., which are employed by the computer in arriving at a solution of the given problem. Following these values, numerous control orders may also be inserted in the problem tape and these orders employed to control the operation of the computing mechanism as described herein. In addition, orders selecting numerous formulas may be also inserted in this tape as well as special orders as described herein.

In addition to the orders, numbers and other information entered in the various sections of the problem tape as described above the switching and control signals are also entered in the problem tape before and after each of the sections so that the information in each of these sections is properly directed to the proper component parts of the computer. These switching signals comprise first a problem start signal PS, a switch-to-routine SWR, a switch-to-printer SWP, a signal to cause perforation in tape A, PFA, a signal to cause completion by perforator B, PFB, and an end-of-number check signal ENC, a return control signal RC and an end-of-tape signal ET. Thus, when it is desired to organize the computer for a particular problem, a switch-to-routine signal SWR is entered in the tape following the problem start signal PS. Following the switch-to-routine signal, special orders are entered into the problem tape which orders control the switching circuits of the printer. A return control signal is then entered into the tape and followed by a SWP signal. Following this signal the printing information is entered into the tape which information in turn is followed by an RC signal and this signal followed by a PFA signal. The PFA signal is then followed by the section of the tape to be entered into the A tape by the A perforator. In this manner, the various sections of the problem tape are separated by switching signals which are employed to direct the subsequently entered information in the problem tape to the correct component of the computer.

When necessary or desirable a special order or orders may be entered into the problem tape to substitute the C perforator **152** for the B perforator **151** and the transmitter **162** for the transmitter **161**. In order to properly control the circuits of the computer the SWR signal should present the special order or orders and an RC signal follow these orders. Following this RC signal the perforate signal PFB should be entered into the problem tape followed by the information desired to be entered into the C problem tape. Following this information an RC signal is entered into the problem tape and then subject to the switching signals, routine orders and other information entered into the problem tape as set forth herein. The use of the third or C tape in this manner permits the use of three storage tapes to solve the problem and it also permits the use of this C tape as a special routine or formula tape which may be repeated in the solution of the problem as often as desired. The C tape is particularly useful where a particular routine is used infrequently or where the routine is more complicated than can be conveniently entered into the formula section of the computer.

After the operator or attendant has prepared such a problem tape, it is inserted in the tape transmitter at one of the computing stations and a start key operated. Thereafter, when a computer becomes idle this tape transmitter is connected through the station connector circuit **130** to the problem tape control circuit **230**. As shown in the drawing in Fig. 1 a group of make contacts are employed to connect the tape transmitter either to

the problem tape control circuit or to the printer control circuit. These connections are indicated by make contacts in the station connector circuit. It is to be understood that this representation is employed merely to show the paths over which information may be conveyed within the computer and that many contacts are employed for connecting the tape transmitter to any of the related circuits through the station connector circuit **130**. These circuit paths are shown in detail in other figures of the drawing as described hereinafter. Upon the connection of a problem tape transmitter to the problem tape control circuit **230** the problem control circuit causes the tape in the transmitter to be advanced until a problem start signal is encountered after which the problem tape control circuit **230** stops the tape and seeks the first order recorded therein which usually is a special order for conditioning the computer for solving the following problem entered in the problem tape. Certain problems require the use of both the A and B storage tapes and related perforators, control circuits and transmitters. Other problems can be readily solved by the computer with the aid of only one tape storage transmitter. Special orders entered in the problem tape are employed to control and select the particular type of operation desired or required for in the solution of any given problem.

The problem control circuit **230** responds to switching signals or information also recorded in the tape and directs the information entered in the different sections of the problem tape to the proper portions of the computer. For example, the printing instructions are directed through the problem tape control circuit to the printer control circuit and then to the printing distributor A for transmission to the station connected by the station connector circuit **130**. Likewise, the problem control circuit **230** directs the information to be recorded in the A tape through the printer control circuit and the reperforator-distributor **106** to the reperforator **150**. The problem tape control circuit **230** is employed to direct information to the reperforator-distributor B and then to the reperforator B or C in accordance with the setting of the mechanism in response to special orders entered in the problem tape or from some other components of the computer. After the necessary or desired information has been routed from the problem tape to the proper tapes, printers, etc., an RC signal restores control to the problem tape circuit. Then a $\overline{\text{SWR}}$ signal in the tape switches the circuits so that the next information entered in the problem tape is directed to the routine control circuit information which causes five of the order relays **227** to be operated at this time.

Instead of entering all of the information and switching signals in the problem tape as described above, the tapes for the tape transmitters may be prepared by the attendant and then manually inserted in the transmitters when desired.

If the five order relays comprise a valid order, one relay in each of five groups of relays will be operated. Thereafter, the order set up on the order relays is employed to control the computer after which another order from the problem tape or from some other components of the computer will be conveyed to the order relays **227**. Numerous alarm and timing circuits and lamp circuits are provided to aid an attendant to discover the condition of the mechanism at any instant of time at which the trouble may occur. This computer and alarm circuit is designated in Fig. 2 by the number **229**.

The computer in accordance with an exemplary embodiment of the present invention is controlled by orders, each order comprising five parts. In general, the first portion of the order comprises a direction or designation of a place to look for a number. A second portion of the order specifies the operation to be performed. A third portion frequently identifies the location of another number entering into the computation. The fourth part of the order indicates where the result of the computation is to be stored, printed or transmitted. The fifth part of the order indicates whether or not the numbers entered into the computation are to be retained or discarded and whether or not certain other ancillary functions are performed.

In accordance with an exemplary embodiment of this invention each order is simultaneously entered upon a group of order relays **227**. By simultaneously entering these orders upon these relays an appreciable operating time is saved and in addition it is possible to readily check that the portions of the order are properly entered. If the circuits do not properly respond to the order or if the orders are improperly entered the equipment is arranged to time-out, actuate an alarm, and stop, make a second trial, or go on to another problem as will be described herein.

In the exemplary embodiment set forth herein means have been provided for entering orders upon the order relays **227** in different manners from different sources. Orders may be entered upon the order relays from the problem tape under control of the problem control circuit **230** and the routine circuit **210**. The computer is also arranged so that orders may be entered upon the order relays from the problem keys **221** through the progress circuit **213** of the routine control circuit **210**. Orders may also be entered upon the order relays **227** from any one of the formula levels **223**, **224**, **225** or **226**.

Inasmuch as it is necessary to store the orders and to transmit them through the circuits of the computer as pointed out above, it is necessary to represent the various components of the orders by electrical signals or symbols in code form. In the tape transmitters and printing and perforating equipment each portion or symbol of an order is represented by a plurality of perforations across the tape or by a plurality of pulses transmitted to the printer or reperforator. In order to readily check and thus insure proper operation of the equipment the first four elements of an order are represented by any three out of six perforations across the tape. Such codes are sometimes called "three out of six" codes. The final portion of the order is represented by codes having four perforations out of six in the tape. Thus, it is easy to distinguish the end of each order in the tape and the circuits have been arranged to respond only to the four out of six perforations in the fifth position in the order.

Numbers are likewise represented on the storage tapes by three out of six perforations in the tape. In other words, the identity of the digit or numeral of each denominational order of a number is represented by a row of perforations across the tape in which three out of six different positions may be punched or perforated.

The calculator mechanism, however, is arranged to employ code representations of numbers of the so-called biquinary code arrangements described in the Williams patent identified herein directed to the calculator portion. It is, therefore, necessary to provide translators for translating codes representing a given number or symbol or portion of an order from one code to another, both upon entering numbers from a tape transmitter to the tape storage registers for later transmission to the calculator. Also in transmitting information from the calculator and other registers to the reperforators **150**, **151** and **152** and also to the printers **112** and **122**, it is necessary to again translate the biquinary representing numbers or other information to the codes employed by the printers or reperforators. However, when the problem is initially entered into the computer from the problem tape, the codes employed in the problem tape transmitter are the same as those employed in the A storage tape and the B storage tape and the C storage tape so that in this case no translation is required between the codes representing numbers, orders, etc. transmitted from the problem tape transmitter **113** or **123** to any of the reperforators **150**, **151** and **152** and from these reperforators through the tapes to the corresponding storage tape trans-

mitters **160**, **161** and **162**. However, when information from the problem tape is employed to set up orders, it is necessary to translate the code used in the problem tape to representations of the various portions of the order and to direct the various portions of the order to the proper relays of the order relays **227**.

The progress circuit **213** provides both of these translating and steering functions. Thus, orders entered in the problem tape transmitter **113** are transmitted over conductors **111** to the station connector circuit and through actuated relay contacts **132** to the problem tape control circuit **233**. The problem tape control circuit switches the tarnsmission path from the station connector circuit to the progress circuit via the operated contacts **233** where the various codes representing the elemental portions of an order are translated into indications of the specific function or information of that portion of the order and then the resulting translation steered to the proper group of order relays **227**.

The order relays **227**, after having an order entered upon them checked, actuate numerous control contacts and initiate the operation of other portions of the progress circuit which complete the execution of each of the functions or information of each portion of the order. The progress circuit **213** in executing the orders makes numerous checks upon the various circuits employed in executing the order. It ascertains that the control circuits for the various registers are all released, that the circuits operate properly, that the circuits are properly restored to their normal or idle condition and that the result of the computations is properly stored in the designated register or other place.

Upon the satisfactory completion of each portion of the order the progress circuit then causes the problem tape control circuit to advance and scan the next order in the problem tape. If the problem tape specifies a formula then upon the entering of this order upon the order relays **227** the progress circuit is conditioned to execute the order and cause the proper formula of the formula director circuit to be selected and set up. In so selecting and setting up a formula, all previously selected formulas of a lower level are cancelled and any previously selected formula in the particular level selected also cancelled. Upon the restoration of the selecting relays of the formulas of the same and lower levels the circuits are advanced and the progress circuit cleared of the order. Thereafter, the orders called for by the formula circuit are entered upon the order relays **227**.

If, for example, a formula of the A formula level **223** is selected then all of the previously selected formulas of levels B, C and D as well as level A are discarded and the various orders incorporated into the particular formula selected and employed to control the computer. Any of the formulas of the A level may select any other formula of any other level and if the selected formula is in a lower level, namely, B, C or D under the assumed conditions, the A formula is not discarded but the operation of the A formula level circuits is merely arrested on the step which selected the formula of a lower level. Then the computer is controlled from the newly selected formula which may advance through all of its stages or steps or it may select another formula. Upon the completion of all the steps of a selected formula the control of the computer mechanism is returned to the formula level which caused or ordered the selection of the particular formula in question and this formula will then advance through additional steps until the problem is completed. These additional steps may include a formula for reselecting itself or for selecting any other formula necessary or desirable to complete the problem.

When the orders originate in the formula control circuits they are entered simultaneously, in part by means of electronic tubes and input transformers which are arranged so that the various orders of any given formula are entered into the computer in a readily changeable manner but nevertheless on a semipermanent basis.

Each of the order relays is provided with an electronic tube in combinaton with an input coil. The core of input coil comprises ferromagnetic material in the form of a toroid or has a configuration of a closed loop of one form or another either with or without an air-gap.

The secondary or input winding is connected to the input or control element or elements of the tube and is wound about the core. The actuating or input winding comprises a single conductor threaded through the center of the closed loop of the core. Upon the selecting of any such conductor each of which is extended through five of said coils to select the five elements of the order, a pulse of alternating current is transmitted over this primary or conductor threaded through the cores. As a result, sufficient voltage is induced in the secondaries of the coils through which the conductor is threaded to apply a sufficient voltage to the tube so as to actuate the relay associated therewith and thus have entered upon it the element of the order.

While the control information for the computers follows the paths described above, the numerical information is transmitted over different paths. The numerical information from the problem tape transmitter such as transmitter **113** is transmitted over conductors **111** to the station connector circuit **130** and operated contacts **132** and **133** to the problem control circuit **230**. As pointed out hereinbefore, contacts **132** and **133** as shown in Fig. 1 in the station connector circuit **130** actually represent a large number of contacts as is apparent from an examination of the detailed circuits shown hereinafter. From the problem tape control circuit, however, the numerical information sometimes called arguments and new problems or equations is transmitted differently from the orders. Instead of contacts **233**, shown in Fig. 2 which represent a large group of contacts directing the orders or information to the progress circuit **213**, contacts **234** direct the information to the printing distributor **105** and then to the printer **112** through the operated contacts **134**. This information causes the printer to put the proper heading to the results of the problem and the proper heading to the various tables and any additional information which it may be desired to have the printer print along with the results of the computations. The information to be stored in the A tape by reperforator **150** is transmitted from the problem tape and through the problem tape control circuit through the operated contacts **235** to the perforator-distributor **106** and reperforator **150** which cause the desired information to be punched or perforated or otherwise stored in the A tape. Likewise, the information to be recorded in the B tape is transmitted through the operated contacts **236** and the perforator-distributor **107** and then to the perforator **151** through operated contacts **135** which stores the information in the B tape. In case it is desired to store information in the C tape from the problem tape, substantially the same path is employed except that contacts **136** are employed instead of contacts **135** for connecting the reperforator **152** to the perforator-distributor **107**. As pointed out hereinbefore, the passing of the information from the tape transmitter such as **113** to either the A tape, the B tape or the C tape requires no translation since the same code is used for recording all of this information. From A to the B or the C tapes the numbers are transmitted through the respective tape storage control circuits **232** and **233** to the respective tape storage registers **267** and **268**. As shown in Fig. 2 the various storage registers are interconnected among themselves and to the calculator section **2521** by means of two cables or sets of conductors. One set of conductors is designated the X multiple and the other set the Y multiple. Thus, when it is desired to transfer a number from the storage tape register A the number entered in this register may be transmitted to other

registers over either the X or Y multiple. Numbers may also be transmitted over either of these multiples from the register to the calculator section. Likewise, the numbers recorded in the B tape control the B transmitter **161** which causes information to be transmitted through the storage tape control B circuit **233**, then to the storage tape register B. As pointed out herein it is necessary in transferring the information from either the A storage tape or the B storage tape to the respective tape storage register **267** or **268** to translate the codes employed to represent the information.

While as described herein information is transmitted from the problem tape through the problem tape control circuits to the A tape storage register, the B tape storage register or the C tape storage register it should be noted that this information may be perforated in control tapes which are manually inserted in any of the transmitters **160**, **161** or **162** in substantially the same manner as the problem tape is inserted in the problem tape transmitter such as **113** or **123**.

In controlling the transmission or transfer of information from any of the storage tape transmitters, provision is made to select the desired information. In order to aid and facilitate the selection of the desired storage information the information stored in the A tape, the B tape or the C tape may be given both page and block numbers. When it is desired to select a particular portion of the tape the corresponding page and block numbers are entered into the respective page and block registers and then an order selected which establishes a connection from the corresponding page and block registers to the storage tape control circuit which causes the computer to advance or reverse the movement of tape through the transmitter in search of the proper page and block registers. When these are found the proper number is transferred to the storage tape register A, **267** or storage tape register B, **268** depending upon which of the A, B, or C storage tapes is being used at the time. When it is desired to set any of the A, B or C tapes, therefore, it is only necessary to set the proper page and block numbers in the corresponding page and block registers and then order the computer to reset or control the movement of the tape in the transmitter until the corresponding page and block numbers recorded in the tape are found by the tape transmitting mechanism.

During the computation of a problem when a number is obtained from either the A or the B storage tape registers **267** or **268** by means of an order which causes the corresponding register to be cleared, the register is cleared as directed and in addition the movement of the tape is initiated so that the next number stored in the tape is transferred through the tape storage control to the tape storage register A so that it will be available when called for by the computer circuits. In this manner, the number may be transmitted from either the A or the B tape to the corresponding tape storage register while other orders are being executed and computations are being performed by the calculator section.

When it is desired to either print or store any one of the three tapes A, B or C, the results of any of the calculations of the desired number to be recorded are entered into the printing register **266** which register then causes the printer control circuit **231** to be actuated. When the printer control circuit **231** first translates each of the codes of a number from a biquinary to a code employed to operate the telegraph mechanism and then transmits these codes in succession from the printer register circuit, it is to be noted that all of the numbers are transmitted substantially simultaneously over both the X and Y multiples but that as stored in the various tapes each one of the characters or symbols must be stored separately and in sequence. Consequently, part of the translating equipment employed for translating the various numbers as set forth herein must include steering circuits for directing each of the portions of the orders and numbers to the appropriate relays and terminal equipment. From the steering and control relays of the printer control circuit the desired information is transmitted either to the proper printer through the printer-distributor 195 and the related contacts and the information to be recorded by the reperforator is likewise transmitted to the switching equipment of the printer control circuit 231 to either one of the reperforators **150**, **151** or **152**. Provision has been made so that upon the entering of the number in the printer register **266**, the printer control circuit **231** is set into operation which causes the proper distribution or transmission of the number element by element in the manner set forth herein. Meantime, the remainder of the computer circuits is released so that they may be performing other computations. If, however, the second order to print immediately follows or follows a short interval of time later before the number previously stored in the printer register has been recorded either by the printer or the perforators, the operation of the computer is stopped until the orders are entered in the proper positions within the computer.

Calculator

The exemplary computer in accordance with this invention described in detail herein employs a calculator of the type shown in Patent 2,538,636, granted to Williams, January 16, 1951. The numerical information is supplied to the computer over an X multiple and a Y multiple and the results of the computation are received from the calculator over the X multiple. A computer in accordance with an exemplary embodiment of this invention provides improved arrangements for controlling the supply of information to the calculator and for controlling the storing of the information received from the calculator. Thus, while the computer in accordance with the present invention employs a calculator disclosed in said Williams patent, it does not employ the control, programming, and other circuits, or the same combinations of these circuits as disclosed in said above-identified Williams patent.

In addition to supplying the numerical information to and receiving the numerical information from the computer as set forth in the above-identified Williams patent other control leads extend to and from the computer. These control leads comprise means for controlling the calculations to be performed by the calculator which calculations may comprise addition, subtraction, multiplication, division, and extracting a square root.

The calculator as disclosed in said Williams patent employs a biquinary code for representing the identity magnitude of the numerals in each of the denominational orders of the numbers employed in the computer. The calculator is arranged so that the numbers are all entered with the decimal point before the first significant figure as in said patent to Williams together with the proper exponent. A separate calculating section is controlled by the exponent in the same manner as described in said above-identified Williams patent which calculating section also controls a shift section to properly shift the significant figures to their proper denominational order prior to performing the ordered calculations. The use of a separate calculator controlled by the exponent to shift the decimal point is sometimes referred to as employing a floating decimal point. Thus in entering numbers in the calculator employed in the present computer it is necessary to enter the sign of the exponent, the magnitude of the exponent, which magnitude is assumed to be between plus and minus 19 thus requiring two denominational orders, the sign of the number and the magnitude of each of the denominational orders. The calculator is arranged to record numbers having a maximum of ten denominational orders or positions.

In order to reduce the time required to transfer num-

bers, all of the above information is conveyed substantially simultaneously over the X and Y multiples consequently, each of the X multiples and Y multiples comprises a large plurality of leads. The sign of the number requires two leads, the sign of the exponent requires two leads, the code representing the identity or magnitude of the digit in the tens denominational order of the exponent requires two leads, the units denominational order of the exponent requires seven leads since it is represented by a biquinary code and each of the tens denominational orders of the number also requires seven leads. In other words, each of the X and Y multiples comprises at least, 83 leads total for transferring numbers to and from the calculator section of the computer.

Inasmuch as the numbers and other information required to be supplied to the computer for solving a problem is perforated in the tape of the type frequently employed in automatic telegraph transmission wherein various symbols, numerals for the various denominational orders of the number or other instructions are represented on the perforated tape by means of a six-element code which codes are sometimes referred to as permutation codes, three-out-of-six, four-out-of-six, etc., it is necessary to provide a translation for translating from the code on the order tape and the information supplied to the computer. A similar translation is required in order to supply information from storage tapes within the computer to the calculator. Likewise, the circuits are arranged to print or record the answer by means of a printing telegraph mechanism, such as a teletypewriter which mechanisms employ a five-element permutation code, or five-element binary code. Consequently, it is necessary to again translate the biquinary code of the calculator to the code of the printing telegraph mechanism when it is desired to record or print a result from the calculator. In addition when it is desired to register routine orders from a problem tape or from the storage tapes, it is again necessary to translate the codes employed in these tapes and to indications representing the orders.

The various translators employ relays which have their contacts arranged so that when the appropriate combinations of the relays of the translator are operated, they will provide the desired corresponding translated code over circuits extending from their contacts.

In addition, the various so-called up-check and down-check circuits disclosed and discussed in said above-identified Williams patent are also incorporated in the calculator employed in the exemplary computer embodying the present invention. These check circuits are employed to check the fact that the relays of the computer and registers thereof are ready and in condition to properly respond to electrical signals representing the numbers to be entered in or upon the various relays prior to actually applying the various electrical signals to the relays. In other words, the down-check circuit is completed or open as the case may be only if all the relays involved are released and the up-check circuit is completed or open only if the proper relays involved therein are operated. Other types of checking circuits are employed to insure the proper operation of both the calculator portion of the computer as well as the control portions thereof.

The calculator is represented in Fig. 2 and is shown in greater detail in Fig. 25 and comprises a number of component registers and other equipment similar to that shown in Fig. 2 of the above-identified Patent 2,538,636, granted to S. B. Williams, January 16, 1951. Briefly, this calculator comprises a pair of exponent registers **2504** for receiving the exponent portion of a number from the X multiple and register **2507** for receiving the exponent portion of a number in the Y multiple. In addition the X register **2503** is provided for receiving the numerical portion of a number from the X multiple and register **2506** is provided for receiving the numerical portion of the number from the Y multiple. An ancillary adder is also provided for adding, or subtracting or otherwise responding to the exponent portions of the numbers. This ancillary adder comprises exponent A register **2513**, exponent B register **2511** and a Z register **2514** in which the result of the computations of the ancillary adder are registered. The output of the Z register is employed to supply the exponent portion of the results of the computation over the X multiple when the computation has been completed and also to control shift relays **2515** which relays are employed to shift the numbers recorded in the X register **2503** and Y register **2506** so that the decimal point will be properly aligned for addition. In other words, the shift relays are employed to shift the numbers so that the tens denominational order of one number is added to the tens denominational order of the other number.

The main adder comprises the A register **2517**, B register **2519** and a C register **2520**. The transfer of numbers within the calculator as well as control of the adding and subtracting, rounding off and other functions which include adding, subtracting, multiplying, dividing and extracting of square root are all performed in a manner described in said above-identified patent to S. B. Williams 2,538,636. Briefly, the calculator responds to control signals received for connecting the calculator to the X and Y multiples and also for controlling the types of computations performed by the calculator and for controlling the supply of the result of the computation to the X multiple.

Fig. 2 of Williams is a flow diagram showing an X multiple **2500** and a Y multiple **2501**. There is an ARX relay for connecting the X multiple to the X register **2503** and the exponent X register **2504** and likewise an ARY relay for connecting the Y multiple into the Y register **2506** and the exponent Y register **2507**. In order to illustrate the invention and particularly in connection with Figs. 4 to 25, inclusive, it will be shown how the number 1.234567 will be transmitted over the X multiple to be added to the number 123.4567 transmitted over the Y multiple. The first of these numbers in computer notation will be +1234567+01 and the second of these numbers will be +1234567+03. Therefore, the figure 01 will be registered in the exponent X register **2504** and the figure 03 will be registered in the exponent Y register **2507**. As soon as these numbers have been registered a circuit will be extended from a ground from the exponent X register and the exponent Y register to operate the YLA relay **2509**. The YLA relay means that the exponent in the Y register is larger than the exponent in the X register and this relay will fundamentally control the further transmission of numbers. Thus, with the YLA relay **2509** operated the exponent in the X register will now be transmitted through the contacts **2510** to the exponent B register **2511** and the number in the exponent Y register will be transmitted through the contacts **2512** into the exponent A register **2513**. The exponent A register constitutes the augend means and the exponent B constitutes the addend means of the ancillary number calculator and in accordance with the number registered therein a result will be summed into the Z register **2514**. This result will primarily operate the shift relays **2515** whereby the number +1234567+1 is shifted until it appears to be +00123456+03.

The number 1234567 in the Y register is now connected through the contacts of the YLA relay represented by the contact **2516** to the A register **2517** of the adder and the sum 1234567 in the X register **2503** is transmitted through the contacts **2518**, thence through the shift relays **2515** so that it is registered in the B register **2519** as 00123456. The numbers in the A register **2517** and the B register **2519** are now summed into the C register **2520** as 12469126. When this sum has been taken, an auto-

matic operation known as the round-off takes place. This consists of adding 5 to the extreme right-hand digit (the eighth significant place) so that if the value in this is less than 5 no carry to the next place will occur but if the value in this place is 5 or more a carry 1 will increase the next to the last right-hand digit by this amount. In the present case this round-off operation will derive the following sum:

12469126
00000005
12469131

It will be noted that the calculator is of that type known as a two-cycle calculator. The first sum having been taken through the contacts of the A and B relays and registered in the C register the sum produced on round-off is taken through the contacts of the A and C registers and registered in the B register.

A correction in the exponent may now be made. Since the number registered in the exponent A register is always the larger, then a sum is taken in the ancillary number calculator adding to this number registered in the exponent A register the number of places by which the first significant digit of the sum in the B registers is displaced to the right or subtracted therefrom the number of places by which this first significant digit is displaced to the left. In the example given, since the sum exactly lines up with the number originally placed in the A register the value 0 will be added to the value 3 in the exponent A register so that the Z register will now contain the value 3 which will be read out along with the number derived and registered in the B register. The numbers in the B register and the exponent in the Z register may now be read out through the RD relay into the X multiple where this result may be transmitted to any given point. This number, by way of example, may be transmitted into the printer register and decimal point locator wherefrom it may be translated and printed or recorded.

As another example of the correction made in the ancillary number register the number 1000000+03 may be subtracted from the number 1234567+03 whereupon the result derived will be 0234567+03 (from a mathematical standpoint). However, the number 03 will be registered in the exponent A register but since the first significant digit of the result 2 is from a columnar standpoint one place to the right, 1 will be subtracted from the figure in the exponent A register so that the Z register will have the value 2 registered therein. This will be read out into the X multiple as the value 02 and at the same time the result 2345670 will be read out into the X multiple in such a way that the digit 2 in the B denominational order of the calculator will be read into the A denominational order of the X multiple to be registered in the A denominational order of any register into which it is transmitted.

Again, if the number 9000000+03 is added to the number 1234567+03 the derived result is 10234567+03 (from a mathematical standpoint). However, since a significant figure now appears in a column 1 to the left of the first significant figure of the addend then the value 1 will be added to the value 3 in the exponent A register and the value transmitted from the Z register will be +04. In like manner, this will also control the transmission of the number 10234567 from the W, A, B, C, D, E and F orders of the calculator into the A, B, C, D, E, F and G orders of the X multiple for registration in any register to which the X multiple may at this time be connected.

Storage register

As set forth herein a group of twelve storage registers A through L is provided for temporarily storing numbers to be used by the calculator section as well as by other sections of the computer. In addition, the number of fixed constant registers such as shown in Figs. 2 and 22 are employed to record permanently certain constants used repeatedly in the solution of the types of problems frequently encountered in the fields in which the calculator is designed to operate. In addition, a page and block register for both the A and B tapes is provided as well as a storage tape register for each of the tapes and a printing register.

Inasmuch as the control circuits for the relay storage registers A through L are typical of each of the registers, the operation of one of these registers will be described in detail. It is to be understood that similar control circuits are provided for each and every one of the other registers and that these registers cooperate with the routine control circuits, the X and Y multiples and other circuits in substantially the same manner. The differences in the case of a tape storage register and the printer register are described herein.

Fig. 21 shows the circuit details of a typical one of relay storage registers and is assumed to be the A storage register.

The storage register such as shown in Fig. 21 comprises four groups of relays. It comprises a group of control relays such as **21**A and **21**B which relays are employed to extend circuits from the routine control circuit into the register circuit. The register also comprises a group of switching or read relays **21**–EUR and **21**–AR through **21**–JR and **21**–RY. The operating circuit for these relays extends through the closed contacts of either relay **21**A or relay **21**B. The operation of relays **21**–EUR, **21**–AR through **21**–JR is employed to connect the storage relays to the X multiple so that a number can either be read into or out of the register over the X multiple when these relays **21**–EUR, **21**–AR through **21**–JR are operated. When relay **21**–RY is operated the number stored in the register is read out on the Y multiple. Relay **21**–YR is arranged to apply ground to one contact of the pairs of contacts controlled by each of the storage relays which are employed to read out the number on the Y multiple.

A group of seven storing relays is required for storing the identity or magnitude of the symbol for each of the denominational orders of the number. In addition, a group of seven relays is required to store the units or lowest denominational order of the exponent and a group of six relays employed to register the sign of the number, the sign of the exponent and the tens digit of the exponent.

In addition, a locking relay **21**–LK is provided for interrupting the locking path of the storing relays for storing the number. Thus, when it is desired to clear the register of a number, it is necessary to operate the locking relay **21**–LK. As shown in the drawing the winding of relay **21**–LK extends to the routine control circuits through operated contacts of either relay **21**A or **21**B.

In addition to the above relays, circuits, and contacts provided in the register circuit, down-check and up-check circuits are provided. For example, a down-check circuit is provided through a break contact on relay **21**A and a break contact on relay **21**B together with break contacts on each and every one of the other relays corresponding to relays A and B in the various registers. This circuit is shown at the top right-hand corner of Fig. 21. While all of the relay contacts for all of the registers are indicated or shown in a chain circuit of contacts shown in the upper right-hand corner of Fig. 21, it is to be understood that the various relays are located in the respective register circuits.

A down-check circuit shown in the left-hand portion of the drawing is provided for each of the register relays. This circuit is completed by and extends through either of the operated contact **2107** or contact **2120** of relay **21**A or **21**B. If any one of the relays fails to close the above circuit and thus fails to release, a trouble alarm is sounded so that the nature of the trouble can be determined. In

addition, an up-check circuit is provided which extends through make contacts in series on each relay of each of the groups of relays and this series circuit from one group of relays extends through the next so that if a proper number of relays in each group or subgroup is operated the up-check circuit is completed which up-check circuit extends through the operated contacts of relay 21A or 21B to the routine control circuits as described herein. In this up-check circuit one of the two binary relays and one of the five quinary relays must operate in each denominational order to complete this up-check circuit. In addition, a group of alarm contacts is provided as shown in the middle column on the left-hand end of Fig. 21. These contacts are arranged in a circuit such that if both of the exponent zero and exponent tens conductors become grounded an alarm is sounded and the presence of the difficulty brought to the attention of the operator or maintenance people. These contacts are shown in the middle column of contacts in the right-hand portion of Fig. 21. These contacts are arranged so that if more than the required number of relays in any group or subgroup is operated, i. e., both binary relays or any two of the quinary relays of any denominational order, an alarm signal is sounded and the operation of the system stopped.

Before starting the execution of any order, the release condition of all the A and B relays is checked and then in case of an idle register the release condition of each one of the register relays is checked. Also the response of a register to reading a number into it is likewise checked. Each one of these checks transmits a signal back to the routine control circuit to indicate that the check has been satisfactory or unsatisfactory and to sound an alarm when unsatisfactory and stop the entire computing mechanism.

Station connector circuit

As shown in Figs. 1 and 2 and also in Figs. 4B and 5B, provision has been made to operate the computer from a plurality of control stations. Each of these control stations is provided with a tape transmitter referred to herein as the problem tape transmitter and also the printer on which the results of the computations are printed. In addition, various control keys and lamps may be provided at each of the stations as may be desired.

Inasmuch as it is desired to control the computer from a plurality of stations, it is necessary to provide a station connecting circuit for connecting the various stations to the computer when it is desired to enter a problem from the respective control stations. In general, when it is desired to initiate the operation of the computer from any control station the problem tape is first prepared and this tape is then inserted in the problem tape transmitter located at the control station and then a start key also located at this station operated.

Thereafter, the circuits operate substantially automatically and independent of further attention of an attendant or operator at either the control station or at the computer.

Since it may be attempted to enter a problem from each or all of the control stations substantially simultaneously the station connector circuit which is shown in Figs. 5A, 5B and 5C is arranged so that the control stations are connected in a fixed sequence or preference. For example, control station 1 is always connected if it has any problems awaiting solution. If station 1 has no problems awaiting station solution, then station 2 is connected and finally with neither station 1 nor station 2 having problems awaiting connection or awaiting solution and station 3 having such problems, then station 3 will be connected.

While only three stations are shown or indicated in the drawings, it is to be understood that as many control stations may be provided as may be desired or convenient.

Figs. 4A and 4B show certain of the equipment located at the control stations as well as tape storage apparatus located at the computing station. Printer 4A–100 is located at station 1, printer 4A–200 is located at station 2 and printer 4A–300 is located at station 3. The problem tape transmitter 4B–100 is also located at station 1. The corresponding problem tape transmitters at stations 2 and 3 have not been shown in Fig. 4A or 4B but are further shown and indicated in Fig. 1. Likewise, the necessary connections to these stations are indicated in Fig. 5B which are similar to the connections of the problem tape transmitter 4B–100. In addition to the printer 4A–100 and the problem tape transmitter 4B–100 a group of keys including start key 5C–01, copy key 5C–02 and the release key 5C–03 are also provided at station 1. Similar keys are provided at stations 2 and 3 to connect to corresponding relays at these stations.

When it is desired to enter problems from station 1 the problem tape is prepared and inserted in the transmitter 4B–100 and then the start key 5C–01 is operated at station 1. The operation of key 5C–01 completes an obvious circuit for the operation of relay 5B–STM1 from ground through the operated contacts of key 5C–01, the break contacts 5B–01 to battery through the winding of relay 5B–STM1. Relay 5B–STM1 in operating closes its locking contacts and completes circuits for maintaining itself operated under control of break contacts of relays 5C–CT1 and 5B–INCT and under control of relay 14–06 and release key 5C–03. If it is desired to enter problems from the other control stations the corresponding relays 5B–STM2, 5B–STM3, etc., are likewise operated.

The sequence or preference circuits for connecting the various stations to the computer in predetermined order as described above are shown at the left-hand portion of Fig. 5C.

Assume for purpose of illustration that the computer is normal and not operating at the time the tape is inserted in the problem tape transmitter 4B–100 and that the key 5C–01 is operated. Under these circumstances, relays 14–06, 14–06B and relay 8–RCN are released with the result that ground is applied to the PG lead which extends from Fig. 14 through Figs. 13, 10, 9, 8, 7, 5B to 5C and then through the operated contacts 5C–01 of relay 5B–STM1, the break contacts 5C–02 of relay 5C–CT2, contacts 5C–03 of relay 5C–CT3 to battery through the winding of relay 5C–CT1. Relay 5C–CT1 in operating closes an obvious locking circuit for maintaining itself operated under control of contacts of relay 5B–STM1 and opens contacts 5B–03 of relay 5C–CT1, thus interrupting one of the locking circuits for relay 5B–STM1.

If relay 5B–STM2 had been operated instead of relay 5B–STM1 then relay 5C–CT2 would operate providing, of course, that relay 5B–STM1 is released. If both relays 5B–STM1 and 5B–STM2 are released and relay 5B–STM3 operated, then relay 5C–CT3 would operate. In other words, relays 5C–CT1, 5C–CT2 and 5C–CT3 are operated in the above order when a plurality of the relays 5B–STM1, 5B–STM2, 5B–STM3 are operated. Likewise, suitable interlocking circuits are shown so that in case any one of the relays 5C–CT1, 5C–CT2 or 5C–CT3 is operated the operation of these relays interrupts locking circuits for the other relays, thus insuring that the other relays release so that any one of the relays 5C–CT1, 5C–CT2, 5C–CT3, etc., may remain operated. Furthermore, the operating circuits of each of these relays go through break contacts of others of these relays and so long as any one of them is operated the others of these relays cannot operate.

Assuming now that relay 5C–CT1 operates and actuates contacts 5C–04 which interrupt the locking circuits for relays 5C–CT2 and 5C–CT3. In addition, the operation of relay 5C–CT1 closes contacts 5B–01 which contacts complete an obvious circuit for operating relay 5B–1A. Relay 5B–1A in operating closes contacts 4A–01 which contacts connect the printing distributor

4A–02 to the printer 4A–100 at station 1. The operation of relay 5B–1A also actuates contacts 4A–03 which contacts remove a short-circuit or holding ground from the printer, thus permitting the printer to receive signals transmitted to it from the printing transmitter-distributor 4A–02 under control of the printer control circuit as described herein. Likewise, the operation of relay 5B–01 causes the left-hand group of contacts in the center of Fig. 5B to be operated which contacts connect the various leads extending from the problem tape transmitter 4B–100 to the conductors 5B–02 which conductors extend to the problem control circuit. In a similar manner, had one of the other relays 5C–CT2 or 5C–CT3 been operated, then the respective relays 5B–2A or 5B–3A would operate and connect the corresponding printer and tape transmitters, respectively, to the printing distributor 4A–02 and the tape transmitter to the problem tape control circuits. When it is desired to release the connection from a control station either the release key 5C–03 is operated or relay 14–06 is operated. The operation of either the key 5C–03 or relay 14–06 interrupts the locking circuit of relay 5B–STM1, thus permitting this relay to release and in turn release relay 5C–CT1 and relay 5B–1A, thus restoring the station control circuit to its normal or idle condition. Thereafter, the station control circuit works as described above and connects any of the other stations in predetermined order which have problems awaiting solution entered into them.

Problem control circuit

The operation of relay 5C–CT1 in the station connector circuit as described above or the operation of either of the other connecting relays 5C–CT2 or 5C–CT3 in the sequence circuit shown in Fig. 5C will close one of the respective contacts 6A–01, 6A–02 or 6A–03 and then complete an obvious circuit for the operation of the start relay 6A–STA.

The operation of the 6A–STA relay completes an obvious circuit for the operation of the 8–ST relay and the 8–ST1 relay shown in Fig. 8 from battery through the windings of these relays and the operated contacts of the 6A–STA relay to ground through the break contacts 801 of the 14–TRCY relay.

As set forth herein, numerous "down-check" circuits are provided to insure that the various relays are released and the equipment is in its normal condition before the computer will accept and compute a new problem or new functions or steps within a given problem or solution. The machine is first set into operation as assumed above when the start key 5C–01 is operated and the 6A–STA relay is operated. If the relays are all normal and the equipment is in condition to accept the instructions and numerous numbers required in the solution of a problem, numerous relays are operated by the down-check circuits. For example, if there is no alarm condition registered in the alarm circuit, the alarm check relay 8–ALN will be operated to the operated contacts 802 of the 8–ST relay to ground through a down-check circuit of numerous relays in the alarm circuit indicating that no alarm is registered in the alarm circuit. Likewise, if the storage tape control circuits are normal, the relay 8–TCBN will be operated in a similar circuit extending through normal contacts in the storage tape control circuit. Likewise, a relay 8–PTN will be operated in a similar down-check circuit extending through the contacts of relays of the printer control circuit. Similarly, relays 8–PCN, 8–CCN and 8–TCAN will be operated in similar down-check circuits extending respectively through the problem tape control circuit, the calculator circuit and the storage tape control circuit.

A typical down-check circuit for at least a portion of the routine control circuit is shown in detail in Figs. 8 and 12 for the operation of relay 8–RCN which circuit extends from battery through the winding of the 8–RCN relay to ground through the operated contacts 803 of the 8–ST1 relay, the normal contacts 804 of the 8–ST4 relay and through a series circuit extending through break contacts of each of the relays 11–UP5, 11–UP4, 11–UP3, 11–UP2, 11–UP1, 12–CT1, 12–CT2, 12–CT4, 11–STE1, 11–STE2, 11–STE3, 11–STE4 and 11–STE5. If all of the above relays are normal or unoperated, then relay 8–RCN operates in the above-described circuit indicating that at least a portion of the routine control circuit is in its normal condition. The operation of the above-described relays in their respective down-check circuits completes a circuit for the operation of relays 8–ST3 and 8–ST4 which circuit extends from battery through the windings of these relays to ground through operated contacts 805 through 812, inclusive, and the operated contacts 813 of start relay 8–ST. The operation of relay 8–ST3 completes a circuit for the operation of relays 7–RG and 7–RG1 from battery through the winding of relay 7–RG, through the break contacts 704, contacts of relay 1409 and also from battery through the winding of relay 7–RG1 and then through the operated contacts 701 of the 8–ST3 relay, through the break contacts 702 of the 7–RCY1 relay to ground through the operated contacts 703 of the 8–ST1 relay.

Assume further for purpose of illustration that the computer had previously been turned off so that relays 17–11 and 17–13 are released. Consequently, upon the operation of relay 8–ST1, contacts 1704 will close and complete circuits from ground through contacts 1704 and normal contacts of relays 17–11 and 17–13 over the respective conductors PCI and SCI which conductors extend to Fig. 5B and cause the operation of relays 5B–SCI and 5B–PCI. The operation of relay 5B–PCI closes the contacts shown in the middle row across Fig. 6A which contacts extend the conductors of cable 5B–02 which conductors are connected through the operated contacts of relay 5B–1A to the conductors from the problem tape transmitter 45–100 to the control relays shown across the lower portion of Fig. 6A.

Relay 5B–SCI likewise connects the conductors extending from the B storage tape transmitter 4C–200 to conductors extending to the B tape control circuit.

The operation of relay 8–ST4 as described above closes contacts 8–15 which contacts complete a circuit for the operation of a high speed hunting relay 6A–HSH from battery through the winding of relay 6A–HSH, the break contacts 6A–01 of relay 6A–SSC, the break contacts 6A–02 of relay 6A–AC3 to ground through the operated contacts 8–15 of relay 8–ST4. The operation of relay 6A–HSH connects the contacts of the problem tape transmitter 4B–100 to scan the tape at high speed and also prepares circuits for operating the start or clutch magnet of this transmitter.

The composition of the problem tape inserted in the problem tape transmitter 4B–100 usually includes the following sections which take the following form:

(A) A section of blank tape, i. e., unperforated tape sufficiently long to permit the tape to be readily inserted in the problem tape transmitter without any perforations other than feed perforations appearing over the sensing pins of the tape transmitter.

(B) Several $\overline{PS}$ symbols. These symbols are problem start symbols and a sufficient number of these symbols is usually punched or perforated in the tape to permit problem identification symbols to be written on the tape alongside or adjacent these perforations. The problem start signal $\overline{PS}$ comprises a code in which a zero position is perforated or punched.

(C) An $\overline{SWR}$ signal which signal is employed to switch the problem tape to control the routine control circuits. This symbol has perforations in every position except in No. 4 position.

(D) Control data usually in the form of orders for conditioning the computer for different types of routine control codes for use with different types of problems.

Orders may also be inserted in this section of the tape for resetting the storage tapes and otherwise conditioning the computer for solving the following problem.

(E) An $\overline{RC}$ code which is employed to restore control of the problem tape transmitter to the problem tape control circuits and disconnect the connection between the problem tape transmitter and the routine control circuits previously established by the $\overline{SWR}$ signal. The $\overline{RC}$ signal comprises perforations in all of the positions of the tape except in No. 1.

(F) An $\overline{SWP}$ symbol which is employed to switch the problem tape transmitter to control the printer.

(G) Data to be printed including the heading of the problem, the heading of any columns to be printed as well as any other data desired to be printed with the solution of the various steps of the problem.

(H) Another $\overline{RC}$ symbol to interrupt the connection between the problem tape and the printer control circuit. This symbol employs the same code as the $\overline{RC}$ signal described above.

(I) The $\overline{PFA}$ symbol which is employed to connect the problem tape to the printing control circuit for transfer of data from the problem control tape to a storage A tape. The $\overline{PFA}$ symbol or code comprises a perforation in all of the positions except in No. 3.

(J) Information and data to be employed by the computer which is to be stored in the storage A tape for the solution of a given problem. The first data entered into the problem tape at this time and transferred to the A storage tape is usually the formula number required to solve the problem or a portion thereof.

A "tape argument check" signal $\overline{TAC}$ is employed after page and block numbers.

A number check code $\overline{NC}$ is employed after each number to indicate the end of the number.

The $\overline{ENC}$ code is employed to advance the computer from one group or type of computations to another group or type of computations or from one phase of the solution of a problem to the next phase of the solution.

(K) Another $\overline{RC}$ symbol as above to interrupt the connection between the problem tape transmitter and the printing control circuit.

(L) A $\overline{PFB}$ symbol which is employed to connect the problem tape transmitter to the printer control circuit for conveying data from the problem tape to the B storage tape. The code of this symbol comprises a perforation in every position across the tape except the No. 2 position. This code is used in the above-described manner only in case two storage tapes are employed to solve the problem.

(M) Data to be transmitted to the B tape which is similar to the data which may be transmitted to the A tape and includes the values of the arguments and other numerical information required to solve the problem.

The information transmitted to both the A and B tapes may be divided up into sections separated by either or both page and block numbers to aid in the hunting and finding various sections and information recorded in the respective tapes.

By use of special orders as described herein the C tape and related equipment may be substituted for the B tape and information similarly recorded in the C tape in a manner similar to the manners information is entered in the A and the B tapes.

(N) Another $\overline{RC}$ signal to interrupt the connection between the problem tape transmitter and the printer control circuit.

(O) Another $\overline{SWR}$ signal to switch the problem tape transmitter to the routine control circuit.

(P) Frequently computer orders to start the operation of the computation of the problem are included in the tape. Additional orders may also be included to specify suitable formula when desired.

(Q) Another $\overline{RC}$ signal to interrupt the above connection between the problem tape transmitter and the routine control circuits.

(R) A group of $\overline{PS}$ signals to indicate the start of a new problem.

(S) The above series of symbols are entered into the tape as required by the next problem. Many problems may be entered into a tape as may be desired.

The tape control readers or transmitters such as **4B–100** are so arranged that they come to rest with the clutch magnets such as **4B–CH** released. In the rest or stop position, all of the pins are permitted to rise and sense any tape that may be in the transmitter. In addition, both the auxiliary contacts **4B–02** and the universal contacts **4B–01** are closed. The transmitter is released by operating the clutch magnet and upon operation of the clutch magnet the transmitter shaft is released and rotated by means of a motor, not shown. During the first portion of the rotation of this shaft the auxiliary contacts open, then the universal contacts open and then the fingers are withdrawn from the tape causing the tape controlled contacts to be all actuated to their spacing position. Thereafter, the tape advances and then the fingers are again permitted to rise and sense the next row across the tape. The auxiliary contacts reclose at about the same time that any of the contacts **0** through **5** close when permitted to do so by a perforation or punch in the tape. At a little later interval of time the universal contacts close and then the transmitter comes to rest.

Thus, when the tape is inserted as described above, the pins are depressed since a blank section of tape is inserted over the pins. Consequently, when the high speed hunting relay **6A–HSH** operates, the circuit for the clutch magnet **4B–CH** is completed from battery through the clutch magnet winding **4B–CH** over lead **22** which extends through the station connector circuit and in particular through contacts of relays **5B–1A** and through contacts of relay **5B–PCI**, contacts **6A–06** of relay **6A–HSH**, conductor **29** to the tape transmitter, through the auxiliary contacts **4B–02** of the tape reader **4B–100**, over conductor **30**, through contacts **6A–07** of relay **6A–HSH**, break contacts **6A–08** of relay **6A–AC3**, operated contacts **6A–09** of relay **6A–HSH** and over lead **7** to the tape transmitter and then through the normal contacts of the zero reading pin and then over lead **24**, through the operated contacts **6A–10** of relay **6A–HSH** and then to ground through the operated contacts **8–15** of relay **8–ST4**. Ground is also connected from conductor **24** through the universal contacts **4B–01** to conductor **23** which causes relay **6A–UC** to operate at this time.

The operation of the clutch magnet **4B–CH** at this time releases the tape reader or transmitter which in turn causes, first, the auxiliary contacts **4B–02** to release and release the clutch magnet **4B–CH**. Next, the universal contacts **4B–01** release and then the tape pins are withdrawn. However, since all of the tape control contacts were maintained in the spacing position the circuits remain in the above-described condition. Then the tape is advanced one position or one row and the sensing fingers released and permitted to rise and sense the perforations in the tape. So long as no perforations appear over the sensing fingers all of the tape control contacts remain in their spacing or normal condition as shown in the drawing. Consequently, as the auxiliary contacts followed by the universal contacts close the above-described circuit for operating the clutch magnet **4B–CH** is completed causing this magnet to operate and release the transmitter shaft for further rotation. With the high speed hunting relay **6A–HSH** operated, the circuits are arranged to hunt for a PS code. In other words, a code having a perforation only in the zero position. In order

to by-pass all other codes, contacts 6A–11 of relay 6A–HSH connect the armature of the No. 5 tape control contact with the back or break contact of the No. 4 tape control contacts. Similarly, contacts 6A–12, 6A–13, and 6A–14 of relay 6A–HSH connect the break or spring contact of each of the tape control contacts with the armature of the next high number tape control contacts. Contacts 6A–15 of relay 6A–HSH connected the front or marking contact of the 0 tape control contacts with the armature of the 1 tape control contacts. Consequently, so long as or when a no perforation is found in the zero position in the tape the circuits are operated as described above. If a perforation is encountered in the zero position in the tape and a perforation is present in another position in the tape, then upon the closure of the universal contacts as the reader or transmitter approaches the stop position a circuit is again completed for the operation of the clutch magnet 4B–CH. Under these circumstances, the circuit extends from ground through the operated contacts 8–15 of relay 8–ST4, the operated contacts 6A–10 of relay 6A–HSH and lead 24 through the universal contacts 4B–01, the operated zero tape control contacts and then over conductor 1 and through contacts 6A–15 of relay 6A–HSH, back over conductor 14 to the armature of the No. 1 tape control contacts. If this contact is operated to its marking position due to a contact finger arising through a perforation or a punch in the tape, ground will be connected to the No. 2 lead and then through contacts 6A–16 of relay 6A–HSH and then through the break contacts 6A–08 of relay 6A–AC3, operated contacts 6A–07 of relay 6A–HSH, conductor 30 to the tape transmitter, through the auxiliary contacts 40–02, conductor 29, the operated contacts 6A–06 of relay 6A–HSH and then over conductor 22 to battery through the winding of the clutch magnet 4B–CH, thus causing the operation of this magnet under these circumstances. If the tape control contact 1 is normal but some other one or ones of these contacts is operated, then the circuit for operating the clutch magnet 4B–CH will extend from the armature and break contact of each of these normal contacts through the above enumerated contacts of relay 6A–HSH to the first one of these tape contacts which are operated and then over conductor 2 and over the above-described circuit. Thus, each time the universal contacts close as the transmitter approaches the rest or stop position, the clutch magnet is reoperated if there is no zero perforation in the tape over the sensing fingers when they are releaased prior to the stop position. Likewise, the circuit for the clutch magnet is closed when the universal contacts close if there is a perforation in the zero position in the tape and also a perforation in any other position of the tape over the reading pins. Under all of these circumstances the clutch magnet is again operated and the tape advanced to the next position.

Under the assumed conditions after all of the blank portion of the tape has been thus by-passed and passed out of the transmitter, the sensing pins will sense the first of the PS codes with the result that the zero pin will pass through a perforation in the tape and actuate its armature to its marking position while each of the remaining tape sensing contacts 1 through 5 is maintained in its spacing position by the unperforated tape above the corresponding tape sensing pins. Under these circumstances with the tape control contacts 1 through 5 maintained in their spacing position as shown in the drawing and the zero control contact actuated to its marking position as the tape transmitter 4B–100 approaches its rest position and the universal contacts 4B–01 close, a circuit will be completed for the operation of relay 6A–AC2 which circuit extends from battery through the winding of relay 6A–AC2, back contacts 6A–17 of relay 6A–AC3, conductor 12 and then through a series circuit of the break contact of the tape control contacts 5, contacts 6A–11 of relay 6A–HSH, normal tape control contacts 4, contacts 6A–12 of relay 6A–HSH, normal contacts 3 of the tape reader, contacts 6A–13 of relay 6A–HSH, normal contacts 2 of the tape reader 4B–100, operated contacts 6A–14 of relay 6A–HSH, normal contacts 1 of the tape reader 4B–100, contacts 6A–15 of relay 6A–HSH, the operated contacts 1 of the tape reader 4B–100, over lead 24 and the operated contacts 6A–10 of relay 6A–HSH to ground through the operated contacts 8–15 of relay 8–ST4.

The operation of relay 6A–AC2 closes contacts 6A–18 and 6A–19. The closure of contacts 6A–18 connects ground to the right-hand winding of terminal of relay 6A–AC3, thus providing a locking circuit for relay 6A–AC2. However, relay 6A–AC3 does not operate at this time because it has ground connected to both of its winding terminals.

The closure of contacts 6A–19 applies ground from contacts 8–15 of relay 8–ST4 through break contacts 6A–28 of relay 6A–AC3 and operated contacts 6A–07 of relay 6A–HSH to lead 30 and then over the above described circuit extending to the clutch magnet 4B–CH. The clutch magnet operates in the above circuit causing the reader to advance and advance the tape. Under the assumed conditions, additional problem start signals or codes $\overline{PS}$ will be encountered in the tape with the next rotation of the tape distributor 4B–100. Shortly after the beginning of the rotation of the reader mechanism at this time the universal contacts open and remove the ground connected to conductor 24 from the above-described operating path of relay 6A–AC2 with the result that relay 6A–AC2 remains operated and relay 6A–AC3 operates in series with relay 6A–AC2.

The operation of relay 6A–AC3 actuates a number of contacts including contacts 6A–05. The actuation of contacts 6A–05 interrupts the circuit of the high speed hunting relay 6A–HSH, thus permitting this relay to release and the release of relay 6A–HSH opens the numerous contacts controlled by this relay and described herein and thus interrupts the above-described circuits for operating the clutch magnet 4B–CH.

In addition, the release of relay 6A–HSH closes contacts 6A–20 which contacts together with the actuation of contacts 6A–05 complete circuits for the operation of relay 6A–SSC and 6A–STG which circuits extend from battery through the windings of these relays, the normal contacts 6A–20 of relay 6A–HSH, the operated contacts 6A–05 of relay 6A–AC3 to ground through the operated contacts 8–15 of relay 8–ST4. Thus, the release of the high speed hunting relay and the operation of the slow speed control relay as described above interrupt the above-described circuits for high speed hunting for PS or problem start signals and rearranges the circuits for testing and reading each row of perforations in the tape which perforations may be used to control the circuits described herein.

As the shaft of the transmitter-distributor continues to rotate after the universal contacts 4B–01 open as described above the tape sensing pins are withdrawn and the tape advanced and these pins released. Under the assumed conditions there will now be entered over the sensing pins a second problem start code. Consequently, as the tape reader approaches a stop position, the zero tape control contact will be actuated while the remaining contacts are maintained in their normal or spacing condition. In addition, the auxiliary contacts and the universal contacts also close.

Relay 6A–SCC in operating, for example, closes contacts 6A–30 through 6A–36, inclusive, which connect the operating windings of relays 6A–0 through 6A–5 and 6A–NO to the tape control contacts of the tape reader or transmitter 4B–100. The operating winding of relay 6A–0 is connected to the armature of the zero contact of the tape reader while relays 6A–1 through 6A–5 are connected to the front contacts of the No. 1 to No 5 tape

control contacts and the operating winding of relay 6A–NO is connected to the back contact of the zero tape control contact of the tape reader 4B–100. In addition, relay 6A–UC is connected to one terminal of the auxiliary contacts 4B–01. The operation of relay 6A–SCC also closes numerous other contacts for interconnecting the circuits from the tape reader or transmitter 4B–100 with the relays of the problem control circuit shown in Figs. 6A, 6B and 6C as described herein.

The operation of relay 6A–SCC also closes contacts 6A–27 which contacts connect the winding of relay 6A–AC through contacts 6A–26 of relay 6A–AC1 to conductor 29 extending through the auxiliary contacts 4B–02 to the station connector circuit as described herein.

The operation of relay 6A–STG as described above in response to the operation of relay 6A–AC3 closes contacts 6B–01 which contacts apply ground to a down-check circuit through break contacts on each of the code relays 6A–5′ through 6A–0′, and on relay 6B–ALM, and on relays 6A–AC and 6B–RC and through two sets of break contacts of relay 6B–STP to battery through the winding of relay 6B–DW. Relay 6B–DW operates in the above-described circuit and applies locking ground from the operated contacts 6A–22 of relay 6A–STG to the locking contacts of the code relays 6A–0 through 6A–5 and 6A–NO. The operation of relay 6B–DW also actuates contacts 6A–21 which contacts apply ground to a number of the contacts of a number of the relays as shown in Fig. 6A. For example, the actuation of contacts 6A–21 completes a locking circuit for maintaining relay 6B–DW operated under control of relays 6B–STP and 6A–STG independent of the contacts in the above-described chain or down-check circuit.

In addition, the operation of contacts 6A–21 of relay 6B–DW applies ground from contacts 6A–22 of relay 6A–STG through the operated contacts 6A–21 and break contacts 6A–23 of relay 6A–AC1 through the operated contacts 6A–24 of relay 6A–SSC to the conductor 24 extending through the universal contacts 4B–01 of the tape reader 4B–100.

The circuits now remain in this condition until the tape reader or transmitter 4B–100 approaches a rest position. Of course, if the transmitter should arrive at its rest position prior to the operation of relays 6A–SSC and 6B–DW, the circuits will operate as described hereinafter as soon as the relays 6A–SSC and 6B–DW operate.

However, assuming that these relays operate prior to the tape transmitter or reader 4B–100 reaching a stop position, as the transmitter mechanism 4B–100 approaches the stop position the tape control contacts are first positioned in accordance with the perforations over the sensing or reading fingers at that time and then the auxiliary contacts close at about the same time. The closure of the auxiliary contacts at this time completes a circuit for the operation of relay 6A–AC from battery through the winding of relay 6A–AC, the break contacts 6A–25 of relay 6A–AC1, the operated contacts 6A–27 of relay 6A–SSC, conductor 29, auxiliary contacts 4B–02, conductor 30, contacts 6A–28 of relay 6A–SSC to ground through the operated contacts 6A–21 of relay 6B–DW and the operated contacts 6A–22 of relay 6A–STG. Relay 6A–AC in operating closes contacts 6A–37 which contacts prepare an operating circuit for relay 6A–AC1 and a locking circuit for relay 6A–AC. Relay 6A–AC1, however, does not operate at this time because it has ground connected to both of its winding terminals. A short interval of time later the universal contacts 4B–01 close and complete circuits for the operation of relays 6A–0 through 6A–5 and 6A–NO under control of the setting of the tape control contacts and also for the operation of relay 6A–UC. A circuit for the operation of relay 6A–UC extends from battery through the winding of relay 6A–UC, conductor 23 extending through the station connector circuit and the closed universal contacts 4B–01, conductor 24 and then through the operated contacts 6A–24 of relay 6A–SSC, the break contacts 6A–23 of relay 6A–AC1 to ground through the operated contacts of relay 6A–21 of relay 6B–DW and contacts 6A–22 of relay 6A–STG.

Under the assumed conditions no problem start signal PS will be over the reading or sensing pins at this time which signal has a perforation in the zero position. Consequently, the zero tape control contacts will be actuated to a marking position while the remaining tape control contacts 1 through 5 will be maintained in the unoperated or spacing condition. Consequently, the operation of the auxiliary contacts as described above completes a circuit for the operation of relay 6A–0. The remaining code relays 6A–1 through 6A–5 remain released. The circuit for operating relay 6A–0 at this time extends from battery through the left-hand operated winding of relay 6A–0 through the operated contacts 6A–30 of relay 6A–SSC and over conductor 1 through the operated 0 tape control contacts to ground through the operated universal contacts 4B–01 over conductor 24 of the circuit path traced above. At this time, ground from conductor 23 extending to the winding of relay 6A–UC as described above which causes the operation of relay 6A–UC also extends through the operated contacts 6A–25 and over lead 2 to the front contacts of the tape control contacts 6A–1 through 6A–5. Since none of these contacts are closed under the assumed conditions this ground does not extend to any of the other code relays 6A–1 through 6A–5.

Relay 6A–0 in operating closes its locking contact for maintaining itself operated under control of relays 6B–DW and 6A–STG to the respective contacts 6A–38 and 6A–22. The operation of relay 6A–0 also closes contacts 6A–39 which contacts complete a circuit for the operation of relay 6A–0′.

The operation of relay 6A–UC closes contacts 6A–40 which contacts complete a circuit for the operation of the clutch magnet 4B–CH in a circuit extending from battery through the winding of the clutch magnet 4B–CH, over lead 22 extending to the station connector circuit, the operated contacts 6A–41 of relay 6A–AC, break contacts 6A–42 of relay 6A–AC1, operated contacts 6A–40 of relay 6A–UC, operated contacts 6A–21 of relay 6B–DW and contacts 6A–22 of relay 6A–STG. The operation of the clutch magnet 4B–CH releases the distributor mechanism which then rotates and first causes the auxiliary contacts 4B–02 to open and remove the short-circuit from around the winding of relay 6A–AC1 which relay operates and locks operated in series with relay 6A–AC. Relay 6A–AC1 in operating opens contacts 6A–42 thus releasing the clutch magnet.. Relay 6A–AC1 in operating also opens contacts 6A–23 which contacts partly open the circuit applying ground to conductor 24. A short time interval later when universal contacts 4B–01 open, relay 6C–UC releases and removes ground from conductor 24, thus removing ground from the universal contacts and also the tape control contacts. The tape transmitter nevertheless advances to the next stop position. In advancing to the stop position the tape fingers are first retracted and then the tape advanced and the fingers then released to sense the next row of perforations in the tape. As the transmitter approaches the stop position, both the auxiliary and universal contacts close as well as the tape control contacts. However, due to the operation of relay 6A–AC1 as described above the closure of these contacts does not cause any of the other relays to operate or the circuits to function unless and until additional relays function as will now be described.

In response to the closure of contacts of relay 6A–0′ as described above, a circuit is completed through contacts 6C–01 of relay 6B–RTC, contacts 6C–02 of relay 6B–RB, contacts 6C–03 of relay 6B–RA, contacts 6C–04 of relay 6B–PRT, contacts 6B–05 of relay 6A–1′, contacts 6C–06 of relay 6A–2′, contacts 6C–07 of relay 6A–3′, contacts 6C–08 of relay 6A–4′, contacts 6C–09 of relay

6A–5′, contacts 6C–10 of relay 6A–NO and operated contacts 6C–11 of relay 6A–0′ through the break contacts 6B–05 of relay 5B–INTC, contacts 6C–04 of relay 6B–SPD to battery through the winding of relay 6C–STP. Relay 6B–STP operates in the above-described circuit and interrupts the operating and locking circuits for relay 6B–DW with the result that relay 6B–DW releases and releases relays 6A–AC, 6A–AC1 if operated and 6A–UC and removes the locking ground from the winding of relay 6A–0. The release of relay 6A–0′ in response to the release of relay 6A–0 as described above interrupts the above-described circuit for the operation of relay 6B–STP with the result that this relay releases and again completes the above-described down-check circuit for the operation of relay 6B–DW which circuit extends from ground through contacts 6B–01 through the down-check circuit above-described to the winding of relay 6B–DW.

The reoperation of relay 6B–DW again completes a circuit for maintaining itself operated as described above and also completes a circuit for applying ground to the conductor 24 extending to the tape control transmitter contacts. Thus, when these contacts reclose and when the universal contacts close, the above-described circuits for operating these various relays are again completed with the result that the clutch magnet is reoperated and the above cycle of operations repeated. This cycle of operations is again repeated each time a problem start signal is sensed over the sensing pins of the tape transmitter.

Assume now that all of the problem start signals PS have been discarded in the above-described manner. Upon the sensing of the last one of these signals the operation of the tape clutch magnet and the operation of relay 6B–STP, the release of relay 6B–DW and the reoperation of relay 6B–DW, the circuits are conditioned as described above with ground applied to the conductor 24 extending through the universal contacts 4B–01 of the tape reader or transmitter 4B–100 and the winding of relay 6A–AC connected to conductor 29 extending through the auxiliary contacts 4B–02 of the tape reader or transmitter 4B–100. At this time the tape transmitter in advancing will retract the sensing pins as described above and then advance the tape to the next perforation which is assumed to be an $\overline{\text{SWR}}$ signal. Thereafter, the tape reading or sensing pins are released and they are actuated against the tape. In this case the perforation will appear on each of the pins except pin No. 4 with the result that the tape control contacts 0 through 3, inclusive, and 5 are actuated to their marking position while the No. 4 contact is maintained in its spacing position. A short time later the auxiliary contacts 4B–02 close and complete the above-described circuit for operating relay 6A–AC. Thereafter, the universal contacts 4B–01 close and apply ground to the armature of the zero tape control contacts and to the front contacts of the 1 through 5 tape control contacts. The circuits for applying ground to these contacts are the same as described above with reference to sensing the PS codes. Consequently, circuits are completed for operating relays 6A–0, 6A–1, 6A–2, 6A–3 and 6A–5 which relays in turn complete their locking circuits for maintaining themselves operated under control of contacts 6A–38 and 6A–22 of the respective relays 6B–DW and 6A–STG. The operation of these relays in turn completes obvious circuits for the operation of relays 6A–0′ through 6A–3′, inclusive, and 6A–5′.

The operation of the universal contacts 4B–01 also completes the above-described circuit for operating relay 6A–UC. The operation of relay 6A–UC closes contacts 6A–40 which contacts complete the above-described circuit for operating the transmitter clutch magnet 4B–CH, thus releasing the transmitter or reader 4B–100. As a result, the transmitter is set into operation and the auxiliary contacts 4B–02 open, first removing a short-circuit from around the winding of relay 6A–AC1 as described and permitting this relay to operate and lock in series with relay 6A–AC. The operation of relay 6A–AC1 actuates contacts 6A–42 and interrupts the operating circuit of the clutch magnet 4B–CH with the result that the transmitter mechanism stops when it comes to the next stop position.

A short interval of time after the auxiliary contacts 4B–02 open, the universal contacts 4B–01 open and remove ground from the tape control contacts and thus interrupt the operating circuits of relays 6A–0 through 6A–3, inclusive, and 6A–5. These relays do not release at this time, however, because they are maintained operated due to ground flowing through their locking winding and contacts as described herein. When the universal contacts 4B–01 open they also interrupt the operating circuit of relay 6A–UC which relay opens contacts 6A–43 and removes ground frfom the conductor 24 extending to the universal contacts 4B–01.

A short interval of time after the universal contacts 4B–01 open, the tape sensing pins are withdrawn from the tape, the tape is advanced and the sensing pins again released to sense the tape. Shortly thereafter the auxiliary contacts reclose and then the universal contacts reclose after which the transmitter or reader is stopped in a stop position. At this time the code in the tape following the SWR code is sensed by these contacts. However, until the circuits operate as described herein the SWR code remains entered upon the code relay 6A–0 through relays 6A–5, 6A–0′ and 6A–5′.

The operation of relay 6A–AC1 together with the release of relay 6A–UC as described above when the transmitter advances after having sensed the SWR code completes a circuit for the operation of relay 6B–RTC which circuit extends from battery through the winding of relay 6B–RTC to the break contacts 6B–06 of relay 6B–ALS and then through operated contacts 6B–07 of relay 6A–5′ and then through operated contacts of relays 6A–3′ 6A–2′, 6A–1′ and 6A–0′ to the GI lead and then through the break contacts 6B–08 of relay 6A–4 which relay is normal at this time since no perforation appears in the fourth position for the SWR code, through the break contacts 6B–09 of relay 6B–RC, the break contacts 6B–10 of relay 6A–UC, contacts 6B–11 of relay 6A–AC1 to ground. Relay 6B–RTC in operating closes contacts 6B–12 which contacts connect ground through the break contacts 6B–13 of relay 6B–RC1 to the upper winding of terminal of relay 6B–RTC1. Relay 6B–RTC1, however, does not operate at this time because ground is connected to both of its winding terminals.

The operation of relay 6B–RTC completes a circuit for the operation of relay 6B–STP which circuit extends from battery to the winding of relay 6B–STP through the break contacts 6B–04 of relay 6B–SPD, the operated contacts 6B–14 of relay 6B–RTC, the break contacts 6B–15 of relay 6B–RTC1 to ground through the operated contacts 6B–16 of relay 6A–0′ which relay is operated at the present time because a perforation is present in the zero position for the SWR code. Relay 6B–STP in operating interrupts the operating and locking circuits of relay 6B–DW, thus permitting this relay to release which relay in turn interrupts the locking circuits for relays 6A–AC and 6A–AC1 which relays thereupon release. The release of relay 6B–DW also opens contacts 6A–38 which contacts interrupt the locking circuit for relays 6A–0 through 6A–3 and 6A–5, thus permitting these relays to release and in turn release relays 6A–0′ through 6A–3′ and 6A–5′. These release of relays 6A–0′ through 6A–3′ and 6A–5′ interrupts the above-described operating circuit for relay 6B–RTC. Consequently, the ground is removed from the center or common connection between the windings of relays 6B–RTC and 6B–RTC1 with the result that relay 6B–RTC1 operates in series with relay 6B–RTC and maintains relay 6B–RTC1 operated.

The operation of relay 6B–RTC1 closes contacts 6B–17 and completes an obvious circuit for the operation of relay 6B–RTC2. Relay 6B–RTC2 in operating in turn closes contacts 6B–18 and completes an obvious circuit for the operation of relay 6B–ALS. The operation of relay 6B–ALS transfers all of the code leads SWR, SWP, PFA and PFB to the winding of relay 6B–ALM. Consequently, if a second switching code such as PS, SWR, SWP, PFA or PFB is received before a restore code RC is received the alarm relay 6B–ALM is operated indicating a trouble condition which also causes the computer to stop until the trouble is cleared.

The operation of relay 6B–RTC1 closes contacts 6C–12 through 6C–17 and connects the contacts 6B–20 through 6B–25, inclusive of the code relays 6A–0′ through 6A–5′, inclusive, of the code relays 900 through 905 of the translating and steering circuit of the routine control circuits.

The operation of relay 6B–RTC1 also closes contacts 1120 for the operation of relay 11–STG. A circuit for the operation of relay 11-STG extends from battery to the winding of relay 11-STG, the break contacts 1104 and 1103 of relay 8–MF, the operated contacts 1120 of relay 6B–RTC1, the operated contacts 804 of relay 8–ST4 to ground through the series down-check circuit which comprises a break contact on each one of the relays of the steering circuit shown in Figs. 8, 9, 11 and 12. When these relays are all normal indicating that the equipment is in condition to respond to signals, relay 11–STG operates and closes contacts 1201. The closure of contacts 1201 completes a circuit for the operation of relay 12–CT1 from battery through the winding of relay 12–CT1, the normal contacts 1202 of relay 11–UP1, the operated contacts 1201 of relay 11–STG to ground through the series down-check circuit comprising a break contact on each one of the code relays 900 through 905. The operation of relay 12–CT1 completes a circuit through its locking contacts 1203 for maintaining itself operated under control of contacts 1205 and 1204 of relays 11–UP1 and 11–STG, respectively. Relay 12–CT1 in operating completes an obvious circuit for the operation of relay 11-STE1 which relay extends the translating contacts of relays 900 through 905 to the first column of order relays of Fig. 46. The operation of relay 12–CT1 also closes contacts 906 which apply ground to the translating contacts of relays 900 through 905 so that upon the operation of these relays one of the relays of the first column in Fig. 46 will be operated.

The operation of relay 6B–RTC1 as described above also actuates contacts 65–15 which contacts interrupt the operating circuit of relay 6B–STP, thus permitting relay 6B–STP to release and restore the operating circuit of relay 6B–DW to the down-check circuit through the code relays 6A–0′ through 6A–5′. If all of these relays are released in response to the above-described operation of relay 6B–DW, relay 6B–DW will again be operated at this time. It should be noted that if the relays 6A–0′ through 6A–5′ are released the relays 900 through 905 will also be released so that both the down-check circuit for operating relay 6B–DW and the down-check circuit for operating relay 12–CT1 as described above will be completed, thus indicating that all of the equipment is now in condition to record a first portion of an order. The operation of relay 6B–DW at this time again completes a circuit for maintaining itself operated as described above and also applies ground to conductor 24 extending through the universal contacts of the tape reader and connects ground to lead 30 extending through the auxiliary contacts of the tape reader 4B–100.

If the tape reader has not reached its stop position or has not closed the universal and auxiliary contacts and the tape control contacts by the time relay 6B–DW operates, the circuits wait until this reader closes these contacts. If, however, the reader or transmitter 4B–100 has reached its stop position then the operation of relay 6B–DW causes the circuits to operate as described hereinafter. In either event the combined operation of relay 6B–DW and the closure of the auxiliary contacts 4B–02 complete a circuit described herein for the operation of relay 6A–AC which relay partially prepares a circuit for the operation of the clutch magnet 4B–CH and also prepares a circuit for maintaining itself operated and for the operation of relay 6A–AC1 when the auxiliary contcats 4B–02 open as described hereinafter.

The combined operation of relay 6B–DW and the operation of the universal contacts 4B–01 apply ground to the tape control contacts of the reader or transmitter 4B–100 and thus complete circuits for the operation of the code relays 6A–0 through 6A–5 in accordance with the perforations in the tape over the sensing fingers. At this time the code over these sensing fingers will be the code following the SWR code. For purpose of description, assume that the order T F 0 7 $\overline{HH}$ is the order next in the problem tape following the SWR signal. This order would not normally immediately follow an SWR signal but assume that it does, for purpose of describing the operation of the system. If the above order is assumed to follow the SWR signal or code in the tape then the T symbol or code with a perforation in the 0, the 4 and the 5 positions will be above the sensing pins of the tape reader 4B–100. Consequently, relays 6A–0 and 6A–4 and 6A–5 will operate at this time upon the application of ground to the tape control contacts through the universal contacts 4B–0. These relays lock operated under control of relay 6B–DW and complete circuits for the operation of relays 6A–0′, 6A–4′ and 6A–5′.

The combined operation of relay 6B–DW as described above and the closure of the universal contacts 4B–01 also complete a circuit for the operation of relay 6A–UC which relay closes contacts 6A–40 and completes the above-described circuit over conductor 22 for the operation of the clutch magnet 4B–CH with the result that the tape reading mechanism is again set into operation. The operation of this mechanism first causes the auxiliary contacts 4B–02 to open and remove the short-circuit from around the winding of relay 6A–AC1, thus permitting this relay to operate in series with relay 6A–AC. Relay 6A–AC1 in operating opens contacts 6A–42 and interrupts the operating circuit of the clutch magnet 6B–CH, thus causing the transmitter to come to rest at its next stop position. Continued operation of the reading mechanism causes the universal contacts to open, the tape sensing fingers to be retracted which in turn restore the tape control contacts to their spacing positions, causes the tape to be advanced, the tape sensing pins to be released and the contacts controlled by them to be operated in accordance with the next set of perforations in the tape which under the assumed conditions will be in positions 1, 4 and 5 representing the symbol or character F, as shown in Fig. 47, to cause the auxiliary contacts to reclose and then the universal contacts to reclose after which the transmitter will come to rest in a stop position. At this time the T symbol is still recorded upon the code relays of Fig. 6 while the tape control contacts are positioned in accordance with the F symbol. However, inasmuch as relay 6A–AC1 has operated and relay 6A–UC released, ground is removed from the universal contacts 4B–01 over conductor 24 so that the setting of the contacts of the tape transmitter is ineffective to actuate any of the relays or circuits at this time.

As described above when the reading mechanism on transmitter 4B–100 is advanced after reading the perforations in the tape representing symbol T and actuating code relays 6A–0 through 6A–5 and 6A–0′ through 6A–5′ to represent the code or symbol T the auxiliary contacts 4B–02 open and remove the short-circuit from around the winding of relay 6A–AC1 and allowing this relay to operate in series with relay 6A–AC. A short time later the universal contacts 4B–01 open and release relay 6A–UC. The opening of the universal contacts

4B–01 also removes ground from the tape control contacts of the reader 4B–100 which interrupts the operating circuit of the code relays 6A–0 through 6A–5, inclusive, but the relays previously operated in this group remain locked operated under control of relay 6B–DW.

The operation of relay 6A–AC1 closes contacts 6B–11 and the release of relay 6A–UC closes contacts 6B–10 which contacts apply ground to the break contacts 6B–09 of relay 6B–RC to the G1 lead. This ground then extends through contacts 6B–26 and 6B–27 in parallel to the G1 lead. Under the assumed conditions relays 6A–2 and 6A–3 are released. From the G1 lead, ground extends through contacts 6B–30 of relay 6A–0', contacts 6B–34 of relay 6A–4' and contacts 6B–35 of relay 6A–5' all in parallel and then through the operated contacts 6B–36 of relay 6B–TRC1 to the code contacts 6B–20 through contacts 6B–25 of the respective relays 6A–0' through 6A–5'. Inasmuch as relays 6A–0', 6A–4' and 6A–5' are operated at this time ground then extends through contacts 6B–20, 6B–24 and 6B–25 to the leads 1, 4 and 5 which leads now extend through the operated contacts 6C–12 through 6C–17 of relay 6B–RTC1 to the windings of the code relays 900 through 905. Under the assumed conditions, relays 900, 904 and 905 are operated. The operation of these relays completes a circuit from ground through contacts 906 of relay 12–CT1 over the T lead to operate relay 46–1T of the order relays. As described herein the operation of relay 46–1T completes a circuit for the operation of relay 45–1RC. When one and one only of the relays in the first column, Fig. 46, operate they complete a circuit for the operation of relay 45–1RC. The operation of relay 45–1RC closes contacts 1107 which contacts complete an obvious circuit for the operation of relay 11–UP1. Relay 11–UP1 in operating interrupts the operating the locking circuit of relay 12–CT1, thus permitting this relay to release and relay 12–CT1 in releasing releases relays 12–CT1 and 11–STE1, interrupting the operating circuit of relay 46–1T. Relay 46–1T does not release at this time because it is held operated under control of its locking circuit as described herein.

The operation of relay 11–UP1 completes a circuit for maintaining itself operated under control of contacts 1204 of relay 11–STG and closes contacts 1109. The actuatoin of contacts 1109 completes a circuit for the operation of relay 6B–STP from battery through the winding of relay 6B–STP, the normal contacts 6B–04 of relay 6B–SPD, the break contacts 6B–02 of relay 6B–RC1, contacts 6B–03 of relay 6B–ALM and then over the STP conductor extending from Fig. 6B through Figs. 8, 11, 12 and 13 and through contacts 1310 of relay 6A–FMY, normal contacts 1301 of relay 10–ROK and then over a conductor back through Figs. 13, 12 and 11 through the break contacts 1110 of relay 12–CT2, the operated contacts 1109 of relay 11–UP1, the break contacts 1112 of relay 11–UP2 and through similar break contacts of relays 11–UP3, 11–UP4 and 11–UP5 to ground through the break contacts 1105 of relay 18–CTR1 and contacts 1106 of relay 7–RG1. Relay 6B–STP in operating in the above-described circuit interrupts both the operating and locking circuits of relay 6B–DW which relay thereupon releases and interrupts the locking circuit of relays 6A–AC1 and 6A–AC, allowing these relays to release. The release of relay 6B–DW also interrupts the locking circuit for the previously operated code relays which code relays 6A–0, 6A–4 and 6A–5 release. The release of these relays in turn releases the relays 6A–0', 6A–4' and 6A–5'. The release of relays 6A–0', 6A–4' and 6A–5' causes contacts 6B–20 to open and contacts 6B–24 and 6B–25 to open and release the corresponding relays 900, 904 and 905. The release of the relays 6A–0', 6A–4' and 6A–5' also recompletes the down-check circuit through break contacts of these relays which circuit is employed later to reoperate relay 6B–DW as will be described. The release of relays 900, 904 and 905 will complete a down-check circuit through the code relays 900 through 905 and the operated contacts 1201 of relay 11–STG, the operated contacts 1202 of relay 11–UP1, the break contacts 1207 of relay 11–UP2 to battery through the winding of relay 12–CT2. Relay 12–CT2 in operating completes a circuit for maintaining itself operated under control of contacts 1209 of relay 11–UP2 and the operated contacts 1204 of relay 11–STG. Relay 12–CT2 in operating operates the steering relay 11–ST2 which relay in turn connects the translator or code contacts from relays 900 through 905 to the relays of the second column of the order relays of Fig. 46. The operation of relay 12–CT2 also closes contacts 930 which contacts apply ground to the translating and code contacts of the code relays 900 through 905. Thus, the steering circuit of the routine control circuit has now been advanced one step so that the code relays 900 through 905 have their contacts connected to the second column of relays of Fig. 46.

The operation of relay 12–CT2 also interrupts contacts 1110 which contacts interrupt the operating circuit of relay 6B–STP and cause this relay to release and again complete the operating circuit of relay 6B–DW.

Thus, the T code has been transferred from the storage tape to the first column of relays of Fig. 46 and the tape transmitter advanced so that it is sensed in the next or F code and the steering relays of Figs. 8, 9, 11 and 12 are actuated so that the F code when it is transferred to the code relays of Fig. 6A will likewise be transferred through the code relays 900 through 905 to one of the relays of the second column of the order relays of Fig. 46.

The combined operation of relay 6B–DW together with the closure of the auxiliary contacts 4B–01 and transmitter 4B–100 again complete a circuit for the operation of relay 6A–AC and the combined operation of relay 6B–DW and the closure of the universal contacts 4B–01 of the tape reader 4B–100 apply ground to the tape control contacts and also cause the operation of relay 6A–UC. As a result, the code relays 6A–0 through 6A–5 and 6A–NO operate in accordance with or under control of perforations or other storage manifestations in the tape or record medium and lock operated and cause the operation of relays 6A–0' through 6A–5'. These relays in turn cause contacts 6A–20 through 6A–25 to be operated in accordance with the relays operated in accordance with the perforations in the tape and under the assumed conditions represent contacts 6B–21, 6B–24 and 6B–25 since perforation will be in the first, fourth and fifth positions in the tape to represent the letter F. In this case, since relay 6A–0 is not operated, relay 6A–NO will be operated.

The operation of relay 6A–UC again closes clutch magnet 6B–CH and releases the transmitter or reader so that it will advance to its next stop position. In so advancing, the auxiliary contacts 4B–02 first open and permit relay 6A–AC1 to operate and then the universal contacts open and remove ground from the tape control contacts and also permit relay 6A–UC to release. As a result, ground is again applied through contacts 6B–11 of relay 6A–AC1, contacts 6B–10 of relay 6A–UC, contacts 6B–09 of relay 6B–RC, contacts 6B–26 of relay 6A–2 in parallel with contacts 6B–27 of relay 6A–3 and then through a parallel group of contacts 6B–31 of relay 6A–1', contacts 6B–34 of relay 6A–4' and contacts 6B–35 of relay 6A–5', contacts 6B–36 of relay 6B–RTC1 and then through the contacts 6B–21, 6B–24 and 6B–25 of the corresponding relays 6A–1', 6A–4' and 6A–5'. This ground then extends to the windings of relays 900 through 905 causing relays 900, 904 and 905 to operate with the result that a circuit is completed for the operation of relay 46–2F. This relay locks operated under control of relay 18–CTR1 and in turn causes the operation of relay 45–2RC. Thus, the second portion of the order is transferred to the second column order relays of Fig. 46. The circuits then continue to function in the manner

described above and cause each of the succeeding portions of the order to be stored in the succeeding columns of relays of Fig. 46.

Upon storing of the fifth portion of the order and the operation of relay 11–5UP, ground is not applied to the stepping lead to operate the stepping relay 6B–STP as was the case upon the operation of the previous relays 11–1UP through 11–4UP indicating the registration of the corresponding portion of the order. At this time the tape reader will be advanced so that the succeeding symbol entered in the tape will be over the sensing pins. However, the code relays 6A–0 through 6A–5 are not operated. Instead, the operation of the problem tape reading mechanism 4B–100 as well as the circuits controlled by the relays described above is stopped until the routine control circuits execute each of the portions of the order as described herein. Upon the completion of the execution of this order which causes the operation of relay 14–07, relay 18–CTR1 is operated in the manner described herein which relay actuates contacts 4653 and releases the order relays of Fig. 46 and also actuates contacts 1105 and 1116. Contacts 1116 in opening interrupt locking circuits of relay 45–5UP and cause the control circuits for the order relays to be restored to normal or their initial condition where they will be ready to control the entering of another number. The actuation of contacts 1105 interrupts the locking circuit of relay 11–STG, thus permitting relay 11–STG to release. The release of relay 11–STG opens contacts 1201 and 1204 which contacts in turn permit relays 11–UP1 through 11–UP5 and relay 11–STE5 to release with the result that the steering circuit of relays of Figs. 8, 9, 11 and 12 are restored to normal. Consequently, the chain circuit through break contacts of these relays checking the down-check condition of the relays is completed. Upon the restoration of the relays of the control circuits for the order relays of Fig. 46 and in particular upon the release of relays 45–1RC, 45–2RC, 45–3RC, 45–4RC, 45–5RC and 45–CO, relay 18–CTR1 also releases and closes contacts 1105, 1116 and 4653.

The completion of the down-check circuit through the relays of the steering and control circuits of Figs. 8, 9, 11 and 12 as described above again completes a circuit for the operation of relay 11–STR which relay operates and closes contacts 1201 and 1204 and thus conditions the steering circuits for responding to the next order.

The operation of relay 11–STG closes contacts 1121 which contacts apply ground to the stepping lead from the operated contacts 1106 of relay 7–RG1, the break contacts 1105 of relay 18–CTR1 and the break contacts 1116 and 1115 of relays 11–UP5 and 11–UP4, respectively, and through break contacts over relays 11–UP3, 11–UP2 and 11–UP1, the break contacts 119 of relay 12–CT1 and the operated contacts 1121. The application of ground to this lead again causes relay 6B–STP to operate and in turn release relay 6B–DW. The release of relay 6B–DW permits the code relays 6A–0 through 6A–5 and 6A–NO to release which relays in turn permit relays 900 through 905 to release and complete the down-check circuit described herein for operating relay 12–CT1. Relay 12–CT1 in operating actuates contacts 1119 which contacts interrupt the ground applied to the stepping lead and thus permit relay 6B–STP to release. The release of relay 6B–STP at this time again closes the operating circuit for relay 6B–DW through the down-check circuit described herein and causes the tape transmitter or reader to transfer the code above these sensing pins to the first column of relays of Fig. 46 in the manner described herein. In this manner, each one of the succeeding elements and portions of each of the succeeding orders recorded in the problem tape is transferred to the order relays of Fig. 46 step by step and these orders executed whereupon the elements of the next order are similarly transferred to the order relays and then this order is executed, etc. The above cycles of operation of the problem control circuit in the problem tape transmitter or reader and the steering circuits and other circuits of the routine order circuits continue so long as additional orders are entered into the problem tape. At the end of this section of the problem tape an RC code is entered into the tape. The RC code comprises a perforation in each and every position except the No. 1 position.

As described above, after the complete order preceding the RC code is entered upon the order relays, the operation of the tape reader and the problem control circuit as well as the steering portion of the routine control circuits is suspended until this order is executed. Upon the execution of each of the portions of the order as described herein, relay 18–CTR1 operates and permits relay 11–STG to release which relay restores the control and steering relays of the routine control circuits shown in Figs. 8, 9, 11 and 12 and conditions these circuits for responding to the elements of another order. The release of these relays completes the down-check circuit for reoperating relay 11–STG which relay then reoperates and closes contacts 1121. Meantime, the order relays of Fig. 46 as well as the control relays of Figs. 44 and 45 are also released and upon the release of these relays, relay 18–CTR1 releases and recloses contacts 1105, 1116 and 4653. The reclosure of contacts 1105 together with the operation of contacts 1121 apply ground to the STP lead for operating relay 6B–STP. Relay 6B–STP in operating again releases relay 6B–DW which relay releases and interrupts the locking circuit of the code relays 6A–0 through 6A–5 and 6A–NO, thus permitting these relays to release and release the corresponding code relays 6A–0′ through 6A–5′ and relays 900 through 905. The release of relay 6B–DW also causes relays 6A–AC1 and 6A–AC to release. The release of relays 900 through 905 completes a down-check circuit described above for operating relay 12–CT1 which relay operates and causes relay 11–STE1 to operate and condition the steering circuit to respond to the first portion of an order. The operation of relay 12–CT1 actuates contacts 1119 which contacts remove ground from the stepping lead and thus permit relay 6B–STP to release. The release of relay 6B–STP together with the closure of the down-check circuit through relays 6A–01′ through 6A–5′ again completes a circuit for the operation of relay 6B–DW. At this time under the assumed conditions, the RC code will be positioned above the tape sensing pins and the transmitter or tape reader at least in one of its stop positions. If the tape reader has not reached the stop position, then the circuits will wait until the various contacts for the transmitter are actuated as it approaches the stop position as described herein. If, however, the transmitter or tape reader 4B–100 has reached its stop position, then the closure of the contacts of relay 6B–DW as described herein completes a circuit for operating relay 6A–AC, applies ground to the locking contacts of relays 6A–0 through 6A–5 and 6A–NO and also completes a circuit described hereinbefore for operating relay 6A–UC. The operation of relay 6A–UC advances the tape transmitter as described above. In addition, the operation of relay 6B–DW also applies ground to the tape control contacts which cause relay 6A–0 through 6A–5 and 6A–NO to operate in accordance with the setting of the tape control contacts which contacts are set in accordance with the perforations in the tape over the sensing fingers at this time. Under the assumed conditions, therefore, with an RC code over the sensing pins, relays 6A–0, 6A–2 through 6A–5 are operated. Likewise, the corresponding relays 6A–0′ and 6A–2′ through 6A–5′ are also operated. Upon the advance of the tape reader 4B–100, the auxiliary contacts open and the universal contacts open with the result that relay 6A–AC1 operates and closes contacts 6B–10 applying ground to the G lead through the break contacts 6B–09 of relay 6B–RC. Ground applied to

the G lead at this time, however, does not extend to the G1 lead or to the code contacts 6B–20 through 6B–25 because all of the contacts 6B–26, 6B–27, 6B–08 and 6B–26 are actuated because the respective relays 6A–2 through 6A–5 are operated in response to perforations in the tape over the tape sensing pins 2 through 5 of the RC code assumed to be over the sensing pins. Instead, this ground is transmitted through the operated contacts 6B–37 of relay 6A–0 which is operated in response to the 0 perforation of the RC code, then through break contacts 6B–41, the operated contacts 6B–42 through 6B–45 to battery through the winding of relay 6B–RC. Relay 6B–RC in operating closes contacts 6B–46 which contacts complete an obvious circuit for the operation of relay 6B–RC1. Relay 6B–RC1 in operating actuates contacts 6B–13 which contacts together with the operated contacts 6B–47 of relay 6B–RC complete a circuit for maintaining relay 6B–RC operated under control of contacts 6B–12 of relay 6B–RTC and contacts 8–16 of relay 8–ST4.

It should thus be noted that under these circumstances the RC code is not transferred to the code relays 900 through 905 but instead is employed to operate relays 6B–RC and 6B–RC1 as described above.

The operation of relay 6B–RC1 actuates contacts 6B–02 which contacts complete a circuit for the operation of relay 6B–STP from battery through the winding of relay 6B–STP, the break contacts 6B–04 of relay 6B–SPD to ground through the operated contacts 6B–02 of relay 6B–RC1. Relay 6B–STP interrupts the operating and locking circuits of relay 6B–DW as described hereinbefore and which causes relay 6B–DW to release and release the code relays which have stored upon them the RC code. Relays 6A–AC and 6A–AC1 are also released at this time.

The actuation of contacts 6B–13 of relay 6B–RC1 interrupts the locking circuit of relays 6B–RTC and 6B–RTC1. Consequently, the operating circuit of relay 6B–ALS is released which restores the switching code contacts to their normal circuits. The release of relay 6B–RTC1 also opens contacts 6A–12 through contacts 6C–17 and thus disconnects the windings of relays 900 through 905 from the code contacts 6B–20 through 6B–25 of the code relays 6A–0′ through 6A–5′. The release of relay 6B–RTC opens contacts 6B–12 which contacts interrupt the locking circuit of relays 6B–RC and 6B–RC1, thus permitting these relays to release and restore the switching circuits of the problem control circuit shown in Figs. 6A, 6B and 6C to their normal condition. The release of relay 6B–RC1 interrupts the above-described operating circuit of relay 6B–STP and permits this relay to release and restore the operating circuit of relay 6B–DW and the down-check circuit including contacts of the code relays 6O–0′ through 6A–5′. Relay 6B–DW in operating together with the closure of the auxiliary contacts and the universal contacts of the tape reader 4B–100 cause the circuits to respond to the next order entered into the problem tape. Assume, for example, that this code comprises an SWP signal for directing the succeeding codes entered in the problem tape to the printer through the printer control circuit.

The SWP code comprises a perforation in the tape in each one of the positions 0 through 4 but no perforation in the No. 5 position. Consequently, when the tape transmitter senses this code the tape control contacts 0 through 4 are actuated to their spacing position. Then when the auxiliary contacts close, relay 6A–AC operates as described above and when the universal contacts 4B–01 close, assuming, of course, that relay 6B–DW is operated as described above, the code relays 6A–0 through 6A–4 operate and relay 6A–UC operates. As a result, relays 6A–0′ through 6A–4′ also operate.

The operation of relay 6A–UP causes the clutch magnet 4B–CH to operate and advance the transmitter or tape reading mechanism 4B–100. This mechanism will thereupon advance to the next stop position and in so advancing opens the auxiliary contacts 4B–02 and the universal contacts 4B–01 retract the sensing pins and restore the tape control contacts, advance the tape and then release the sensing pins which are positioned in accordance with the succeeding row of perforations in the tape. As the transmitter approaches its rest position the auxiliary contacts will close and then the universal contacts will close as described herein. Upon the advance of this transmitter and the opening of the auxiliary contacts as described above, relay 6A–AC1 operates and then the universal contacts 4B–01 open and cause relay 6A–UC to release as well as interrupt the operating circuit of the code relays 6A–0 through 6A–4 which are set to represent the printer code SWP. The operation of relay 6A–AC1 and the release of relay 6A–UC causes the respective contacts 6B–11 and 6B–10 to close and apply ground to the G1 lead which now extends through contacts 6B–28 of relay 6A–5 which relay is not operated by the SWP code and then through operated contacts of relays 6A–0′ through 6A–4′ to the SWP lead and then through the normal contacts 6B–49 of the 6B–LS relay, then over the SWP lead to the printer control circuit. If the printer control circuit is busy employed printing information from the printer register or perforating information from the printer register or busy for any other reason the SWP lead is open in the printer control circuit. Consequently, the circuits will remain in the above-described condition as the tape reader advances to the next row of perforations in the tape but the SWP lead is locked upon the code relays 6A–0 through 6A–4 as described above. When and if the printer becomes idle, the SWP lead is completed through the printer control circuit back to the junction between the windings of the 6B–PTR and 6B–PTR1 relays causing the operation of relay 6B–PTR. The operation of relay 6B–PTR closes contacts 6B–38. The operation of these contacts together with the operated contacts 6B–16 of relay 6A–0′ in response to the 0 perforation in the problem tape of the SWP code complete a circuit for the operation of relay 6B–STP which relay causes relay 6B–DW to release and the release of relay 6B–DW interrupts the locking circuit of relays 6A–AC and 6A–AC1 and also interrupts the locking circuit of the code relays 6A–0 through 6A–4, thus permitting these relays to release. In turn, relays 6A–0′ through 6A–4′ release and interrupt the connection described above to the junction between the windings of relays 6B–PRT and 6B–PRT1, thus permitting relay 6B–PRT1 to operate and maintain relay 6B–PRT operated. The operation of relay 6B–PRT1 causes relay 6B–PRT to operate and this relay in turn causes relay 6B–ALS to operate. The operation of relay 6B–PRT1 also causes contacts 6C–21 through 6C–25 to operate and connects the code contacts 6B–21 through 6B–25 to the printer control circuit for transmitting the succeeding codes entered in the problem tape to the printer through the printer control circuit. The operation of relay 6B–ALS described above again transfers all of the switching code leads to the 6B–ALM relay so that is another switching code is received before a restore or release code RC is received an alarm is indicated and the operation of the computer stopped. The operation of relay 6B–ALS also closes contacts 6B–48 which contacts together with the operated contacts 6B–39 of relay 6B–PRT2 connect the winding of the stepping relay 6B–STP to the EP lead extending to the printer control circuit. Thus, when the printer control circuit is ready to receive a code it will apply ground to this lead to operate the stepping relay and advance the problem control circuit as set forth herein. The circuits are now in condition for transmitting information entered into the problem tape directly to the printer circuit for printing the problem heading, headings of columns to be printed by the printer and such other matter as may be desired to enter in the printer.

After the desired information has been printed, an RC code is entered in the problem tape which causes the circuits to be restored as described above. The other switching codes PFA and PFB operate in substantially the same manner as described above causing the corresponding switching relays to operate. In this case the switching leads also extend through the printer control circuit and the storage tape control circuit to insure that both of these circuits are idle when it is desired to transfer information to the A storage tape and to the B storage tape. After the information entered into the problem tape in each of these sections of the tape has been transmitted to the respective storage tapes, then an RC code is entered into the problem tape which interrupts the previously established paths and thereafter the next switching code establishes the next desired path. Under the assumed conditions this path will be another SWR code followed by an order selecting a desired routine or other functions. The control of the computations may be wholly from the problem tape if desired. In case a formula is selected, then relay 8–MF is operated which relay causes relay 6A–FMY to operate and to actuate contacts 1103 and 1104 with the result that the relay 11–STG is released releasing the previously operated relays 12–CT1 and 11–STE1 of the steering circuits in the routine control circuit.

Key set

Provision is made for operating the computer from a set of keys associated therewith. An entire problem may be set up on these keys or they may be employed to correct errors discovered by the computer in the problem tape or errors otherwise noted or detected. The key-set is shown in Fig. 10 and comprises two groups of ten keys and a group of six keys. The keys of the key-set are non-interfering and locking. When any one of the keys is depressed it is locked down and prevents the operation of any other key of the key-set. The depressed key is then released by the operation of a release magnet.

These keys may be employed to set up orders in the computer, they may be employed to select formulas incorporated in the computer, they may be employed to select special orders, and they may be employed to record numbers in the various storage elements of the machine. These keys may likewise be employed to correct any of the above instructions, numbers or orders already stored or entered into the computer.

For the purpose of illustration, it is assumed that it is desired to clear the number stored in register A by operation of the key-set. In order to clear register A it is necessary to enter the order A T T T $\overline{\text{CH}}$. It is, of course, assumed that the computer has been put into operation by suitable orders from a problem tape as described herein and that it is desired to correct a number or other information or to supply additional information. Under these circumstances, the various start relays 6A–STA, 8–ST, 8–ST1, 8–ST3, 8–ST4, 7–RG1, 7–RG, etc. are all operated. Relay 7–RG1 in operating also completes a circuit for the operation of relay 45–STP from ground through the operated contacts 1106 of relay 7–RG1 through the break contacts of relays 31–TST, 45–4RC through 45–1RC, 11–KEY and 13–DCP to battery through the winding of relay 45–STP. Relay 45–STP in turn, completes a circuit for operating relay 45–FR which relay then locks operated under control of relays 7–RC1 and 45–5UP and prepares circuits for operating other relays as will be described herein. In addition, numerous down-check circuits operate. These circuits are described herein when involved in the various operations discussed herein.

When it is desired to employ the key-set to enter information into the computer the 10–ROK key will be operated by the attendant. The operation of the 10–ROK key completes an obvious operating circuit for the 10–ROK relay.

The 10–ROK relay in operating transfers the STP lead at contacts 1301 from the problem control circuit of Figs. 4, 5, and 6 to a path extending to the 13–CIS relay. The operation of the 10–ROK relay also completes an obvious circuit for the operation of the 10–ROK1 relay extending from battery through the winding of the 10–ROK1 relay, the operated contacts 1002 to ground through the left-hand break contacts of the 13–RNK key.

The operation of the 10–ROK1 relay disconnects the windings of relays 900, 901, 902, 903, 904 and 905 from the contacts in the problem control circuit controlled by the problem tape at contacts 910 through 915 and connects the windings of these relays to the contacts of the keys shown in Fig. 10 at the respective contacts 920 and 925.

The operation of the 10–ROK relay as described above also completes an obvious circuit for the operation of the 11–KEY relay. The operation of relay 10–ROK completes a circuit for the operation of relay 11–STG which circuit extends from battery through the winding of relay 11–STG, the operated contacts 1101 of the 11–KEY relay, contacts 1102 of the 10–ROK relay, the operated contacts 804 of the 8–ST4 relay to ground through the down-check circuit comprising the break contacts of relays 11–UP5 through 11–UP1, 12–CT1 through 12–CT4 and 11–STE4 through 11–STE1 and 11–STE5. The 11–STG relay in operating completes a locking circuit for maintaining itself operated from battery through its winding and the operated contacts 1101 of the 11–KEY relay, the break contacts 1103 of the MF relay and operated contacts 1104 of the 11–STG relay, the break contacts 1105 of the 18–CTR1 relay to ground through the operated contacts 1106 of the 7–RG1 relay. The operation of the 11–STG relay completes a circuit for the operation of the 12–CT1 relay from battery through the winding of the 12–CT1 relay, the break contacts 1202 of the 11–UP1 relay, the operated contacts 1201 of the 11–STG relay to ground through the break contacts of relays 905 through 900. Relay 12–CT1 in operating completes a circuit for maintaining itself operated under control of relay 11–UP1 from battery through its winding and its operated contact 1203 to ground, through the break contacts 1205 of relay 11–UP1 and the operated contacts 1204 of relay 11–STG.

Relay 12–CT1 completes an obvious circuit for the operation of relay 11–STE1 and relay 11–STE1 in operating closes numerous contacts shown in Fig. 12 between the contacts of relays 900 to 905 of Fig. 9 and the secondary or locking windings of relays 46–1A through 46–1T shown in Fig. 46. The contacts of relays 900 through 905 are employed for translating the code employed in wiring the keys shown in Fig. 10, and also the code employed in the problem tape as described herein, which code comprises grounding a plurality of the six leads from the keys or the tape-controlled contacts. The contacts of relays 900 through 905 are employed to ground one of twenty or one of six leads extending to the twenty relays 46–1A through 46–1T in response to the codes from the keys or tape.

The circuits are now prepared for entering orders from the key-set comprising keys of Fig. 10. The circuits will remain in the above-described condition until some one of the keys shown in Fig. 10 is operated by the attendant of the computing mechanism.

For the purpose of illustration it is assumed that the order A T T T $\overline{\text{CH}}$ is written on the key-set and entered into the computer. This order will cause the computer to clear register A. In other words this order will release register A and restore this register to its normal condition with nothing stored in it.

As pointed out herein each one of the various orders comprises five parts. The various component parts and the various possible orders are set forth in the table shown in Fig. 47. The A entered in the first position causes the control circuits to select the A register. The T entered in the next three positions or the columns indicates a dummy or by-pass and is employed when the particular

order in question does not require information in that particular position or column to be supplied to the computer. The $\overline{CH}$ entered in the fifth position of the order will cause the mechanism to clear the register identified in the first position of the order and hold or not clear other registers of the computer.

Under the assumed conditions, the key designated **1011** in Fig. 10 is depressed. All of the keys of Fig. 10 are provided with a locking arrangement which, when the key is actuated, causes that key to remain actuated until released in the manner described hereinafter and prevents the actuation of any of the other keys of Fig. 10 until the actuated key is released. It should also be noted that the first twenty keys, that is, the keys in the first two rows designated by the letters and symbols shown in the first four columns in the code chart of Fig. 47, the last row of keys, bears the designations in the fifth column of the code chart. Thus, it is essential that one of the first twenty keys be operated for each of the first four columns and one key in the last row be operated for the fifth part of the order. When the various keys are not properly operated, that is, if the key in the third row is operated for one of the first four parts of the order, the order is not properly entered or recorded in the mechanism, thus indicating an error in operating the keys.

When key **1011** is depressed a circuit is completed for the operation of relay **10**–KA–J which circuit extends from battery through the winding of relay **10**–KA–J and through the break contacts **1012** of the RNKA relay to ground through the right-hand operated contacts of key **1011**.

The operation of relay **10**–KA–J completes a circuit for the operation of relay **10**–ROK–**2** extending from battery through the winding of relay **10**–ROK–**2** to ground, through the operated contacts of relay **10**–KA–J. Relay **10**–ROK–**2** in operating completes a circuit for maintaining itself operated from battery through its winding and its operated contacts **1005** to ground through the operated contacts **1001** of relay **10**–ROK–**2**.

Relay **10**–ROK–**2** in operating applies ground through contacts **1006** of the **10**–ROK–**2** relay and contacts **1007** of the **10**–CIS**1** relay to the code contacts of the key-set shown in Fig. 10. As a result, with key **1011** depressed ground is applied to circuits extending through the K**1** lead, K**2** lead and K**3** lead extending to Fig. 9 and then through contacts **921**, **922** and **923** to the windings of relays **901**, **902** and **903**, thus completing the operation of these relays. The operation of the three relays **901**, **902** and **903** completes a circuit from ground through the operated contacts **906** of the **12**–CT**1** relay to contacts **909** of relay **901**, contacts **908** of relay **902** and contacts **907** of relay **903** to the A conductor extending to the secondary or locking winding of relay **46**–**1**A.

Relay **46**–**1**A in operating completes a circuit for maintaining itself operated from battery through its left-hand winding and operated contacts **4652**, the break contacts **4651** of relay **45**–CO**1**, break contacts **4650** and **4653** to ground through the operated contacts **4501** of the **7**–RG**1** relay.

A group of contacts on each of the relays **46**–**1**A through **46**–**1**T are connected in a chain circuit for controlling the operation of relay **45**–**1**RC. Likewise, each of the relays **46**–**2**A through **46**–**2**T as well as of the relays **46**–**3**A through **46**–**3**T, **46**–**4**A through **46**–**4**T and **46**–**5**A through **46**–**5**F are likewise connected in chain circuits for controlling the operation of the respective relays **45**–**2**RC, **45**–**3**RC, **45**–**4**RC and **45**–**5**RC. The chain circuit of the contacts controlling relay **45**–**1**RC is arranged so that a circuit is completed through the winding of relay **45**–**1**RC when and only when one and only one of the relays **46**–**1**A through **46**–**1**T is operated. Likewise, a circuit is completed through the winding of relays **45**–**2**RC when and only when one and only one of the relays **46**–**2**A through **46**–**2**T is operated. The other relays **45**–**3**RC, **45**–**4**RC and **45**–**5**RC are similarly operated when and only when one and only one of the corresponding series of the relays **3**, **4** and **5** of Fig. 46 is operated. These chain circuits are provided to insure proper operation of the system because each and every order comprises the operation of one and only one of the relays in the respective columns or series of relays **1** through **5** of Fig. 46 as described herein.

Upon the operation of relay **46**–**1**A a circuit will be completed for the operation of relay **45**–**1**RC which circuit extends from battery through the winding of this relay and the normal or break contacts of each of the relays **46**–**1**T through **46**–**1**B and then through the operated contacts of relay **46**–**1**A to ground.

The operation of relay **45**–**1**RC closes contacts **1107** shown in Fig. 11. These contacts, of course, are associated with and controlled by relay **45**–**1**RC. The closure of contacts **1107** of relay **45**–**1**RC completes a circuit for the operation of relay **11**–UP**1** indicating that the first part of the order has been entered and registered by one of the relays **46**–**1**A through **46**–**1**T, i. e., relay **46**–**1**A under the assumed conditions. A circuit for the operation of relay **11**–UP**1** may be traced from battery through the winding of relay **11**–UP**1** through the operated contacts **1108** of relay **12**–CT**1** to ground through the operated contacts **1107** of relay **45**–**1**RC.

The operation of relay **11**–UP**1** completes a circuit for maintaining itself operated from battery through its winding and its operated contacts **1206** to ground through the operated contacts **1204** of relay **11**–STG. The operation of relay **11**–UP**1** also interrupts the locking circuit described herein for maintaining relay **12**–CT**1** operated which circuit extends through contacts **1205** of relay **11**–UP**1**, thus permitting relay **12**–CT**1** to release. Relay **12**–CT**1** in releasing in turn causes relay **11**–STE**1** to release thereby interrupting the above-described operating circuit extending through the left-hand winding of relay **46**–**1**A. Relay **46**–**1**A, however, does not release at this time because it is maintained operated by the locking circuit described above.

Relay **11**–UP**1** in operating actuates contacts **1202** which contacts, in addition to releasing relay **12**–CT**1** as described above, also prepare a circuit for the operation of relay **12**–CT**2** which circuit extends from battery through the winding of relay **12**–CT**2**, the break contacts **1207** of relay **11**–UP**2**, the operated contacts **1202** of relay **11**–UP**1** to ground through the operated contacts **1201** of relay **11**–STG and the normal or break contacts of each of the relays **900** through **905**, inclusive, when these relays are all released as described hereinafter.

Relay **11**–UP**1** closes contacts **1109** which contacts in turn complete a circuit for the operation of relay **13**–CIS which circuit extends from battery through the winding of relay **13**–CIS through the operated contacts of relay **10**–KA–J, which relay was previously operated due to the operation of key **1011**, the operated contacts **1302** of relay **10**–ROK–**2**, the operated contacts **1301** of relay **10**–ROK, the normal contacts **1110** of relay **12**–CT**2**, the operated contacts **1109** of relay **11**–UP**1**, the break contacts of relays **11**–UP**2** through **11**–UP**5** to ground through the break contacts **1105** of relay **18**–CTR**1** and the operated contacts **1106** of relay **7**–RG**1**.

The operation of relay **13**–CIS completes an obvious circuit for the operation of relay **10**–CIS**1**. Relay **10**–CIS**1** in operating completes a circuit for maintaining itself operated from battery through its winding and its operated contacts **1008** and the operated contacts **1013** of relay **10**–KA–J to ground.

The operation of relay **10**–CIS**1** opens contacts **1007** and interrupts the ground supplied to the code contacts of the keys of Fig. 10.

Removal of this ground by the contacts **1006** of relay **10**–ROK**2** at the open contacts **1007** of relay **10**–CIS**1** causes these relays **900** through **905**, inclusive, to all release, i. e., in a specific example described herein relays **901**, **902** and **904** will release and the remaining relays

900, 904 and 905 will remain released. The release of these relays completes a checking circuit for the operation of relay 12–CT2 as described above.

Relay 12CT2 in operating completes a circuit for maintaining itself operated from battery through its winding and operated contacts 1208 and the break contacts 1209 of relay 11–UP2 to ground through the operated contacts 1204 of relay 11–STG. Relay 12–CT2 in operating completes an obvious circuit for the operation of relay 11–STE2 which relay in operating closes numerous contacts of Fig. 12 and connects the translating contacts of relays 900 to 905, inclusive, to the left-hand windings of relays 46–2A through 46–2T.

Relay 12–CT2 in operating opens contacts 1110 which contacts interrupt the operating circuit described above for operating relay 13–CIS. Relay 13–CIS in releasing closes the break contacts 1010 which contacts complete a circuit for the operation of the release magnet 10–A–J for the set of keys A through J, i. e., the first row of keys of Fig. 10. The release of the key 1011 under the assumed conditions interrupts the above-described operating circuit of relay 10–KA–J which relay releases and interrupts the locking circuit of relay 10–CIS1 which relay in turn releases and interrupts the operating circuit of the release magnet 10–A–J which magnet releases and restores the keys to their normal condition where they are ready for the operator or attendant to actuate another key.

The release of the key 1011 interrupts the operating circuit of relay 10–KK–T which relay releases and interrupts the locking circuit of relay 10–CIS1. Relay 10–CIS1 in releasing closes contacts 1007 and reapplies a code ground to the code keys so that the relays 900 through 905 will respond to the next key depressed.

Thus, the circuits are arranged so that a path is provided from the keys through the relays 900 through 905 to the order relays of Fig. 46 and upon the operation of one of the order relays and only one of the order relays in response to the operation of a key which circuits are advanced step by step first to release the path from contacts of relays 900 through 905 to the order relays then to release relays 900 through 905 and thereupon establishing other paths from these contacts to a second or succeeding set of the order relays of Fig. 46, to then release the keys and then restore the key-set to its normal condition, thus indicating to the operator or attendant that a second key may be depressed.

Under the assumed conditions the operator or attendant will now depress key 1003 since T is assumed to be the second part of the order in the second column of the code sheet of Fig. 47. The operation of this key causes the operation of relay 10–KK–T. Inasmuch as relay 10–ROK–2 is locked operated at this time the operation of relay 10–KK–T merely prepares a locking circuit for the 10–CIS11 relay as described herein. The operation of key 1003 causes relays 900, 904 and 905 to operate which relays in turn cause relay 46–2T to operate at this time since the second steering relay 11–STE2 is now operated instead of the first steering relay 11–STE1 as described above when key 1011 was depressed. Relay 46–2T in operating completes a circuit for maintaining itself operated from battery through its left-hand winding and its operated contact 4654, the normal contacts 4651 of relay 45–CO1, the normal contacts 4650 of the test relay 31–TST, and normal contacts 4653 of relay 18–CTR1 to ground through the operated contacts 4501 of relay 7–RG1.

The operation of relay 46–2T completes a circuit for the operation of relay 45–2RC providing this is the only one of the relays 46–2A through 46–2T to be operated. The operation of relay 45–2RC causes contacts 1110 to close and complete a circuit for the operation of relay 11–UP2 since the contacts 1111 of relay 12–CT2 are already closed. The operation of relay 11–UP2 causes contacts 1209 to be actuated, thus interrupting the locking circuit of relay 12–CT2 which relay thereupon releases and releases relay 11–STE2 disconnecting the windings of relays 46–2A through 46–2T from the contacts of the code relays 900 through 905, inclusive. Relay 46–2T does not release at this time because it is held operated by its locking circuit described above. The operation of relay 11–UP2 also completes a circuit for maintaining itself operated from battery through its winding and operated contacts 1209 to ground through the operated contacts 1204 of relay 11–STG. Relay 11–UP2 in operating causes contacts 1112 to be actuated which contacts complete a circuit for the operation of relay 13–CIS from ground through the operated contacts 1106 of relay 7–RG1, contacts 1105 of relay 18–CTR1 and the break contacts of relay 11–UP5, 11–UP4, 11–UP3, the operated contacts of relay 11–UP2 and break contacts of relay 12–CT3 and through the operated contacts 1301 of relay 10–ROK and contacts 1302 of relay 10–ROK–2 to the winding of relay 13–CIS through the operated contacts of relay 10–KK–T. Relay 13–CIS in operating completes a circuit for the operation of relay 13–CIS1 as described hereinbefore. Relay 10–CIS1 in operating removes the operating ground from the code contacts of keys of Fig. 10, thus causing relays 900, 904 and 905 to release. The release of relays 900, 904 and 905 together with the released relays 901, 902 and 903 completes a circuit for the operation of relay 12–CT3 extending from battery through the winding of relay 12–CT3 and the break contacts of relay 11–UP3, the operated contacts of relay 11–UP2, 11–UP11, the operated contacts of relay 11–STG to ground through the break contacts on each of the relays 900 through 905, inclusive. Relay 12–CT3 in operating closes locking contacts 1210 which contacts complete a circuit for maintaining relay 12–CT3 operated under control of relay 11–UP3 to ground through the operated contacts 1204 of relay 11–STG. Relay 12–CT3 in operating completes an obvious circuit for the operation of the steering relay 11–STE3 which relay connects the contacts of the code relays 900 through 905 to the left-hand windings of relays 146–3A through 46–3T, inclusive. The operation of relay 12–CT3 also actuates contacts 1113 which contacts interrupt the operating circuit of relay 13–CIS. Relay 13–CIS, in turn, releases and completes a circuit for the operation of the release magnet 10–K–T which magnet restores the key 1003 to normal and conditions the circuit for receiving the third portion of the order. The release of key 1003 interrupts the operating circuit of relay 10–KK–T which relay releases and interrupts the locking circuit of relay 10–CIS1 which relay also releases and in turn reapplies operating ground to the code contacts of the code keys of Fig. 10 thus preparing a circuit for recording the third digit.

The circuit responds in substantially the same manner as described above when the third key, which again will be key 1003 under the conditions assumed above, was operated the second time except that a third set of steering relays, code relays and the like are operated. Likewise, when key 1003 is actuated the third time to record the fourth portion of the order, a circuit responds in substantially the same manner and causes relay 46–4T to operate and then key 1003 is released for the third time and the circuits prepared for receiving the fifth portion of the order.

After the operation of key 1003 the third time which records the fourth portion of the order, relay 11–UP4 operates in response to the operation of relay 46–4T. The operation of relay 11–UP4 interrupts the locking circuit of relay 12–CT4 which relay in turn releases and releases relay 11–STE4. Relay 11–STE4 in releasing interrupts the connections between the contacts of the code relays 900 through 905 in the fourth column of the order relays 46–4A through 46–4T. Relay 46–4T, however, does not release at this time because it is locked up in its locking circuit extending from battery through its left-hand winding and locking contacts and through

the break contacts **4651**, **4650** and **4653** to ground through the operated contacts **4501** and the **7**–RG1 relay.

Relay **11**–UP4 also completes a circuit for maintaining itself operated under control of contacts **1204** of relay **11**–STG. Relay **11**–UP4 in operating also completes a circuit for the operation of relay **13**–CIS from battery through the winding of relay **13**–CIS, contacts **1305** of relay **10**–KK–T, operated contacts **1302**, **1301** and break contacts **1114** of relay **11**–STE5, the operated contacts **1115** of relay **11**–UP4, the break contacts **1116** of relay **11**–UP5, the break contacts **1105** of the **18**–CTR1 relay to ground through contacts **1106** of the **7**–RG1 relay. Relay **13**–CIS in operating completes an obvious circuit for the operation of relay **10**–CIS1 which relay locks operated under control of relay **10**–KK–T.

Relay **10**–CIS1 in operating opens contacts **1007** and removes ground from the code contacts of the keys of Fig. 10, thus permitting the operated ones of the relays **900** through **905** to release. In releasing, all of the relays **900** through **905** complete a circuit for operating relay **11**–STE5, said circuit extending from battery through the winding of relay **11**–STE5, the break contacts **1212** of the **11**–UP5 relay, the operated contacts **1211** of relay **11**–UP4, the operated contacts of relays **11**–UP3, **11**–UP2, **11**–UP1, the operated contacts **1201** of relay **11**–STG to ground through a set of break contacts on each of the relays **900** through **905**. The operation of relay **11**–STE5 completes circuit paths between the contacts of relays **900** through **905**, inclusive, to the left-hand windings of relays **46**–5A through **46**–5F, inclusive, and also at contacts **1213** applies an operating ground to these contacts for operating some one of the relays **46**–5A through **46**–5F, inclusive.

Relay **11**–STE5 in operating also completes a circuit path for maintaining itself operated under control of relay **11**–UP5 which locking circuit extends from battery through the winding of relay **11**–STE5, the operated contacts **1214** of relay **11**–STE5, break contacts of relay **11**–UP5 to ground through the operated contacts **1204** of relay **11**–STG. The operation of relay **11**–STE5 also opens contacts **1114** thus interrupting the operating circuit described above for relay **13**–CIS which relay releases and completes a circuit for the operation of the release magnet **10**–K–T which magnet thereupon releases key **1003**. The release of key **1003** interrupts the operating circuit of relay **10**–KK–T thus permitting this relay to release which in turn releases relay **10**–CIS1. Relay **10**–CIS1 in releasing reapplies ground through the operated contacts **1006** of the operated relay **10**–ROK–2, the released contacts **1007** of relay **10**–CIS1 to the code contacts of the keys of the key-set shown in Fig. 10. At this time the circuits are conditioned for receiving and enter the fifth element of the order. Under the assumed conditions, a fifth part of the order comprises a $\overline{CH}$ so that key **1012** will be operated which key when operated locks operated and thus prevents further operation of the keys of the key-set until this key is released as will be described hereinafter.

The operation of the key **1012** completes an obvious circuit for the operation of relay **10**–FHC1 which relay applies ground through contacts **1012** to the operating winding of relay **901**. The operation of key **1012** completes a circuit for operating three other relays **900** through **905** causing the operation of the four relays in response to the operation of key **1012**. By causing the operation of any three of the relays **900** through **905** in response to the operation of any one of the first twenty keys of the key-set for entering the first four parts of an order and causing the operation of four of the relays **900** through **905** in response to the operation of any one of the third row of keys for entering the fifth part of the order the circuits are arranged to check the proper operation of the keys. Thus, if one part of an order is omitted this fact will become more apparent since the circuits are arranged to operate satisfactorily in response to and only in response to four successive operations of any one at a time of the first twenty keys followed by the operation of one of the keys shown in the last row in Fig. 10. If four or more relays **900** through **905** are operated for any of the first four parts of the order, then two or more of the order relays in a column in Fig. 46 will be operated and as a result the corresponding relay **45**–1RC, **45**–2RC, **45**–3RC, or **45**–4RC will not be operated. Consequently, the circuit will not advance. Also, if more than four relays **900** through **905** are operated by the fifth part of the order then two or more of relays **46**–5A through **46**–5F will be operated and prevent the operation of relay **45**–5RC. If less than three of the relays **900** through **905** are operated for any of the first parts of the order or less than four of these relays for the fifth part of the order, then a relay will not be operated in the corresponding column of order relay of Fig. 46 with the result that the circuit will not advance. The operation of relay **45**–5RC together with the operation of each of the other relays **45**–1RC through **45**–4RC, in response to the operation of one and only one of the code relays in each of the columns of Fig. 46, completes a circuit for the operation of relay **45**–5UP which circuit extends from battery through the winding of relay **45**–5UP, operated contacts on each of the relays **45**–1RC through **45**–5RC, the break contacts **4502** of the test relay **31**–TST to locking ground through the break contacts **1116** of relay **18**–CTR1 and the operated contacts **1106** of relay **7**–RG1.

The operation of relay **45**–5UP causes contacts **1117** to close and complete a circuit for the operation of relay **11**–UP5 from ground through the operated contacts **1117**, the break contacts **1118** of relay **31**–TST, the operated contacts of relay **11**–STE5 and through the winding of relay **11**–UP5 to battery. The operation of relay **11**–UP5 completes a circuit for maintaining itself operated under control of relay **11**–ST6.

The operation of relay **11**–UP5 interrupts both the operating and locking circuits for relay **11**–STE5 thus permitting this relay to release and interrupt a connection between the contacts of relays **900** through **905** and the left-hand windings of relays **46**–5A through **46**–5F. The operation of relay **11**–UP5 also operates contacts **1116** whch contacts prevent the further operation of relay **13**–CIS at this time. Consequently, the key-set shown in Fig. 10 will remain locked with key **1012** depressed until released as described hereinafter.

The operation of relay **45**–5UP indicated that all five parts of an order have been received and properly entered on order relays of Fig. 46. Inasmuch as there is only one set of these order relays provided, it is necessary that the order be executed before another order may be entered from the key-set. Consequently the key-set is maintained locked during the time the computing mechanism executes the order entered on the order relays of Fig. 46. Under the assumed conditions the order entered upon the order relays comprises A–T–T–T–$\overline{CH}$. Consequently, relays **46**–1A, **46**–2T, **46**–3T, **46**–4T and **46**–5B are all operated at this time.

The operation of relay **45**–UP indicates that a complete order has been set on the order relays. Inasmuch as the order relays must be operated from tubes under conditions described elsewhere herein and in addition it is desirable to control a number of circuits from various of the order relays additional relays are operated from contacts of certain of these order relays as soon as certain of the specific order relays are operated in order to provide supplementary contacts. In addition, inasmuch as certain of the order relays do not require the computing mechanism to perform any functions in response to the operation of these relays, these relays may be operated at once. Thus, for example, relay **44**–4T1 operates as soon as relay **46**–4T operates. Relay **44**–TR1 operates as soon as relay **46**–5B operates. Likewise, the

operation of relay **46–2T** completes an obvious circuit for the operation of relay **16–T2A**. The operation of relays **15–5UP** and **16–T2A** completes a circuit for the operation of relay **18–SQR** which circuit extends from battery through the winding of relay **18–SQR** to ground through the operated contacts **1804** of relay **16–T2A** and break contacts **1805** of relay **15–OC5** to ground through the operated contacts **1801** of relay **15–5UP**. Relay **18–SQR**, in operating, completes a circuit for the operation of relay **16–DC1B** from battery through the winding of relay **16–DC1B**, contacts **1605** of relay **18–SQR**, break contacts **1612** to ground through the operated contacts **1513** of relay **18–SQR**. In addition, the operation of relay **46–2T** completes an obvious circuit for the operation of relay **15–OC2**. The operation of relay **46–3T** completes an obvious circuit for the operation of relay **15–OC3** and th operation of the relays **44–4T1** and **44–4TR1** and completes a circuit extending from ground through the break contacts **1505** of relay **44–5E1**, which relay is released at this time since relay **46–5E** is not operated, and the operated contacts **1506** of relay **44–TR1** and contacts **1507** of relay **44–4T1** to battery through the winding of relay **15–OC4**. Thus, since no function is required of the three middle portions of the order being described the relays **15–OC2**, **15–OC3** and **15–OC4** indicating a completion of the execution of these portions of the order are at once operated.

The operation of relay **45–UP** also causes contacts **4503** to be operated which provides an obvious circuit for operating relay **45–CO** which relay locks operated under control of relays **45–5UP** and **45–IRC** through **45–5RC**. Relay **45–UP** in operating causes contacts **4504** and **4505** to operate. The operation of contacts **4505** interrupts the locking circuit of relay **45–STP** which relay then releases. The operation of contacts **4504** interrupts both the operating and locking circuits of relay **45–FR** thus causing relay **45–FR** to release if it had been previously operated. The operation of contacts **4504** in addition completes a circuit for the operation of relay **15–5UP** which circuit extends from ground through the operated contacts **4501** of relay **7–RG1**, the operated contacts **4504** of relay **45–5UP**, lead **4506** which extends to Fig. 15 and then through the break contacts **1501**, the break contacts **1304** to the winding of relay **15–5UP**.

The operation of relay **15–5UP** initiates the execution by the control circuits of the order recorded on the order relays of Fig. 46. The operation of relay **15–5UP** causes contacts **1801** to be operated which contactcs normally apply ground to conductors **1802** and **1803**. However, since relay **15–OC2** is already operated as described above, the operation of relay **15–5UP** applies ground to lead **1803** only. Conductor **1802** extends to the order contacts of the order relays in the second column of Fig. 46. Likewise, conductor **1803** extends to order contacts of the relays of the fifth column of Fig. 46. The application of ground to conductor **1803** completes a circuit for the operation of relay **15–CLRA**. The operation of relay **15–CLRA** connects the winding of relay **15–DC1A** to a down-check conductor extending to the storage registers. The operation of relay **15–5UP** also causes contacts **1502** to close which contacts prepare locking circuits for the order completing relays **15–OC1** through **15–OC5**, inclusive. The operation of relay **15–5UP** also closes contacts **1901** which prepares locking circuits for relays **19–(+)SN**, **19–(−)SN**, **19–COMP1**, **19–DC3** and **19–DC3A**.

The operation of relay **15–5UP** also closes contacts **1503** and thus completes a circuit for the operation of relay **15–DC3** which circuit extends from battery through the winding of relay **15–DC3**, the break contacts **1504** of relay **15–DC3A**, the operated contacts **1503**, to ground through a series circuit extending through break contacts **2101** of relay **21–A** and contacts **2102** of relay **21–B** and then through the corresponding contacts on the A and B relays of each of the other register circuits shown in Figs. 22, 23 and 24. If all of the A and B relays of the register circuits are released and this down-check circuit is complete, relay **15–DC3** operates and prepares an operating circuit for relay **15–DC3A** and a locking circuit for itself by closing contacts **1504**. Relay **15–DC3**, however, does not operate at this time because it has ground connected to both ends of its winding.

The operation of relay **15–DC3** closes contacts **1901** which contacts supply ground to conductor **1903** which conductor extends to the order contacts of the order relays of the first column of Fig. 46.

The application of ground to lead **1903** completes a circuit for the operation of relay **21A** which circuit extends from battery through the winding of relay **21A**, previously operated contacts **2103** of relay **46–1A**, over the lead **1903** to ground through the break contacts **1902** of relay **15–OC1** to ground through the operated contacts **1901** of relay **15–DC3**.

The operation of relay **21A** closes contacts **2104** which contacts complete a circuit for the operation of relay **21–LK** which circuit extends from battery through the winding of relay **21–LK**, contacts **2104**, conductor **2105**, which conductor extends to Fig. 16, break contacts **1602** to ground through the operated contacts **1603** of relay **16–T2A**. Relay **21–LK** operates in the above-traced circuit and interrupts the locking circuits for all of the register relays of register A by opening break contacts **2109**, **2110**, **2111**, and **2112**. A number of these relays are shown in Fig. 21. The first row of relays records the sign of the number, the sign of the exponent and the tens denominational order of the exponent. The second row of relays is employed to record the units denominational order of the exponent, while the third row of relays represents the relays employed to record the first denominational order of the number and the last row of relays is employed to represent the last denominational order of the number. It is to be understood that additional rows of relays are provided in the storage register, one row of each denominational order and that all of these additional relays are similar to the various relays of each of the rows shown in Fig. 21. Each of the rows of relays, except the first row has seven relays to record the identity of the digit in the respective denominational orders of the number in accordance with a biquinary code.

The operation of relay **21–LK**, as described above, interrupts the locking circuit of all of the relays of the register, both the relays shown in Fig. 21 and the other relays similar to the relays in Fig. 21 not actually shown but only indicated in Fig. 21.

The operation of relay **21A** removes the short circuit from around relay **19–DC3A** thus permitting this relay to operate and lock relay **19–DC3** operated. The release of all of the register relays of storing register A together with the operation of relay A completes a circuit extending from ground **2106** through a set of normal contacts on each of the registering relays of the storage register A, the operated contacts **2107** and then through the break contacts **1504** and the operated contacts **1505** of relay **15–CLRA** to battery through the winding of relay **15–DC1A**.

When and if all of the register relays of the storing register A are released, the above-described circuit is completed for the operation of relay **15–DC1A**.

The release of the register relays in the storing register A together with the operation of relay **21A** completes a circuit for the operation of relay **15–OC1** which circuit extends from battery through the winding of relay **15–OC1** through the operated contacts **1505** of relay **15–DC1A**, the operated contacts **2108** of relay **21A**, then to ground through normal contacts of relays of the storing register A. Relay **15–OC1** in operating completes a circuit for maintaining itself operated from

battery through its winding and its operated locking contact **1506** to ground through the operated contacts **1502** of relay **15–5UP**.

The operation of relay **15–DC1A** completes a circuit for the operation of relay **15–OC5** which circuit extends from battery through the winding of relay **15–OC5**, contacts **1510** of relay **15–DC1A**, contacts **1511** of the operated relay **16–T2A** to ground through contacts **1512** of relay **46–3T**.

Relay **15–OC5** in operating completes a locking circuit for maintaining itself operated under control of relay **15–5UP**. In addition relay **15–OC5** in operating interrupts the circuit of relay **18–SQR** which relay releases and in turn releases relay **16–DC1B**.

With relay **15–5UP** operated and each of the relays **15–OC1**, **15–OC2**, **15–OC3**, **15–OC4** and **15–OC5** operated, a circuit is completed for the operation of relay **18–CTR1**. Relay **18–CTR1** in operating locks operated under control of relay **45–CO** in a circuit from ground through contacts **1806** and **1807** to battery through the winding of relay **18–CTR1**.

The operation of relay **18–CTR1** indicates that the complete order has been executed by the routine control circuits.

In addition, the operation of relay **18–CTR1**, as described above, actuates contacts **1105**. The actuation of contacts **1105** interrupts the locking circuit of relay **11–STG** thus permitting relay **11–STG** to release. The release of relay **11–STG** interrupts the locking circuits of relays **11–UP1** through **11–UP4** and **11–STE5** thus permitting all of these relays to release. The release of relays **45–5UP**, **11–STG**, and **11–UP5** also causes relay **11–UP5** to release. The release of these relays again completes the down-check circuit through contacts of these relays as described above and causes relay **11–STG** to be reoperated.

Relay **18–CTR1** in operating opens contacts **1116** which contacts cause relay **45–5UP** to release. Relay **45–5UP** in releasing completes an obvious circuit for the operation of relay **45–CO1** which relay opens contacts **4655** and removes the battery supply from the right-hand windings of the order relays of Fig. 46. The operation of relay **18–CTR1** also opens contacts **4653** and allows the previously operated order relays, i. e., relays **46–1A**, **46–2T**, **46–3T**, **46–4T** and **46–5B** to release. The release of all of the order relays causes the relays **45–1RC** to **45–5RC** to in turn release and interrupt the locking circuit of relay **45–CO** which relay in turn releases. The release of the order relays as described above also releases the additional or order repeating relays such as **45–41**, **16–T2A** and relay **45–TR1**. The release of relay **45–5UP** interrupts the locking circuit of relay **15–45UP** which in turn releases the locking circuit of relays **19–DC3**, **19–DC3A**, **15–DC1A**, **15–OC1** to **15–OC5**. These relays all release and restore the control circuits to their normal condition.

The release of relay **45–CO** indicates that all of the order relays of Fig. 46 and all of the relays **45–1RC** through **45–5RC** have released and are thus ready to receive another order. The release of relay **45–CO** causes relays **45–CO1** and **18–CTR1** to release. The release of relay **45–CO1** closes contacts **4655** which reconnect battery to the right-hand windings of the order relays of Fig. 46.

The release of relay **18–CTR1** causes contacts **1105** to be closed and completes a circuit for the operation of relay **13–CIS**, which circuit now extends from battery through the winding of relay **13–CIS**, the operated contacts **1304** of relay **10–FHC1**, the operated contacts **3102**, **1301**, the operated contacts **1118** of relay **11–STG**, the break contacts **1119** of relay **12–TC1** and break contacts of each of the relays **11–UP1** through **11–UP5** to ground through the break contacts **1105** and the operated contacts **1106** of relay **7–RG1**.

The operation of relay **13–CIS** completes an obvious circuit for the operation of relay **10–CIS1**. Relay **10–CIS1** in operating removes ground from the code contacts of the depressed key **1012** which causes the relays **900** to **905** to release. The release of these relays completes a circuit for operating relay **12–CT1** as described above which relay locks under control of relay **11–UP1**. The operation of relay **12–CT1** completes an obvious circuit for the operation of the steering relay **11–STE1** which relay connects the contacts of relays **900** through **905** to the left-hand windings of the relays of the first column in Fig. 46. The operation of relay **12–CT1** in addition causes contacts **1119** to be opened which in turn interrupts the operating circuit of relay **13–CIS** which relay then releases and completes a circuit for the operation of the release magnet **10–FFC** of the key-set shown in Fig. 10. The operation of release magnet **10–FFC** releases the key **1012** and the release of key **1012** in turn interrupts the operating circuit of relay **10–FHC1**. The release of relay **10–FHC1**, in turn, interrupts the locking circuit of relay **10–CIS1** which relay releases and thus returns the key-set to the condition where it is ready for recording and entering an additional order in the computer mechanism.

Thus the key-set shown in Fig. 10 may be employed to enter each one of the five parts of an order into the computing mechanism after which the mechanism will execute the order and then return the key-set to the condition where it is ready for operation of entering another order or number into a computing mechanism in the manner described above.

When it is desired to release control of the computing mechanism from the key-set, key **10–ROK** will be restored to its normal or unoperated position thus releasing relay **10–ROK**. The release of relay **10–ROK** in turn causes relays **10–ROK1**, **10–ROK2**, and **11–KEY** to release. The release of relay **11–KEY** in turn releases relay **11–STG** and relay **11–STG** causes any of the relays **11–UP1** through **11–UP4**; **12–CT1** through **12–CT4**; and **11–SE1** through **11–STE5** to release thus restoring the circuits to their normal condition.

If an error is made in entering a portion of an order key **10–ROK** is released which restores the circuits to normal as described above and thus clears out the error and all the other parts of the order previously entered. Then key **10–ROK** is reoperated and the order correctly entered in the manner described above.

Storage tape control circuits

A storage tape control circuit is employed to control the storage tape transmitter. As shown in Fig. 23 two storage tape control circuits are provided. A storage tape control circuit A is provided for controlling the A tape control transmitter and a storage tape B control circuit is provided for controlling the B storage tape transmitter. In addition, the B storage tape control circuit is arranged to control the C storage tape transmitter when the C transmitter is substituted for the B transmitter under control of the special orders as described herein. The control circuits are provided to control the forward and backward movement of the tape through the reversible tape control transmitter or tape reader. In controlling the movement of the tape through the transmitters, it is necessary to recognize the symbols for page identification, block identification and reset identification and to compare block and page numbers with numbers stored in block and page registers and to translate the information stored in the proper place on the tape into bi-quinary codes and transmit the information to the corresponding tape storage registers. Fig. 24 shows details of the tape storage register.

Figs. 53 through 62 when arranged as shown in Fig. 52 show details of the B storage tape control circuit together with the manner in which these circuits cooperate with the

other circuits of the system. Attention is directed to Fig. 61 which shows a portion of the circuits shown in Fig. 23 and indicates the connections of the tape storage register shown in Fig. 24. In other words, the circuits shown in Figs. 53 through 62 may be substituted for the tape storage control circuit indicated in Fig. 23 assuming, of course, that Fig. 24 is connected to the X multiple, the Y multiple and the numerous control circuits extending to the routine control circuit as shown in the drawing. These control circuits are similar to the storage control circuits described with reference to Fig. 21 and the routine control circuits.

Briefly, in employing the storage tape transmitters in the computer, it is necessary first to enter the proper page or block number or both in the corresponding page or block registers. The detailed description herein is directed to the storage tape B transmitter and the storage B tape control circuit so that reference will likewise be made to the block B register and the page B register. It is to be understood that the operation of the A control circuit which cooperates with the A page register and the A block register and the A tape control transmitter or reader is similar to that set forth herein with respect to the B tape except that no provision is made to substitute any other transmitter for the A transmitter or to control any other transmitter than the A transmitter from the storage tape control circuit A. It is to be understood, of course, that when desired such additional transmitters may be controlled from the A tape storage control circuit similar to that described herein with reference to the B storage tape control circuit.

Thus, in order to condition the B tape reader or storage tape control circuit, it is necessary to enter in either the B page or block register a number which designates the particular sections in the B storage tape. Then it is necessary to enter an order in the computer directing the storage tape B control circuit to hunt in, on, or over, the storage tape for the corresponding page, block or page and block number entered in this tape. Upon locating the number the storage tape control circuit is then arranged to convey the subsequent number to the storage tape register as shown in Fig. 24. When this register is cleared the storage tape control circuit is advanced so that the next succeeding number in the storage tape B is then transferred to the storage tape register B. The above process is then repeated as long as desired or until an $\overline{\text{ENC}}$ signal is encountered in the storage tape at which time the operation of the computer is directed to the next problem or the next portion of a given problem or the next portion of the problem control tape or the next order of a formula.

The storage tape control circuit is also arranged to cooperate with the key-set shown in Fig. 10 so that the number stored in the tape storage register such as shown in Fig. 24 may be cleared from the key-set and another number substituted therein from the key-set. This arrangement is provided to permit the correction of numbers encountered by operation of the keys of the key-set shown in Fig. 10. For example, a number may be cleared from the storage register A shown in Fig. 21 by suitable operation of the key-set shown in Fig. 10 and then the proper number entered from the key-set in Fig. 10 in the B tape storage register shown in Fig. 24 and thereafter the key-set employed to enter another order in the routine control circuits for transferring the number set in the B tape storage register shown in Fig. 24 to the A storage register shown in Fig. 21. The operation of this system may then be advanced when a new number and the operation of the routine control circuits, formula director circuits and other circuits are resumed and proceed in their normal manner. The following table shows the numerical values of the various digits, the corresponding codes perforated in the tape, the translator relays operated in response to these perforations and the translated bi-quinary leads grounded:

Numerical Value	3 Hole Tape Code	Translator Relays Operated	Bi-quinary Leads Grounded
0	1-2-3	(NO) (1') (2') (3')	T00—T0
1	1-2-4	(NO) (1') (2') (4')	T00-T1
2	1-2-5	(NO) (1') (2') (5')	T00-T2
3	1-3-4	(NO) (1') (3') (4')	T00—T3
4	1-3-5	(NO) (1') (3') (5')	T00—T4
5	1-4-5	(NO) (1') (4') (5')	T5—T0
6	2-3-4	(NO) (2') (3') (4')	T5—T1
7	2-3-5	(NO) (2') (3') (5')	T5—T2
8	2-4-5	(NO) (2') (4') (5')	T5—T3
9	3-4-5	(NO) (3') (4') (5')	T5—T4

In addition, the following tape shows the switching or control codes perforated in the storage tape and the functions performed by these codes when sensed by the tape transmitter or tape reader:

3 Hole Tape Code	Function
012	Block Identification.
013	Recycle Code for Storage Transmitter.
014	Page Identification.
015	Data Number Check.
023	Sign of Number Negative.
024	Sign of Number Positive.
045	Tape Argument Check.
1 Hole Tape Code	
4	End of Numbers Check.

In order to properly locate and identify the various sections of the storage tape a three-digit adder is provided. Inasmuch as most of the page and tape numbers are three-digit numbers only a three-digit adder is provided. However, provision has been made to employ a larger number of digits by repeatedly using the adder first for the first digits of a number and then for a succeeding group of digits. The numbers are entered into the page and block registers in their normal manner. These registers form a part of the adder and the page and block numbers from the tape are read into the adder in the form of their nine's complement. These two numbers are added together and then one is added to the sum by grounding the carry one lead of the units digit or order of the adder. If the page or block number entered into the tape and sensed by the tape reader corresponds with the number in the corresponding register, then the sum will be zero indicating that the proper section of the tape is located at the reader. If the sum is not zero, then it is necessary to determine whether the sum is positive or negative. If the sum is positive, the tape is advanced and if the sum is negative the tape is reversed. This process is repeated until the proper section of the tape is found. Each of the storage tapes A, B and C after it passes out of the perforator or recording mechanism is threated through a tape transmitter or reading mechanism. While these mechanisms are located adjacent each other, nevertheless the recording and reading positions are separated by an appreciable distance, of the order of five to ten inches, so an appreciable length of tape extends between these positions. Now if the computer is seeking information recorded in this portion of the tape, the tape will become taut between these two positions. If the tape between the reader or transmitter and the perforating or reperforating mechanism becomes taut in the hunting process, then provision is made to insert a number of by-pass perforations or punches in the tape to permit the characters or symbols last stored in the tape to be advanced through the tape reader.

Assume now that a suitable number has been entered into the B block register and that an order has been entered into the routine control circuits which direct the

storage tape B control circuit to hunt for the block number entered into the B block register.

When the computer is set into operation and relays 8–ST, 8–ST1, 8–ST2, 8–ST3, 8–ST4 and relays 7–RG and 7–RG1 operated as described above, contacts 2301 of relay 7–RG1 and contacts 2302 and 2303 of relay 8–ST3 close and apply ground to the STG lead extending to both the storage tape control A and the storage tape control B circuits. Ground applied to the STG lead of the tape storage control circuit B extends from Fig. 59 through Figs. 58, 57 to Fig. 62 to battery through the winding of relay 62–SG1. Relay 62–SG1 connects the winding of relay 62–RDC to the down-check circuit extending serially through break contacts of each of the register and numerous control relays of the tape storage register over the D. C. lead shown in Fig. 61 and also in Fig. 23. If the down-check circuit is completed, relay 62–RDC operates and closes its locking contact 6201 for maintaining itself operated independently of the down-check circuit through the register relays.

The tape storage register circuit remains in this condition until an order is entered into the routine control circuits for directing the B routine control circuit to hunt for a number previously entered into the block register by the routine control circuits. The order directing the tape control circuit to hunt for a block number applies ground to the B1 lead from the routine control circuit. If an order had been entered into the routine control circuit directing that the tape control circuit hunt for a page number then the B1 lead would be grounded. Similarly, if a special order is entered into the routine control circuits directing that the tape be reset then the RSTB lead will be grounded. Under the circumstances assumed above wherein an order is entered into the routine control circuits for directing the storage tape control circuits to hunt for a block number, ground applied to the B1 lead extends through the break contacts 5901 and 5902 of relay 59–HBN and through the break contacts 5903 of relay 56–PIC to battery through the winding of relay 59–HBN. Relay 59–HBN in operating closes its contacts 5904 for maintaining itself operated to a circuit extending through the operated contacts 5905 of relay 62–SG1. Relay 59–HBN in operating closes contacts 5901 which contacts apply the ground received over the B1 lead from the routine control circuit and apply this same ground to the BIR lead. The ground applied to the BIR lead indicates that the tape storage control circuits have received the ground over the BI lead and have responded to this ground. The routine control circuits then respond to the ground received over the BIR lead and advance and are restored to normal awaiting another order. Meantime, the tape storage control circuits proceed in the following manner to locate a proper position on the storage tape and then to fill the tape storage register from the number recorded in the B storage tape as described hereinafter.

Relay 59–HBN closes contacts 5905 which contacts complete a circuit for the operation of relay 59–B1 which circuit extends from battery through the winding of relay 59–B1, operated contacts 5905 of relay 59–HBN, break contacts 5906 through a down-check circuit to the connecting relays of the three-digit adder shown in Fig. 60 through contacts 5907 of relay 62–SG2, contacts 5908 of relay 59–TCK, contacts 5909 of relay 62–RDC to ground through contacts 5910 of relay 62–SG1.

The operation of relay 59–B1 closes contacts 5911 which contacts complete an obvious circuit for the operation of relay 59–TCK and also apply ground to the switching or cut-through relays of the three-digit adder employed to determine which direction to take. Relay 59–TCK closes contacts 2304 which contacts apply ground to the locking circuit of the register relays of the tape storage tape register shown in Fig. 24.

The operation of relay 59–B1 together with the operation of relay 59–HBN completes circuits for operating the switching or cut-through relays for connecting the relays in the adder circuits shown in Fig. 60 with the relays of either the B page or the B block register. With relay 59–HBN operated, a circuit is completed for the operation of relay 60–BCA over the lead BCAW of the A digit of the binary adder shown in Fig. 60. A circuit for the operation of relay 60–BCA extends from battery through the winding of relay 60–BCA over lead BCAW through the operated contacts 5912 to ground through the operated contacts 5911 of relay 59–B1. Likewise, similar circuits are completed over leads BCAW and BCCW for operating corresponding relays 60–BCB and 60–BCC, not shown in the drawing, for the B and C digits. These connecting relays in operating extend connections from the B block register to the adder circuits shown in Fig. 60.

The operation of relay 59–TCK in addition closes contacts 6202 which contacts complete a circuit for the operation of relay 62–SG2 which circuit extends from battery through the winding of relay 62–SG2, break contacts 6203 of relay 53–ICS4, break contacts 6204 of relay 53–ICS3, break contacts 6205 and 6206 of relays 53–TAB and 55–TAA, the operated contacts 6202 to ground over the TSG lead extending to the routine control circuit and through contacts 2303 of relay 8–ST3 and contacts 2301 of relay 7–RC1. Relay 62–SG2 in operating connects locking ground to numerous locking contacts of the storage tape control circuit and in addition closes contacts 5401.

The closure of contacts 5401 completes a circuit for the operation of relay 54–HSC1 which circuit extends from battery through the winding of the high speed control relay 54–HSC1, through break contacts 5403 of relay 54–SSC, break contacts 5402 of relay 53–ICS4 to ground through the operated contacts 5401 of relay 62–SG2. The operation of relay 54–HSC1 together with the operation of relay 59–B1 conditions the contacts of the B storage transmitter or tape reader to hunt or scan the storage tape for the block identification or indication code BI which comprises perforations in the 0, 1 and 2 positions in the tape. Had the order received from the routine control circuit required that the storage control circuit hunt for a page number, then the 59–P1 relay would operate instead of the 59–B1 relay and the operation of the 59–P1 relay together with the operation of relay 54–HSC1 would condition the tape transmitter for hunting for the page identification code which has perforations in the 0, 1 and 4 positions.

Had the order received from the routine control circuit been a reset order in response to a special order entered into the routine control circuit, then relay 59–R1 would operate instead of relay 59–B1 and relay 59–B1 would condition the tape transmitter contacts to hunt for the recycle code which comprises a perforation in the zero, first and third positions in the tape.

The B tape transmitter is shown in Fig. 4B and has been repeated in Fig. 53 in order to facilitate the understanding of the operation of the tape transmitter control circuits.

Under the assumed conditions, relays 59–B1 and 59–R1 will be released and relay 59–B1 operated. As a result a circuit is completed through the break contacts 5404 of relay 59–B1, the break contacts 5405 of relay 59–B1, the operated contacts 5406 of relay 59–B1, the operated contacts 5407 of relay 54–HSC1, over conductor 23 to the tape transmitter or reader through the universal contacts and then through the tape control contacts of the transmitter or reader to either relay 53–HSC or to relay 53–ISC1. The circuits are conditioned to hunt for the block code indication having perforations in the 0, 1 and 2 positions on the tape. If such a code is over the contact pins of the transmitter at this time, then relay 53–HSC will not operate but relay 53–ISC1 does operate. If any other code is over the transmitter pins at this time

then relay 53–HSC operates. For example, assume that a code is over the sensing pins of the transmitter which does not have a perforation or punch in the zero position. Under these circumstances, a circuit extends from the universal contacts and to the armature of the zero contact pin, then over conductor 7, the operated contacts 5304 of relay 54–HSC1, the break contacts 5302 of relay 53–ISB1, contacts 5301 of relay 53–ISCB to battery through the right-hand winding of relay 53–HSC causing relay 53–HSC to operate. Again assume that the code over the contact pins has a perforation in the zero, the first and the fifth position in the tape. Under these circumstances the ground connected to the universal contacts of the circuit described above extends through the operated zero contacts over conductor 1, the operated contacts 5408 of relay 54–HSC1, over conductor 14 through the operated one of the tape control contacts, over conductor 2 of the operated contacts 5409 of relay 54–HSC1, the operated contacts 5410 of relay 59–B1 and contacts 5412 of relay 54–HSC1, over conductor 15, the normal No. 2 tape control contacts and over conductor 9 through contacts 5305 of relay 54–HSC1, contacts 5306 of relay 53–ISB1 and contacts 5307 of relay 53–ISB2 to battery through the left-hand winding of relay 53–HSC. Similar circuits may be traced from the ground connected to the universal contacts and through the universal contacts which are closed by the readers at rest and through the tape control contacts for the other codes stored in the tape and listed hereinbefore.

The operation of relay 53–HSC at this time, assuming some code other than the block identity code BI is over the sensing pins, completes a circuit for operating the transmitter or tape reader of the clutch magnet which circuit extends from battery through the clutch magnet and over conductor 22 through the operated contacts of relay 54–STS, the break contacts 5413 of relay 55–ALM, the break contacts 5414 of relay 53–ISC1, the break contacts 5415 of relay 53–ISC4, the operated contacts 5416 of relay 53–HSC to ground through the break contacts 5417 of relay 54–STC.

Relay 54–STC is operated at this time since it is assumed that the tape control contacts of the transmitter are closed because it is assumed that sufficient tape has been perforated with problem data to cause these contacts to close. The operation of the transmitter clutch magnet releases the tape reader or transmitter which transmitter advances and interrupts the universal contacts and then withdraws the sensing pins, advances the tape and releases the sensing pins so that they may sense the next code combination. Relay 53–HSC, however, does not release at this time because it is maintained operated in a locking circuit from battery through its right-hand winding and its operated contacts 5308, the break contacts 5308 of relay 53–ISC4 to ground through the operated contacts 5310 of relay 62–SG2. As a result the clutch magnet of the tape transmitter or reader remains operated and the above cycle of operations of the transmitter or tape reader is repeated. This cycle of operations continues to be repeated until the block identification code BI comprising the perforation or punch in the 0, 1 and 2 positions in the tape is sensed by the sensing mechanism. At this time a circuit will be completed for the operation of relay 53–ISC1 which circuit extends from battery through the winding of relay 53–ISC1, the break contacts 5311 of relay 53–TRV, the break contacts 5312 of relay 53–ISB2, the operated contacts 5313 of relay 53–HSC, the operated contacts 5314 of relay 54–HSC1 over conductor 3 to the tape reader through the operated contacts 2 of the tape reader over conductor 15 and then through the operated contacts 5412, 5411 and 5409 of relays 54–HSC1, 59–B1 and 54–HSC, respectively, and then over conductor 2 to the B tape transmitter through the operated No. 1 contacts of this transmitter, then over conductor 14 and through the operated contacts 5408 of relay 54–HSC1 and over conductor 1 to the tape reader and then through the operated zero contacts of the tape reader to the universal contacts of the tape reader over conductor 23 through contacts 5407 of relay 54–HSC1, the operated contacts 5406 of relay 59–B1, the break contacts 5405 of relay 59–R1 to ground through the break contacts 5404 of relay 59–B1.

Relay 53–ISC1 in operating actuates contacts 5414 which contacts interrupt the clutch magnet of the B tape transmitter or reader and allow this magnet to release. The clutch magnet may release with the sensing pins still sensing the block identification code which causes the operation of relay 53–ISC1. The clutch magnet also may not release in time to so stop the transmitter in which case the transmitter would be advanced to its next stop position. However, inasmuch as the block identification codes are always repeated twice, the second block identification code would then be over the tape sensing pins when the B tape reader or transmitter reaches its stop position. One of the reasons for repeating the block identification code is to allow sufficient time for the transmitter to come to rest after high speed hunting as described herein. The page identification code is also repeated twice for similar reasons.

The operation of relay 53–ISC1 also closes contacts 5315 which contacts complete an obvious circuit for the operation of relay 53–ISC3. Relay 53–ISC3 in operating closes contacts 5316 and 5317. Contacts 5316 in operating complete an obvious circuit for maintaining relay 53–ISC3 operated under control of contacts 5318 of relay 62–SG2 and contacts 5317 complete an obvious circuit for the operation of relay 53–ISC4.

Relay 53–ISC in operating actuates contacts 5309 and 5402. The actuation of contacts 5402 interrupts the operating circuit of relay 54–HSC1, thus permitting this relay to release. The actuation of contacts 5309 together with the release of contacts 5305, 5304 and 5407 of relay 54–HSC1 interrupt the locking and operating circuits of relay 53–HSC, thus permitting this relay to release. The release of contacts 5407 and of relay 54–HSC1 and contacts 5313 of relay 53–HSC interrupts the operating circuit of relay 53–ISC1, thus permitting this relay to release.

The release of relay 54–HSCI causes contacts 5418 to close and complete a circuit for the operation of the slow speed control relay 54–SSC. The above-described release of relay 54–HSC1 and the operation of relay 54–SSC change the connections to the tape control contacts so that these contacts are now in condition to respond to and scan each and every code combination stored in the tape. Thus, the left-hand or operating windings of relays 54–0 through 54–5 and 54–NO are connected to the tape control contacts. The left-hand winding of relay 54–0 is connected to the front contact and the left-hand winding of relay 54–NO is connected to the back or break contact of the zero tape control contacts and the left-hand windings of relays 54–1 through 54–5 are connected to the armatures of the tape control contacts 1 through 5, inclusive.

The operation of relay 53–ISC3 as described above closes contacts 5801 which contacts complete a down-check circuit which extends serially through break contacts on each of the tape control relays of each of the three digits of the adder circuit shown in Fig. 60 for the operation of relay 58–TADC. Relay 58–TADC closes its locking contacts 5802 and then completes an obvious circuit for maintaining itself operated under control of contacts 5803 of relay 62–SP3 and contacts 5801 of relay 53–ISC3. The operation of relay 58–TADC closes contacts 6207 which contacts complete a down-check circuit through the steering relays of the tape control circuit for the operation of relay 62–SDC. The completion of this down-check circuit insures that all of the steering relays are in their normal position at this time. Relay 62–SDC closes its locking contacts 6208 for maintaining itself operated in an obvious circuit extending

through contacts 6207 of relay 58–TADC, contacts 6209 of relay 59–TCK and contacts 6210 of relay 62–RDC. The release of relay 53–HSC, the operation of relay 54–SSC and the operation of relay 62–SDC complete a circuit for the operation of relay 56–AA which circuit extends from battery through the winding of relay 56–AA, the break contacts 5601 of relay 55–AAB, the break contacts 5501 of relay 55–AAB, the break contacts 5602 of relay 56–AA', the break contacts 5603 of relay 62–STT, the operated contacts 5604 of relay 62–SDC through a down-check circuit extending through break contacts on each of the code relays 54–5' through 54–0', contacts 5422 of relay 54–CMC, the operated contacts 5419 of relay 54–SSC, the break contacts 5420 and 5421 of relays 54–HSC and 53–TRV, respectively.

Relay 56–AA operates in the above-described circuit and completes a circuit for maintaining itself operated from ground through the operated contacts 5605 of relay 62–SDC, the break contacts 5606 of relay 56–AA' and the operated contacts of relay 56–AA, the break contacts 5601 of relay 55–AAB. The operation of relay 56–AA' also connects ground from the contacts 5605 of relay 62–SDC, the break contcts 5606 of relay 56–AA' and the operated contacts of relay 56–AA over the *b* lead extending through Fig. 55 to Fig. 54 and then through the break contacts 5423 of relay 59–KC and over conductor 30 through the station connector circuit to the B tape transmitter or reader through the auxiliary contacts thereof and over conductor 29 and through the break contacts 5424 to battery through the winding of relay 54–CMC. Relay 54–CMC closes its contacts 5425 which connect the ground on the *b* lead to the other terminal of relay 54–CMC1. The ground from the *b* lead also extends through the break contacts 5426 of relay 54–CMC1, the operated contacts 5427 of relay 54–SSC, over conductor 23 to the universal contacts of the B tape transmitter and then through the armature of the zero tape control contact and also over conductor 13 through contacts 5427 of relay 54–SSC to the No. 3 conductor extending to the front contact of the tape control contacts 2, 3 and 5, the operated contacts 5428 of relay 54–SSC to conductor 5 extending to the front contacts of the No. 4 tape control contacts and through contacts 5429 of relay 54–SSC over conductor 2 to the front contacts of the No. 1 tape control contacts, thus applying ground to all of the tape control contacts. In addition, conductor 13 also extends through contacts 5430 of relay 54–SSC to the winding of relay 54–UC.

The ground thus applied to each of the tape control contacts extends through the operated ones of these contacts to battery through the left-hand windings of the code relays 54–0 through 54–5 and 54–NO, thus operating these relays in accordance with the perforations over the sensing pins. The operation of the code relays 54–0 through 54–5 completes obvious circuits for maintaining themselves operated under control of each of the steering relays and also completes obvious circuits for operating the corresponding relays 54–0' through 54–5'.

In addition, relay 54–UC also operates in the above-described circuit and completes a circuit for the operation of the clutch magnet of the B tape transmitter which circuit extends from battery through the winding of the B tape transmitter clutch magnet over conductor 22 through the operated contacts 5431 of relay 54–DTS, the break contacts 5413 of relay 55–ALM, break contacts 5414 of relay 54–ISC1, the operated contacts 5415 of relay 53–ISC4, the operated contacts 5432 of relay 54–CMC, the break contacts 5433 of relay 54–CMC1, the operated contacts 5434 of relay 54–UC to ground over the *b* lead through the operated contacts of relay 56–AA, the break contacts 5602 of relay 56–AA' and the operated contacts 5605 of relay 62–SDC. The operation of the clutch magnet at this time releases the transmitter mechanism and causes it to advance. In advancing, the mechanism will first open the auxiliary contacts which remove ground from the above-described circuit connected between the mid-point windings of relay 54–CMC and relay 54–CMC1, thus permitting relay 54–CMC to operate. A short interval of time later the universal contacts will open and cause relay 54–UC to release and also remove ground from the tape control contacts of the circuits described above. Relays 54–0 through 54–5, however, are maintained operated at this time under control of relay 56–AA.

Under the assumed conditions, with the transmitter previously stopped with either the first or the second of the block identification codes over its sensing pins, relays 54–0, 54–1 and 54–2 as well as relays 54–0', 54–1' and 54–2' will be operated.

Under these conditions, the operation of relay 54–CMC1 and the release of relay 54–UC complete a circuit through the respective contacts 5502 and 5503, contacts 5504, 5505, 5506 and 5507 for the operation of relay 55–AAB. Relay 55–AAB operates in the above-described circuit and actuates contacts 5501 for maintaining themselves operated under control of the operated contacts of relay 56–AA. The actuation of contacts 5501 of relay 55–AAB also interrupts the locking circuit of relay 56–AA and permits relay 56–AA to release. Relay 56–AA in releasing interrupts the locking circuit of relay 55–AAB, thus permitting this relay to release and restore the circuits of relay 56–AA to their initial condition as described above. The release of relay 56–AA also removes ground from the *b* lead, thus interrupting the locking or holding circuits for relays 54–CMC and 54–CMC1, permitting relays 54–CMC and 54–CMC1 to release. The release of relay 56–AA also interrupts the locking circuit for the code relays 54–0, 54–1 and 54–2, permitting these relays to release and in turn release relays 54–0', 54–1' and 54–2'. The release of the code relays 54–0', 54–1' and 54–2' again completes the above-described circuit for the operation of relay 56–AA which relay reoperates and applies ground to the *b* lead.

If the succeeding code advanced over the code pins on the tape transmitter is another block identification code then the above cycle of operations is repeated. However, if the succeeding code is a block number and as the tape transmitter approaches the rest position with the application of ground to the *b* lead completes the above-described circuit for the operation of relay 54–CMC. About the time the tape auxiliary contacts close, the tape sensing contacts also close and a short time later the universal contacts close and apply ground to the tape sensing contacts in the above-described circuits and also complete a circuit for the operation of relay 54–UC. The application of ground to the tape sensing contacts causes the code relays to operate and lock operated under control of relay 56–AA as described above and cause the corresponding code relays 54–0' through 54–5' to operate.

The operation of relay 54–UC at this time again completes a circuit for operating the clutch magnet of the B transmitter which magnet operates and releases the clutch mechanism which then advances to its next stop position. In so advancing the universal contacts first open and again permit relay 54–CMC1 to operate and a short interval of time later the universal contacts open and interrupt the clutch magnet which will permit the transmitter to come to rest at its next stop position. The opening of the universal contacts also locks ground from the tape control contacts which contacts are then retracted and the tape advanced and the contacts later released to sense the next position in the tape. However, ground is not reapplied to these contacts so that the reclosure of these tape control contacts at this time is without effect. The code relays 54–0 through 54–5 and 54–NO are not released but are maintained operated with the identity of the digit of the first denominational order of the block number registered upon these relays.

As the tape reader or transmitter B advances after

having sensed the first order of the block number in the tape the auxiliary contacts open and complete a circuit for operating relay **54**–CMC1 which relay interrupts the circuit of the clutch magnet, thus insuring that the transmitter or reader will stop in its next stop position. A short interval of time later the universal contacts open and remove ground from the tape control contacts and thus interrupt the winding of the code relays as described above. In addition, the opening of the universal contacts permits relay **54**–UC to release which relay releases and connects ground to contacts of the code and translating relays **54**–0′ through **54**–5′. Under the assumed circumstances with the relays **54**–0′ through **54**–5′ having entered upon them the identity or magnitude of the digit of the first denominational order of the block number, relay **54**–NO will also be operated because as set forth in the table of codes for the numbers, all of the codes representing one of the digit values have no perforation in the zero position. Consequently relay **54**–NO operates on each of the codes representing a digit value. As a result, contacts **5508** close and complete circuits from ground through contacts **5502** and **5503** of relays **54**–CMC1 and **54**–UC, respectively to the translating contacts of the code relays **54**–0 through **54**–5 and **54**–0′ through **54**–5′. These grounds are applied to the bi-quinary leads **T00**, **T5** and **T0** through **T4** as also set forth in the code table herein in accordance with the identity of the digit values shown in the table and set up on the code relays. The bi-quinary leads identified above extend from Fig. 55 through Figs. 56, 57 and 58. At this time, relay **56**–AA is operated as described above with the result that the contacts **5810** through **5816** of relay **55**–AA are operated and extend the bi-quinary leads to the windings of the tens denominational order of the three-digit adder shown in Fig. 60, in other words, relays **60**–TA**00**, **60**–TA**5** and **60**–TA**0** through **60**–TA**4**. The above relays of the adder **60**–TA**00** through **60**–TA**4** which are thus operated are locked operated under control of contacts **6001** of relay **58**–TADC. The operation of the above-identified relays **60**–TA**00** through **60**–TA**4** of the adder complete an up-check circuit over lead TUA, assuming, of course, that one of the relays **60**–TA**0** and **60**–TA**5** are operated and one of the relays **60**–TA**0** through **60**–TA**4** are operated. The lead TUA extends from Fig. 60 through Figs. 58 and 57 to Fig. 56 and connects ground to the winding of relay **56**–AA′. Relay **56**–AA′ in operating actuates contacts **5606** and completes a circuit for maintaining itself operated under control of contacts **5605** of relay **62**–SDC and interrupts the locking circuit of relay **56**–AA. Inasmuch as the operating circuit of relay **56**–AA was interrupted when contacts **5422** of relay **54**–CMC operated, relay **56**–AA now releases and removes ground from the *b* lead as described herein. As a result, relays **54**–CMC and **54**–CMC1 release. In addition, the release of relay **56**–AA also interrupts the locking circuit for the code relays **54**–0 through **54**–5 and **54**–NO, thus permitting these relays to release. The release of the corresponding code relays **54**–0′ through **54**–5′ together with the release of relay **54**–CMC and the operation of relay **56**–AA′ complete a circuit for the operation of relay **56**–AB which relay operates and connects the bi-quinary leads **T00** through **T4** to the B digit of the adder and causes the tape reading circuits and control circuits to advance in the same manner as described above with respect to relay **56**–AA. Consequently, the identity of the digit of the next denominational order of the block number is entered into the B digit relays of the adder in Fig. 60. In a similar manner, the magnitude of the digit in the third denominational order of a block number entered in the B tape is read and entered upon the C digit relays of the adder circuit in Fig. 60.

It should be noted that in entering the magnitude of the digits from the tape in the relays of the adder the nine's complement of the digit value is entered into the adder. These complements are then added with the number entered into the B block register. In addition the carry 1 read into the lowest denominational order is permanently grounded so that if the block number read from the tape corresponds with the block number in the adder the sum will be zero. If the number in the tape is less than the number in the adder the output sum will be plus and if the number from the tape is greater than the number in the adder the output or sum will be a negative number. The adder is arranged to provide only three outputs since the actual magnitude of the number is not desired. Instead, it is only desired to know which of the three above conditions exists. Consequently, the adder is arranged to provide only three different outputs after each of the digits have been added and the carries added in as required by the sum.

The code following the last or third denominational order of the block number entered in the tape will be a TAC code which has perforations or punches in the zero, fourth and fifth positions. In order to register the TAC code on the code relays **54**–0 through **54**–5 and **54**–NO as well as relays **54**–0′ through **54**–5′, relay **56**–CA operates in the above-described circuit extending from ground through contacts **5421**, **5420**, **5419**, **5422** and break contacts of the code relays **54**–0′ through **54**–5′, etc. and relay **56**–CA in operating causes ground to be again applied to the *b* lead which ground is applied to the tape control contacts and causes the TAC code to be entered upon the code relays **54**–0 through **54**–5 and also causes the advance of the tape transmitter to its next stop position where the next code in the tape is positioned under the sensing pins. Meantime, relays **54**–0′ through **54**–5′ have the TAC code entered upon them and contacts **5502** are operated by the operation of relay **54**–CMC1 when the auxiliary contacts of the tape transmitter open and contacts **5503** of relay **54**–CU close when the universal contacts of the tape transmitter close. Consequently, a circuit is completed from ground through contacts **5511** of relay **54**–0′, contacts **5509** of relay **54**–4′ and contacts **5510** of relay **54**–5′ contacts **5512** of relay **56**–CA to battery through the winding of relay **55**–CAA which relay **56**–CAA operates in the above-described circuit.

By this time the adder will have had sufficient time to obtain the sum of a block number from the block register B and the block number entered upon the B tape and transferred to the tape control registers of the adders shown in Fig. 60. For a sum of zero the **60**–AO, **60**–BO relays operate. For a sum other than zero one contact of all the relays **60**–CNO, **60**–BNO and **60**–ANO will operate. Consequently, if the sum is zero a series circuit through operated contacts **5606** of relay **60**–CO, contacts **5607** of relay **60**–AO and contacts **5608** of relay **60**–BO operate and compete a series chain circuit through these contacts as will be described hereinafter. If the sum is not zero then the circuit is completed through one or more of the contacts **6211** of relay **60**–CNO, contacts **6212** of relay **60**–BNO or contacts **6213** of relay **60**–ANO, any of which contacts will complete an obvious circuit for the operation of relay **62**–SNC. Relay **62**–SNC operates and closes contacts **6001** and **6002**. If the sum is positive then relay **60**–AO will be operated by ground applied to its upper winding terminal or relay **60**–ANO will be operated by ground applied to its left-hand winding. In either event, the grounds applied to either the winding of relay **60**–AC or the left-hand winding of relay **60**–ANO are applied through the operated contacts **6001** of relay **62**–SNC to a conductor extending through the break contacts **5513** of relay **62**–ST2 to the winding of relay **55**–SP, thus causing relay **55**–SP to operate. On the other hand, if the sum is negative, then relay **60**–ANO will be operated on its right-hand winding. The ground for operating this relay is connected through the contacts **6002** of relay **62**–SNC through the break contacts **5609** of relay **62**–SP2 and through the contacts **5319** of relay

55–CAA and through the winding of relay 53–TAB to battery.

Assume first that the sum from the adder of Fig. 60 is positive so that relay 55–SP operates in the above-described circuit. The operation of relay 55–SP closes contacts 6214 of relay 55–SP and completes an obvious circuit for the operation of relay 62–SP1. Relay 62–SP1 in operating completes an obvious circuit for locking itself under control of contacts 6215 of relay 62–SG2 and in addition completes a circuit for the operation of relay 62–SP3 from battery through the winding of relay 62–SP3, the break contacts 6216 of relay 62–SP2, the operated contacts 6217 of relay 55–CAA and the operated contacts 6218 of relay 62–SP1. Relay 62–SP3 in operating completes an obvious circuit for maintaining itself operated under control of contacts 6219 of relay 58–TADC. The operation of relay 62–SP3 actuates contacts 5803 of relay 62–SP3, thus interrupting the locking circuit of relay 58–TADC and allowing relay 58–TADC to release. The release of relay 58–TADC opens contacts 6219 and thus causes relay 62–SP3 to release. The release of relay 58–TADC opens contacts 6001 and thus causes the release of all of the tape argument relays of the adder 60–TA00 through 60–TA4 for the A digit and corresponding tape argument relays for the B and C digits, thus restoring these relays to normal and also interrupting the above-described operating circuit for relay 55–SP.

The release of relay 58–TADC opens contacts 6207 and thus interrupts the locking circuit of relay 62–SDC. Relay 62–SDC in release opens contacts 5605 and contacts 5610 of relay 62–SDC. The opening of these contacts releases the previously operated steering relays 56–AA', 56–AB' and 56–AC' as well as relay 56–CA, thus restoring the steering chain circuit to its idle or normal condition. The release of relay 55–SP restores contacts 6214 to normal and thus completes an obvious circuit for the operation of relay 62–SP2. The above-described release of relay 62–SDC and the release of relay 56–CA removes ground from the *b* lead and thus permits relays 54–CMC and 54–CMC1 to release. The release of relay 56–CA also interrupts the locking circuit of the code relays 54–0 through 54–5 and 54–NO, thus causing these relays to release and release the corresponding relays 54–0' through 54–5', the release of which relays again completes the above-described circuit for the operation of relay 56–AA. Relay 56–AA in operating again grounds the *b* lead which causes the next code on the tape relays to be transferred to the code relays 54–0 through 54–5 and 54–NO. In addition, relay 54–CMC is operated and the *b* tape transmitter clutch magnet operated to advance the transmitter. The transmitter in advancing first interrupts the auxiliary contacts which permit relay 54–CMC to operate and then opens the universal contacts which contacts disconnect ground from the code contacts of the tape transmitter and also permit the release of relay 54–UC. The code relays 54–0 through 54–5 and 54–NO, however, which were operated under control of the setting of the tape sensing pins are not released. As before, relays 54–0' through 54–5' are also positioned in accordance with the succeeding code. Assume that the next code is another TAC code as is the usual case with the ordinary type of block numbers entered in the B tape, then the code relays will be positioned in accordance with the TAC code, namely relays 54–0, 54–4, 54–5 as well as relays 54–0', 54–4' and 54–5' will be operated. Consequently, upon the operation of relay 54–CMC1 and the release of relay 54–UC as described above a circuit is again completed through contacts 5502, 5503, 5511, 5509, 5510, contacts 5527 of relay 56–AA, contacts 5514 of relay 62–SP1, and contacts 5528 of relay 55–TAA to battery through the winding of relay 55–TAA. The operation of relay 55–TAA indicates that the block number read from the tape was too low and indicates that the control circuits should search for the next block number. The operation of relay 55–TAA opens contacts 6206 and thus interrupts the locking circuit of relay 62–SG2 whereupon relay 62–SG2 releases and interrupts numerous locking circuits of relays of the control circuit including the circuit for maintaining relay 54–SSC operated which relay releases. The release of relay 62–SG2 also opens contacts 5318, thus releasing relays 53–ISC3 and 53–ISC4 allowing these relays to release. The release of relay 53–ISC3 opens contacts 5801 and releases relay 58–TADC which relay in turn causes relay 62–SCD to release and again release relay 56–AA. The release of relay 56–AA releases the code relays of Fig. 54 and allows these relays to release which relays in turn release relay 55–TAA which relay in releasing again closes the operating circuit of relay 62–SG2 which relay reoperates and causes relay 54–HSC1 to reoperate and causes the control circuits to hunt at high speed for the next succeeding block code in the control tape. In so hunting the circuits operate as described above and after locating the next block identification code in the tape they will enter the block number in the tape argument relays of the adder and proceed as described hereinbefore.

If the output from the adder circuits of Fig. 60 as a result of the sum of the number recorded in the B block register and the complement of the number read from the block in the B tape had been negative instead of positive, then upon the operation of relay 55–CAA in response to the first TAC code, i. e., a code having perforations in the 0, 4 and 5 positions on the tape, relay 53–TAB operates instead of relay 55–SP. A circuit for operating relay 53–TAB extends from battery through the winding of relay 53–TAB, the operated contacts 5319 of relay 55–CAA over a conductor 5320 which conductor extends from Fig. 53 through Figs. 54, 55 and 56 through the break contacts 5609 of relay 62–SP2, then over conductor 5611 which extends through Figs. 57, 58 and 59 and through the operated contacts 6002 of relay 62–SNC to ground through the locking contacts 6003 of relay 60–ANO which ground has operated relay 60–ANO on its right-hand winding indicating that the sum of the addition performed by the adder is negative.

Relay 53–TAB in operating closes contacts 5321 for maintaining itself operated under control of the operated contacts 5322 of relay 53–ISC4 and the operated contacts 5323 of relay 62–SG1. Relay 53–TAB in operating also closes contacts 5324 which contacts complete an obvious circuit for the operation of relay 53–TRV. Relay 53–TRV in operating actuates contacts 5435 which contacts connect ground to lead 28 extending through the station connector circuit to the B tape transmitter for operating the reverse magnet of this transmitter.

Relays 53–TAB and 53–TRV in operating as described above open contacts 6205 and 6204, respectively, and interrupt the locking circuit of relay 62–SG2. Relay 62–SG2 thereupon releases and interrupts the locking circuit of relay 53–ISC3 and the operating circuit of relay 53–ISC4 thus permitting these relays to release. The release of relays 62–SG2, 53–ISC3 and 53–ISC4 causes the relays locked operated under control of these relays to release. The release of relay 53–ISC3 opens contacts 5801 and interrupts the locking circuit of relay 58–TADC permitting relay 58–TADC to release. Relay 58–TADC in turn opens contacts 6207 and interrupts the locking circuit of relay 62–SDC which relay releases and causes all of the steering relays in Fig. 56 to release. Likewise, the release of relay 58–TADC interrupts the locking circuit of all the tape argument register relays of the three-digit adder shown in Fig. 60, thus allowing these relays to release and restore to normal. The release of relay 53–ISC4 completes the locking circuit for maintaining relay 53–TRV operated under control of contacts 5322 and 5323 of relays 53–ISC4 and 62–SG1.

The release of relay 62–SG2 also opens contacts 5401 and permits relay 54–SSC to release which disconnects the slow speed control circuits from the contacts of the

tape transmitter or reader and restores these circuits to normal. The release of the steering circuit relays of Fig. 56 interrupts the locking circuit of relays **54–0** through **54–5** and **54–NO**, thus releasing these relays. The release of relay **53–ISC4** also interrupts the locking circuit of relay **53–TAB** and since the operation circuit for this relay is also released due to the release of relay **55–CAA**, then the steering relay **56–CA** releases in response to the release of relay **62–SDC**.

The release of relay **53–TAB** recloses contacts **6205** and again completes the operating circuit of relay **62–SG2** which relay reopens and closes contacts **5401** to complete the above-described circuit for operating the high speed control relay **54–HSC1**. Relay **54–HSC1** sets up the connections to the tape control contacts of the transmitter or tape reading device connected to the tape control circuit through the station connector circuits as described herein for high speed hunting which under the assumed conditions is hunting for a block identification code in the tape. The operation of relay **54–HSC1** completes circuits through all tape control contacts for operating relay **53–HSC** which relay operates and applies ground to the transmitter clutch magnet over conductor **22** as described above due to the fact that the reverse magnet is operated now and the tape is stepping backwards instead of forward in response to the actuation of the tape transmitter or reader. As the tape steps back it will cause the sensing contacts to sense the immediately preceding block identification codes which have been determined to be the wrong ones as described above. Consequently, it is undesirable to have a tape transmitter stop in response to sensing these codes perforated in the tape. Due to the fact that relay **53–TRV** is now locked operated, contacts **5311** are actuated. Consequently, when the first of the block identification codes comprising the perforations in the 0, 1 and 2 positions is sensed, relay **53–ISB** operates instead of relay **53–ISC1** as described above. Relay **53–ISB** in operating closes contacts **5325** and completes an obvious circuit for the operation of relay **53–ISB1**. Relay **53–ISB1** closes contacts **5326** which contacts prepare a locking circuit for relay **53–ISB1** and an operating circuit for relay **53–ISB2**. Relay **53–ISB2** does not operate at this time, however, because ground is applied to both of its winding terminals. Since relay **53–ISC1** does not operate at this time relay **53–HSC** remains operated and the tape is advanced to the next block identification code. As shown in the drawing, relay **53–ISB** is provided with a shunt resistance which makes this relay slow in releasing. Of course, any suitable slow release relay or means for causing relay **53–ISB** to be slow may be employed for relay **53–ISB**. Relay **53–ISB** is made slow in releasing so that it will maintain itself operated between the sensing of the two block identification codes. In this manner, relay **53–HSC** is maintained operated at this time and the hunting circuits hunt past the first two block indicating codes in the tape since these are identified with an improper block number is previously determined. After the second of the two block identification codes have beeen sensed, relay **53–ISB** releases and permits relay **53–ISB2** to operate. Relay **53–ISB2** in operating actuates contacts **5327** and reconnects the winding of relay **53–ISC1** to the circuit which is closed under control of the sensing of a block identification code. Consequently, the next time a block identification code passes under the sensing pins of the tape transmitter or reader, relay **53–ISC1** operates and interrupts the high speed hunting circuits in the manner described above and initiates the low speed control circuits whereupon the relay **53–ISC4** again operates and interrupts the locking circuit of relay **53–TRV** permitting this relay to release. As a result the tape is again advanced step by step and each of the codes sensed and the block number recorded in the tape adjacent to the most recently sensed block identification code is transferred to the tape argument relays of the adder of Fig. 60 as described above and the circuits operate in the above-described manner. If the number is still too high, the above cycle is repeated and the tape moved back still further.

Assume now that the sum from the adder of Fig. 60 is zero then the number entered in the B block register and the number entered into the tape argument relays from the B tape are the same. As described hereinbefore this sum will be obtained by the time the first of the TAC codes following the number is sensed and transferred to the control circuits in the manner described above. At this time the steering relay **56–CA** is operated and relay **55–CAA** is operated in response to the TAC code as described above. When the sum from the adder is zero as described hereinbefore relay **62–SNC** does not operate. Consequently, contacts **6001** and **6002** do not operate so that neither relay **55–SP** nor relay **53–TAB** operates. Instead, as described hereinbefore when the sum standing in the adder is zero the adder relays **60–AO**, **60–BO** and **60–CO** are all operated. Consequently, a circuit is completed for the operation of relay **56–CA′** from battery through the winding of relay **56–CA′**, the operated contacts **5611** of relay **56–CA**, the operated contacts **5612** of relay **55–CAA**, the operated contacts **5613** of relay **59–B1**, contacts **5607**, **5608** and **5606** of relays **60–AO**, **60–BO** and **60–CO**, respectively, to ground. Relay **56–CA′** in operating in the above-described circuit actuates its contacts **5614** which contacts complete a circuit for maintaining relay **56–CA′** operated under control of contacts **5610** of relay **62-SDC** and interrupt the locking circuit of relay **56–CA** and also remove ground from the *b* lead causing the advance of the tape control transmitter or reading device as described hereinbefore. The release of relay **56–CA** interrupts the locking circuit of the code relays **54–0** through **54–5** and **54–NO** which relays in turn permit relays **54–0′** through **54–5′** to also release. The removal of ground from the *b* lead permits relays **54–CMC** and **54–CMC1** to release. As a result, the above-described circuit through contacts **5421**, **5420**, **5419**, **5422** and break contacts on each of the relays **54–0** through **54–5′** now extends to the winding of relay **57–CA1** causing this relay to operate and again apply ground to the *b* lead which advances the tape reading device and the control circuits to respond to the second TAC code entered into the B storage tape.

The code relays of Fig. 54 respond to this code and now complete a circuit for the operation of relay **55–CA1A** which circuit extends from ground through contacts **5502**, **5503**, **5511**, **5509**, **5510**, operated contacts **5515** of relay **57–CA1** to battery through the winding of relay **55–CA1A**. Relay **55–CA1A** operates and closes contacts **5615** and contacts **5616**. Contacts **5616** in closing complete an obvious circuit for the operation of relay **56–PIC**. Relay **56–PIC** in operating closes contacts **5617** which maintain ground on the armature of the contacts **5613** of relay **59–B1**. Relay **56–PIC** in operating opens contacts **5903**, thus causing relay **59–HBN** to release. Relay **59–HBN** in releasing completes a circuit for maintaining relay **59–TCK** operated from battery through the winding of relay **59–TCK**, the operated contacts **5913**, the break contacts **5904** of relay **59–HBN**, the break contacts **5914** of relay **59–HBN**, the break contacts **5915** of relay **59–RCS** to ground through contacts **5905** of relay **62–SG1**.

The release of relay **59–HBN** opens contacts **5905** and **5904**, thus permitting relay **59–B1** to release and complete a circuit for the operation of relay **57–CA1′** which circuit extends from battery through the winding of relay **57–CA1′**, the operated contacts **5701** of relay **57–CA1**, the operated contacts **5615** of relay **55–CA1A**, the break contacts **5617** of relay **59–PI**, the break contacts **5613** of relay **59–B1** to ground through the operated contacts **5617** of relay **56–PIC**. In addition, a circuit extends

through the operated contacts of the adder to ground as described above.

The operation of relay 57–CA1′ actuates contacts 5602 which contacts interrupt the locking circuit of relay 57–CA1 and also remove ground from the *b* lead. As a result the control circuits return to normal and cause the tape transmitter to advance where the pins will next sense the sign of the number. At this time relay 57–SN is operated. Consequently, contacts 5519 and 5520 are actuated with the result that the sign of the number was transferred to the tape storage register and recorded in the tape storage register by operation of the proper relays. When these relays operate they apply ground to the USN lead as shown in Fig. 61 which causes relay 57–SN′ to operate and which relay again advances the steering circuit and causes the number in the tape to be entered upon the relays of the storage tape control circuit and then convey to the relays of the tape storage register assigned to record the digit the next denominational place or order of the number. In this manner, the above cycle of operations is completed until three digits of the number have been entered upon the storage relays of the B tape storage register. If the symbols recorded in the tape represent a number then the circuits operate as described herein, each denominational order causing a chain or sequence circuit to advance one step so that the next digit of the number may be entered in and upon the proper relays of the tape storage register. Provision has been made to automatically supply zeros in the last four or seven places in the number. Thus, if a code representing a positive exponent is received after the digit in the third denominational order has been entered into the relays of the storage tape control circuits and apparatus, either the relay 55–PC or relay 55–MC is operated in response to this code representing the sign of the number. At this time the chain circuit or steering circuit will be advanced so that relay 57–D will have operated. The operation of these relays relays the number to the proper relays for entering the sign on the exponent of the number. In addition, either of these relays at this time completes an obvious circuit for the operation of relay 62–7Z, since relay 57–D of the sequence circuit was operated as described above. The operation of relay 62–7Z causes the tape storage control apparatus described herein to enter to enter zeros in the remaining seven places of the number. If additional numbers are entered in the tape instead of the number check code, then the circuit continues as described above and causes each of these numbers to be stored in the stape storage control registers in their proper denominational positions.

Likewise, if it is only desired to use six figures of the number, then relay 62–4Z operates to advance the circuits substantially the same as described above with reference to the operation and release of the various control relays. When the register has been completely filled, the sequence circuit is advanced to operate the 58–EN relay which relay causes the tape control contacts to sense and respond to a number check NC code insterted in the B tape at this time.

The number check code comprises perforations in the 0, 1 and 5 positions and causes relay 62–ENC to operate in a circuit extending from battery through the winding of relay 62–ENC, through the operated contacts 6219 of relay 58–UCC which relay operated when the units digit of the exponent was completely registered in the storage tape control register, the operated contacts 6220 of relay 58–EN, then over conductor 6221, which conductor extends through Figs. 57, 56, the operated contacts 5521 of relay 62–SDC, the break contacts 5522 of relay 62–RCS and the operated contacts 5523, 5524, 5525 of relays 54–5′, 54–1′ and 54–0′, respectively, to ground through the break contacts 5503 of relay 54–UC and contacts 5502 of relay 54–CMC1. Relay 62–ENC in operating applies ground to the TRC lead through the operated contacts 5916 of relay 58–UCC and break contacts 5917 of relay 62–RDC. This ground is then relayed through the register circuit to the routine control circuit signifying that the register is filled and that the routine control circuit may withdraw the number from the register. Depending upon the type of order employed by the routine control circuit the number stored in this register may be repeatedly used as often as desired. In addition, when desired the number can be cleared from the register under control of the orders entered in the routine control circuit as described herein.

The operation of relay 62–ENC completes an obvious circuit for the operation of relay 62–STT which relay then locks operated under control of contacts 6222 of relay 59–TCK. The operation of relays 62–ENC and 62–STT causes contacts 6223 and 6224, respectively, to open and interrupt the locking circuit of relay 62–RDC which relay thereupon releases and in turn opens contacts 6210 which contacts open a locking circuit of relay 62–SDC and permit this relay to release. The release of relay 62–SDC opens contacts 5605, 5610, 5703, 5704, 5705, 5804 and 5905 thus permitting all of the steering relays to release. The release of these steering relays removes ground from the *b* lead permitting relays 54–CMC and 54–CMC1 to release and removing ground from the locking windings of the code relays 54–0 through 54–5 and 54–NO, thus causing all these relays to release. Thereafter, the circuits remain in substantially the condition described with relay 54–SSC operated, relays 62–SG1 and 62–SG2 operated, relays 53–ISC3 and 53–ISC4 operated as well as the relays held operated under control of the above-enumerated relays. So long as the number remains in the tape control storage register, the relays remain in the above-described condition. When the register, however, is cleared under control of the routine control circuits, the down-check circuit through the register circuit is again completed over the D. C. lead shown in Fig. 61 and through the released contacts 6223 of relay 62–ENC, the operated contacts 6225 of relay 62–SG1 to battery through the winding of relay 62–RDC indicating that the register has been cleared of the number previously entered into it. It should be noted that relay 62–ENC releases when the steering circuit and code relays release as described above.

Relay 62–RDC in operating again completes a path for the operation of relay 62–SDC assuming that all of the steering relays have returned to their normal condition. The reoperation of relay 62–SDC closes contacts 5604 which contacts now complete the down-check circuit through the code relays 54–0′ through 54–5′ to the winding of relay 57–SN because contacts 5603 of relay 62–SDT are operated at this time since relay 62–SDT operated in response to the operation of relay 62–ENC and had remained operated ever since because relay 59–TCK was released. As a result relay 57–SN operates and applies ground to the *b* lead which causes the tape reading device and the control circuits therefor to advance and have entered upon them the succeeding information recorded in the tape which, under the assumed conditions, represent the sign of the next number. This information is relayed to the sign registers of the storage tape control register and thereafter the identity of each of the digits of the succeeding number is transferred from the storage tape to the tape control storage register and stored therein on relays assigned to each of the denominational orders of the number. When this second number is completely entered in the register, relay 62–ENC again operates as described above and releases the steering relays and other relays as described above and indicates that the number may be withdrawn from the tape register. The above cycle of operations is repeated for each number entered in the tape after the particular block number is identified as described above. Should the number check code be received too soon in any number indicating a missing digit in the tape, the 55–ALM alarm relay operates. Likewise, if too many digits or denominational orders are entered into a number in the tape before or between the number check NC codes, the alarm relay is

operated. Should the plus or minus code be received at any other than the fourth or seventh or eleventh denominational positions of the number, the alarm circuit is also operated indicating some denominational order has been lost or mutilated or otherwise is ineffective to properly control the circuits.

If in advancing as described above the tape should become taut between the tape transmitter or sensing device and the tape reperforator or recording device, contacts of the tape transmitter connected to conductor **20** and **21** open and release relay **54–STS** which relay releases contacts **54–31** and connects ground extending to the clutch magnet of the transmitter to magnet **69–PDG** in the printer control circuit which causes the perforator to perforate the by-pass codes in the tape, thus providing additional tape so that the remaining information recorded in the B tape may be conveyed through the sensing position of the tape reader or tape transmitter. Of course, at any time during the operation of the computer and while a number is stored in the storage register, the routine control circuits can cause the tape control circuits to hunt for another block number in the manner described herein at which time the above cycles of operation will be repeated as may be required to find the desired numbers. The number previously stored in the tape control register must, of course, be cleared before another number from the tape may be entered into this register.

Assume now that no block number is called for by the routine control circuits and that the computer has exhausted all of the numbers in a particular block selected by the routine control circuit. When the routine control circuits including the formula director and formula circuits have utilized the last number in the storage tape register, they will clear this number from the register which will again activate the storage tape control circuits in the manner described above, namely, relay **57–SN** is operated and the transmitter advanced to sense the next information recorded in the B tape. However, at this time since the last number has been utilized and withdrawn from the tape an ENC code, namely, a perforation in only the No. 4 position is encountered. At this time a circuit will be completed over the ENCB lead extending through relays of the register circuit to the routine control circuit. This circuit extends from ground through break contacts **6225** of relay **54–0**, contacts **6226** of relay **54–1**, the operated contacts **6227** of relay **54–SSC**, contacts **6228** of relay **54–3**, operated contacts **6229** of relay **54–4**, break contacts **6230** of relay **54–5**, the operated contacts **6231** of relay **57–SN** and then over the ENCB lead and through operated contacts of either the A or the B relay of the tape control register circuit to the routine control circuit. Ground applied to this lead from the routine control circuit causes the routine control circuit to advance to the next problem entered into the problem tape thereof or else to another step or portion of a given problem being solved. Thus, for example, if the routine control circuit had ordered some formula which formula also controlled a number of repeating computations and the argument for each computation was withdrawn from the tape register, thereafter the computation was performed by the formula reselecting itself and withdrawing another argument. When all the numbers have been withdrawn from the tape storage register and the ENC lead grounded, the operation of the particular formula in question is interrupted and the control of the computer restored to the problem tape or to the C tape or to a higher level formula depending upon the programming of the computer as described herein.

It is sometimes desirable to include within one block interval on the tape more than one block number. In other words, all of the information which may be called for between blocks say, for example, 150 and 160, may be located within an interval on the tape between two block identification symbols or codes. In this case, the first block identification symbols for this group of block numbers will comprise two block identification codes followed by the first number of the group as, for example, 150 and this number is in turn followed by one TAC code and this TAC code in turn is followed by the upper limit which under the assumed conditions will be 160 which in turn is followed by the second TAC code. In responding to these codes the tape control circuit responds as described above in locating the block identification code and the first TAC signal. When a number is encountered after the first TAC signal instead of the second TAC signal the control circuit responds in three different ways. If the block number in the block register corresponds to the first block number on the tape so that the output of the adder circuit is zero, then the desired information is within the immediately following section of the tape. Consequently, the succeeding block numbers are by-passed and ignored by the circuits. The transmitter steps off these numbers. If the first block number is lower than the number entered into the B block register, then the adder is cleared and the second number is entered into the adder. If the sum on the adder is still positive, then it indicates that the desired block number is outside the range of information in the following block on the tape so that the circuits respond by causing the high speed hunting circuits to be reestablished as described herein. If, however, the output of the adder is zero or negative, then the circuits are conditioned to advance and transfer the first number from the tape to the register because the block number desired is within the limits.

If, however, upon comparing the first portion of the block number with the number in the block register, it is found that the number is negative, then the circuits hunt in the reverse direction at high speed for the next block indication in the manner described herein since the desired information is not in the section of the tape following the block number. Block numbers of the type referred to are sometimes called hyphenated block numbers.

In the foregoing description it has been assumed that the B storage tape transmitter was connected through the station connector circuit to the B storage tape control circuit described herein in detail. When the C storage tape reader or transmitter is connected to the B storage tape control circuit by means of special orders as described herein, then the C tape transmitter or reader cooperates with the control circuits in the same manner as described herein with respect to the cooperation between the B tape reader or transmitter and the B storage tape control circuits. In other words, the control circuits will cause the C tape transmitter to search for the block number corresponding to the block number entered into the block register and thereafter transfer the succeeding numbers to the tape storage register one after another as they are withdrawn and cleared by the routine control circuits including the formula circuits.

It is also desirable at times to connect the C tape transmitter to the tape control circuits and cause the control circuits to position the C tape with respect to the transmitter or C reader in the manner described herein and then to disconnect the C transmitter from the storage tape control circuits and connect it in place of the problem tape and use the information recorded in the C tape as an additional routine or formula for further controlling the operations of the computer. It is within the scope of this invention to provide the C tape with a plurality of routines which are separated by different block indications and then select the desired routine under control of the tape control circuits in the manner described herein and then reemploy the C tape or the selected portion thereof as a formula. The formulas in the C tape may call for other formulas as well as for a repetition of the formula being employed by the C tape. In this case, it is necessary to select the formula which will cause the C tape to be discon-

nected from the problem tape control circuit and reconnect it to the storage tape control circuit for resetting it at the beginning of a particular routine or formula and then reconnecting it again to the problem tape control circuit. Of course, any of the formulas entered on the C tape may likewise call for other formulas entered in the C tape as well as for any of the other formulas under control of the formula director or it may call for a return of the control of the computer to the problem tape all under control of the special orders and other routine control circuits as described herein.

Test circuit

In operating the computer system in accordance with the exemplary embodiment of the invention set forth herein, it is frequently desirable to check the operation of certain portions of the equipment when the system is first placed into operation as well as at intervals of time thereafter. In order to facilitate such tests, various test features of keys are incorporated in the system together with a plurality of lamps to indicate the operation of various elements or features of the system. For example, Fig. 31 shows a group of test keys employed to test the operation of the pulse generators also shown in Fig. 31 and also the operation of the routine order, coils, tubes and relays shown in Fig. 46. In addition, the lamps shown in Fig. 30 are provided to indicate the proper operation of this equipment. The coils, tubes and relays of Fig. 46 are employed to set up the routine orders for controlling the operation of the computing machine. As described herein each of the routine orders or instructions comprises five parts. Twenty coils, tubes and relays are provided for each of the first four portions of each so-called routine order while six tubes, relays and coils are provided for the fifth portion of each of the orders or instructions.

When it is desired to determine that all of the tubes, relays and coils are properly functioning the one or the other of the test keys **3111** and **3112** is operated. Key **3111** is operated when it is desired to test the impulse generator designated the odd impulse generator and key **3112** is operated when it is desired to test the even impulse generator.

Assume first that key **3111** is operated. The operation of key **3111** at this time interrupts the connection from conductor **3117** and the odd impulse generator and connects the odd impulse generator to conductor **3119** extending to keys **3114** and **3115**. The operation of key **3111** also completes a circuit for the operation of relay **31**–CO from battery to the winding of relay **31**–CO, the left-hand operating contacts of key **3111** to ground through the break contacts of keys **3114** and **3115**. The operation of the relays **31**–CO at this time interrupts the obvious operating path of relay **31**–CO1 which relay thereupon releases and interrupts the connection between the odd impulse generator and the odd key **3119** at the contacts **3121**.

After the operation of either key **3111** or **3112** a switch is operated to engage any one of its various contacts A through T. In case it is desired to test each and all of the coils and relays of Fig. 46 the switch **3116** will be first set on its A contacts and a test made as described hereinafter and then go to its B contacts and the test repeated after which the switch will be successively moved to each one of the following contacts and the test repeated for each of these contacts. Contacts of switch **3116** are closed connected to conductors threaded through various of the coils of Fig. 46. For example, the A conductor is shown threaded through coils **1A46**, **2A46**, **3A46**, **4A46** and **5A46**. Likewise, the B conductors will be threaded through coils **1B46**, **2B46**, **3B46**, **4B46** and **5B46**. Each one of the succeeding conductors C through T is threaded through the corresponding coils C through T. In order that after the first six succeeding conductors connected to the test switch are threaded through the various coils extend through only four coils instead of five coils. However, it is to be understood that all of the conductors employed herein for selecting and setting up routine orders are threaded through five coils, that is, a coil for each of the five columns shown in Fig. 46. For example, each of the conductors employed in selecting, designating and setting up routine orders passes through one of the coils **1A46** through **1T46**. This same conductor also passes through one of the coils **2A46** through **2T46**. This conductor likewise is threaded through one of the coils **3A46** through **3T46**. The conductor also passes through one of the coils **4A46** through **4T46** and through one of the coils **5A46** through **5F46**.

After the operation of either of the keys **3111** or **3112** either key **3114** or **3115** is operated. Assuming now that key **3114** is first operated. The operation of this key completes an obvious circuit for the operation of the test relay **3114** which relay closes contacts **3050** and applies operating ground to the contacts of the relays of Fig. 46 employed to operate the various lamps shown in Fig. 30, the lighting of which lamps indicates the operation of the respective relays of Fig. 46. The operation of the test relay **3114** also causes the contacts **4650** to be operated and applies locking ground to the locking contacts of all the relays of Fig. 46 through the break contacts **4651** of the CO1 relay designated **45**–CO1 in Fig. 45.

Assuming now that key **3111** has been operated and switch **3116** set on the A contact and that it is desired to test the operation of all of the coils in the A level. Key **3114** will be operated. The operation of key **3114** at this time in addition to operating relay **3113** as described above also interrupts the operating circuit of relay **31**–CO which relay releases and completes a circuit for the operation of relay **31**–CO1. Relay **31**–CO1 in operating closes contacts **3121** which contacts complete a circuit extending through A conductor from ground over the A conductor which extends through coils **5A46** through **1A46**, the A contacts of switch **3116**, resistor **3123**, the left-hand operated contacts of key **3114**, the right-hand operated contacts of key **3111**, the break contacts of key **3119**, the operated contacts **3121**, the break contacts **3125** to battery through resistor **3127**. The ground connected to resistor **3127** changes the charge on the coupling condenser **3129** and transmits a positive pulse to the starting electrode of tube **3131**. The upper terminal of condenser **3129** is normally charged to a negative voltage through resistor **3129** and the negative battery connected thereto. Connecting ground to this terminal, therefore, raises the potential of the upper terminal of condenser **3129** and causes a positive pulse to be transmitted through this condenser and applied to the starting electrode tube **3113**. The resistor **3133** provides a voltage divider for applying a biasing voltage to the starting electrode of tube **3113** which is insufficient to produce a discharge through this tube until a positive voltage is applied through the condenser **3129**. The application of this positive voltage through condenser **3129**, however, initiates a discharge through tube **3131** which discharge immediately is transferred between the main electrodes of this tube and causes relay **31**–OD to operate. The operation of relay **31**–OD causes contacts **3125** to operate. The operation of contacts **3125** at this time connects ground to the right-hand terminal of coil **3135**. The coil **3135** is connected in series with condenser **3137** to ground. Normaliy, the upper terminal of condenser **3137** is charged to a negative voltage through resistor **3139** and a coil **3135**. The operation of contacts **3125**, however, connects a ground over the A lead threading the A lead coils as described above to the right-hand terminal of coil **3135** which ground tends to discharge the condenser **3137**. The inductance of coil **3135** and the capacitance of condenser **3137** as well as the resistance of the coil and the connecting leads includ-

ing the conductor A threading coil of the A level in Fig. 46 are so chosen that upon the operation of contacts **3125** as described above, an oscillating transient is set up which causes an oscillating current having, in an exemplary embodiment of this invention, a frequency of approximately 1200 cycles to flow over the A lead. The current of this oscillating transient induces a voltage in the secondary windings wound on each of the coils **1A46** through **5A46** of sufficient magnitude to initiate a discharge through the control gap of each of the tubes connected to these coils. These discharges are immediately transferred to the main discharge paths through the tubes and cause the operation of the corresponding relays **46–1A**, **46–2A**, **46–3A**, etc. These relays lock operated in an obvious circuit through their own operated contacts, break contacts **4651** and the operated contacts **4650**. In addition, each of these relays closes contacts **3001**, **3002**, **3003**, **3004** and **3005** which contacts in turn complete a circuit for lighting of the respective lamps **3011**, **3012**, **3013**, **3014** and **3015** in a circuit extending from battery through the lamp and the corresponding operated contacts to ground through the operated contacts **3050**. Each of the lamps **3011** through **3014** completes a circuit described above indicating that the circuits of the eight coils of Fig. 46 including the associated tubes and relays are operated satisfactorily. The resistor **3123** in the circuit of the A lead as described above applied a more severe operating condition for operating the coils and lamps and relays than is encountered in normal operation of the system because this resistance is not normally included in the corresponding leads threading the various coils employed in the setting up and designating a routine order.

Upon noting that all of the A level lamps of Fig. 30 light indicating that all of the A level coils operate satisfactorily, the attendant will release key **3114** which key in releasing interrupts the operating circuit of relay **3114** and again completes the operating circuit of relay **31–CO**. The release of relay **3113** at this time releases contacts **4650** and thus interrupts the locking circuit of relays **46–1A** through **46–5A** and also interrupts the circuit of lamps **3011** through **3015** at contacts **3050**. The operation of relay **31–CO** interrupts the operating circuit of relay **31–CO1** which relay releases and disconnects the pulse generators from keys **3120** and **3119**, thus allowing the upper terminal of condenser **3129** to again become charged to negative voltage where it will be ready again to initiate the operation of the pulse generating circuit. The condensers connected to the tube **3131** and relay **31–OD** are of such a magnitude that relay **31–OD** will remain operated for only a predetermined short interval of time after which the discharge through the tube **3131** is interrupted and relay **31–OD** released. The attendant will then move the switch **3116** to the next or B conductor to test all the coils in the B level. If it is desired to also test the even generator, keys **3112** will be operated instead of **3111**. Thereafter, the remaining keys operate in succession in the same manner. Under these circumstances the test conductor extends through contacts **3122** and **3126** and employs the even generator including condensers **3130** and coil **3136** and condenser **3138** in place of the corresponding elements of the odd generator.

It is also desirable sometimes to test the margin on the tubes in Fig. 46 to be sure that these tubes do not falsely operate. Under these circumstances, the tubes are tested in a similar manner except that key **3115** is operated instead of key **3114**. The operation of key **3115** instead of key **3114** substitutes a higher resistance **3124** for the resistance **3123**. The magnitude of the resistor **3124** is so chosen that when key **3115** is operated instead of **3114** after first operating either key **3111** or **3112** and **3116** in the manner described above, none of the relays of Fig. 46 should operate. If any of the relays do operate as evidenced by any lighted lamps in Fig. 30, a trouble condition is indicated which must be corrected before the computer is put into operation.

Control of the computer by routine orders

As set forth herein the computer is controlled by a plurality of routine orders, each of which comprises five parts. In general, the first portion indicates where a number is to be obtained, the second portion indicates the operation to be performed, the third portion indicates where a second number, when required for computations, is to be obtained, the fourth portion, in general, indicates where the results of the computations are to be recorded or entered in a register and the fifth portion of the order indicates whether or not the first and third portions of the number are to be cleared from the place in which they were obtained or whether they are to be held in the respective registers from which they were to be obtained. The fifth portion also is employed to indicate certain other types of operation.

The chart shown in Fig. 47 shows the symbols representing the functions performed by the different portions of an order. The first column on the left indicates the codes representing the various symbols of the first four parts of an order as employed in the problem and storage tapes. The second column, headed Column 1, lists the twenty possible different codes and designations of the first portion of the order and the functions or information represented by these codes. The third column, headed Column 1A, indicates an alternative function or information represented by the last four codes of the first portion of the order when a $\overline{1R}$ code or symbol is employed in the fifth place in an order. The fourth column, headed Column 2, shows the same twenty codes which may form the second portion of the order with the functions represented by and performed in response the corresponding codes. The fifth column, headed Column 3, shows the corresponding codes and information represented by them for the third portion of the order. Likewise, the sixth column, headed Column 4, shows the codes and information represented by these codes for the fourth column of the order. It should be noted that the first ten codes in both the fifth and sixth columns have a double function indicated. These codes represent both a group of storage registers and also a group of numerals. The numerals are employed when the second portion of the order comprises one of the first four or the sixth code shown in Column 4 of Fig. 47. Otherwise, these codes designating the register are represented by the codes in Columns 5 and 6. Column 7 of Fig. 47 headed Column 4A, shows alternative functions for the last ten codes for the fourth portion of an order which alternative functions are employed when the $\overline{TR}$ code or symbol is employed as the fifth portion of the order. The next to last column of Fig. 47, headed Column 5, shows the six possible codes for the last portion of the order.

The last or eighth column of Fig. 47 shows the code used in the problem tapes and storage tapes to record the symbols of the fifth portion of an order. It is to be noted that codes for the first four portions of an order each have three out of a possible six perforations in the tape while the codes for the fifth portion of an order each have four out of a possible six perforations. By so choosing the codes the computer circuits may be readily arranged to operate only if the proper number of perforations or equivalent indications represent each part of an order. Thus, if one portion of an order is lost the computer stops at once instead of taking a code from a succeeding order to make up the five parts of the order.

The first code $\overline{CC}$ of the fifth portion of an order is employed when it is desired to clear the register designated in the first and third portions of the order. The second code $\overline{CH}$ in Column 7 of Fig. 47 indicates that the register designated in the first portion of the order

is to be cleared while the number recorded in the register designated in the third portion of the order is to be held in the register. The third code $\overline{HC}$ in Column 7 indicates that the number in the register designated in the first portion of the order is to be held in that register while the number in the register designated in the third portion of the order is to be cleared from the register after it is employed for the computing or other functions performed in response to the order. The fourth code $\overline{HH}$ in Column 7 causes the numbers recorded in both the registers designated in the first portion of the order and in the third portion of the order to be held in these registers after the computer has executed the order in question. The codes representing the hold orders are always used in the fifth place in the order unless it is desirable or necessary to clear a register after the number entered therein has been transferred to another register or otherwise employed by the computer.

The fifth code $\overline{CP}$ in Column 7 is employed when it is desired to prepare numbers from the different registers and the sixth code $\overline{TR}$ of Column 7 is employed to transfer to the functions represented in the last portions of Columns 3 and 7 as pointed out above.

When any one of the five elements in an order is not required to perform any function in carrying out or executing the specific order, the last code T called a "dummy" function in the first four portions of the order is employed which code causes the equipment to advance over that portion of the order without producing any function in the computing calculation.

When the first portion of the order comprises the S code which designates the X register of the calculator, it is necessary to use either codes 3 or 4 in Column 8, headed Column 5 in Fig. 47, because the number in the X register of the calculator is not to be released on a Clear order, but is released automatically by the calculator circuit at the proper time.

When the E code is used as a second portion of the order, a number recorded in one of the storage tapes or in one of the storage registers will be translated into a formula number. In this case, the first nine denominational places of the number are employed to represent a maximum of three different three-digit formula numbers. The first portion of the order indicates the location, i. e., the register in which the number is stored or located, the second portion of the order will be the E code and A in the third portion of the order indicates that the first three denominational places of the number are to be employed as a formula number and the B code in the third position of the order indicates that the second three denominational places of the number are to be employed as a formula number, the C code in the third position of the order indicates that the third three denominational places of the number in the designated register are to be employed as the formula number. The first denominational place in each of the three groups of the number designates the formula levels A, B, C, or D. If the digit in the first denominational place of the designated three denominational places of the number is a 0, then an A formula is designated. If the digit in this first denominational place of the selected three places of the number is a 1, then a B formula is designated. Likewise, if this digit is a 2, a C formula is designated. If it is a 3, a D formula is designated. The fourth portion of the order having an E for the second portion is usually a T and the fifth portion is usually an HH or a CH.

Using the R designation in the fourth position in the order together with any calculator operation in the second position of the order will cancel the read-out from the calculator. These designations or positions of orders can be used with $\overline{CP}$ in the fifth position of the order when the result of the order is not required or when in a formula it is desired to check a tape register for the ENC code.

A code representing a plus sign when received from the calculator in response to the $\overline{CP}$ code in the fifth position in the order is employed to cause the computer to proceed to the next step of a formula. The code representing the zero or minus sign received from the calculator under similar circumstances causes the computer to return the control to a higher level and to cancel the read-out of the computer. Registers in Columns 1 and 3 are held under both of the above conditions.

When the J code is employed in the second position of the order, it indicates an absolute value in addition and so the answer is always read out with a plus sign in response to such an order.

Order I ≡ T A $\overline{C\ H}$

It is frequently desirable to transfer a number from one register to another to have it more readily available or to make the coding of the formulas more uniform and simpler, or for other reasons. Assume, for example, that it is desired to transfer a number from the I register to the A register. In order to accomplish such a transfer the order I ≡ T A $\overline{C\ H}$. Such an order may be read from the problem tape or be part of one of the formulas or it may be written up on the key-set shown in Fig. 10 in the manner described herein, or such order may be read from the C tape when it is substituted for the problem tape as described herein. Such an order will cause relays **46–1I**, **46–2S**, **46–3T**, **46–4A** and **46–5B** to be operated. These relays will either be operated due to discharges through the associated gas tubes in response to a step of a formula or over their secondary windings in response to the operation of the key-set or the operation of one of the sets of the tape control contacts which control these relays as described herein. The operation of the computer in response to this order is substantially the same and independent of the source or origin of the order, or the manner of operation of the above relays of Fig. 46. The operation of these relays causes various control circuits to advance in response to the operation of the keys of Fig. 10 or the problem tape or tape C when tape C is substituted for the problem tape and the operation of the control relays in turn releases the keys of Fig. 10 or causes them to take a step in the manner set forth herein.

Unless pointed out differently with special reference to special conditions, the operation of the computer, after a complete order has been entered on the relays of Fig. 46, is substantially as will be described herein and substantially independent of the source or origin of the order.

Furthermore, the operation of the system for all orders is substantially the same in so far as the check circuits are concerned.

In order for the equipment to proceed to execute an order, it is essential that each portion of the order be properly entered. In other words, one and only one of the first column of relays in Fig. 46 must be operated and one and only one relay in each of the other columns of relays in Fig. 46 must be operated. When one and only one relay for each portion of an order is operated, the corresponding relays **45–1RC** through **45–5RC** will be operated and complete a circuit for the operation of relay **45–5UP** which circuit extends from batttery through the winding of relay **45–5UP** through a set of operated contacts of each of the relays **45–1RC** through **45–5RC** to ground through the break contacts **1116** of relay **18–CTR1** and the operated contacts **1106** of relay **7–RG1**, relay **7–RG1** having been previously operated in response to the initiation of the operation of the computer.

Relay **45–5UP** in operating completes a circuit for the operation of relay **45–CO** which relay in turn locks operated under control of relays **45–1RC** through **45–5RC**. Relay **45–5UP** interrupts the locking circuits of relays

45–STD and 45–FR and causes these relays to release if they are operated at this time.

The operation of relay **4611** selects the I storage register and causes the A relay thereof to be connected to the G1 lead.

The operation of relay **46–2S** causes contacts **1808** of relay **46–2S** to operate and prepare a circuit for the operation of relay **18–TR**. The operation of relay **46–2S** also causes contacts **4401** to close and complete a circuit for the operation of relay **44–RO**. It should be noted that the relay **44–RO** operate in response to the operation of any of the relays **46–2J**, **46–2M**, **46–2N**, **46–2O**, **46–2P**, **46–2Q**, **46–2R**, **46–2S**, or **18–SQR** indicating that the order entered upon the order relays of Fig. 46 is a routine order.

The operation of relay **46–3T** causes contacts **1512** of relay **46–3T** to close and in turn complete an obvious circuit for the operation of relay **15–OC3**. The operation of relay **46–3T** indicated that no function was to be performed in response to the third portion of the order and as a result relay **15–OC3** indicating the completion of the third portion of the order is immediately operated.

The operation of relay **46–4A** causes contacts **4901** to close and these contacts together with contacts **2902** of relay **44–RO** partially prepare a circuit for the operation of relay **21B** of the A storage register.

The relay **21B** does not operate at this time, however, but operates later under control of the routine control circuits as will be described presently.

The operation of relay **46–5B** in response to the fifth portion of the order as described above causes contacts **4402** to close and complete an obvious circuit for the operation of relay **44–TR1**.

The operation of relay **46–5B** also causes contacts **1516** to close and prepare a circuit for the operation of relay **15–CLRA** which relay does not operate at this time because ground is not applied to the G5 lead.

The operation of relay **44–TR1** prepares numerous control circuits by operating contacts thereof which circuits will be described when they are completed and perform their intended functions, for example, a group of contacts of the 44–TR1 relay as shown in Fig. 17 which cooperate with contacts of relays **46–4K** to **46–4P**, inclusive. Inasmuch as the exemplary order being described does not involve the operation of any one of these relays **46–4K** to **46–4P** the circuits and contacts of these relays will not be further described at this point.

As pointed out above, when one and only one of the relays in each of the columns of relays in Fig. 46 has been operated in response to the entering of the respective portions of a complete order, the complete registration of the order causes relay **45–5UP** to operate. This relay in turn completes a circuit for the operation of relay **15–5UP** which circuit extends from battery through the winding of relay **15–5UP** through the break contacts **1304**, break contacts **1501**, over lead **4506** and the operated contacts **4504** of relay **45–5UP** to ground through the operated contacts **4501** of relay **7–RG1**.

The operation of relay **15–5UP** sets the routine control circuits into operation to execute the order set up on the order relays of Fig. 46.

In executing any order the routine control circuits are arranged to provide certain preliminary routine checks to insure that the various component circuits and equipment of the computer are in condition to properly respond to routine orders. Such preliminary checks include the insuring that the A and B control relays of all of the storage registers, of the tape storage registers, of the fixed numbers registers and all of the page and block registers are released, indicating that none of the registers of the computer are connected to any of the control leads or to the X multiple or to the Y multiple. In other words, indicating that none of the registers is employed by the computer in the execution of any operation by the computer. This checking and control takes place prior to the execution of each and every order by the computer. However, the detail circuits employed in this check will be described with reference to only several orders including the order now being described. It is to be understood, however, that these circuits operate in substantially the same manner described at the beginning of the execution of each and every order entered on the order relays of Fig. 46.

Relay **15–5UP** applies ground to the locking contacts of a large group of relays. Relay **15–5UP**, for example, in operating, closes contacts **1502** which, in turn, apply ground to the locking contacts of relays **15–OC1** through **15–OC5**. Likewise, contacts **1901** close upon the operation of relay **15–5UP** and apply ground to the locking contacts of relay **19 SN**, **19–SN**, **19–COMP1** and **19–DC3**.

Relay **15–5UP** also closes contacts **1903** and **1801** upon operating. The closure of contacts **1801** applies ground to the G2 lead **1802**, through break contacts **1809** of relay **15–OC2** and also through the break contacts **1805** of relay **15–OC5** to the G5 lead designated **1803**.

The closure of contacts **1903** due to the operation of relay **15–5UP** completes a circuit through break contacts of the A and B relays of all of the registers of the computer from ground through these contacts, contacts **1903**, break contacts **1909** of relay **19–DC3A** to battery through the winding of relay **19–DC3**. If all the A and B relays in the registers are released, thus indicating that none of the registers are being employed by the computer, relay **19–DC3** operates in the above-described circuit. Relay **19–DC3**, in operating, closes contacts **1904**, which relay completes a locking circuit for both relays **19–DC3** and **19–DC3A**. Relay **19–DC3A**, however, does not operate at this time because ground is connected to both of its winding terminals.

The application of ground to the G5 lead, designated **1803**, in response to the closure of contacts **1801** of relay **15–5UP**, completes a circuit for the operation of relay **15–CLRA** from battery through the winding of relay **15–CLRA**, the closed contacts **1516** of relay **46–5B**, the break contacts **1805** of relay **15–OC5** to ground through the operated contacts **1801** of relay **15–5UP**. The operation of relay **15–CLRA** completes a circuit for the operation of relay **15–CLRM** which circuit extends from battery through the winding of relay **15–CLRM** and the operated contacts **1540** of relay **15–CLRA** to ground through the operated contacts **1542** of relay **15–5UP**. Relay **15–CLRM** in operating closes its locking contacts **1543** for maintaining itself operated under control of relay **15–5UP**.

The operation of relay **15–DC3**, as described above, causes a number of contacts to be actuated including contacts **1910**, which contacts connect ground through the break contacts **1902** of relay **15–OC1** to the G1 lead designated **1903**. The application of ground to this lead completes a circuit which extends to contacts of relay **46–1I**, which relay is operated by the first portion of the order being described, and then extends through the winding of the A relay of the I storage register to battery, thus causing the operation of this relay.

The application of ground to the G2 lead **1802**, completes a circuit which extends from ground through the operated contacts **1801** of relay **15–5UP** and the break contact **1809** of relay **15–OC2** over conductor **62**, the operated contacts **1808** of relay **46–2S** to battery through the winding of relay **18–TR**. Relay **18–TR** in operating in the above-described circuit causes contacts **1911** to close, which contacts apply ground to the G4 lead for operating relay **21B** in a circuit extending from ground through the operated contacts **1911** of the **18–TR** relay, break contacts **1605** of relay **15–OC4**, break contacts **1606** of relay **19–COMP**, conductor **1607**, which conductor extends through Figs. 19, 20, 17, 16 and 29 to contacts **2901**, which contacts are closed due to the opera-

tion of relay 46–4A as described above, closed contacts 2902 of the operated relay 44–RO to battery through the winding of relay 21B.

The operation of either or both of the A relay of the I register and relay 21B of the A register interrupts the circuit from ground through the set of break contacts on each of the A and B relays of each of the registers, which contacts are connected in a series circuit extending through contacts 1913 of relay 15–5UP, and the unoperated contacts 1909 of relay 15–DC3A to the left-hand winding terminal of relay 19–DC3. As a result of interrupting this series check circuit through the break contacts of the A and B relays of each of the register circuits, ground is removed from the left-hand winding terminal of relay 19–DC3. Relay 19–DC3, however, does not release at this time because it is maintained operated in a circuit extending from battery through its winding and the winding of relay 19–DC3A, contacts 1904 of relay 19–DC3 to ground through the operated contacts 1901 of relay 15–5UP. In addition, relay 19–DC3A operates and is maintained operated in the above-described circuit, thus indicating that one or more of the A or B relays of at least one of the registers has operated. Relay 19–DC3A, in operating, actuates contacts 1504 and transfers the series check circuit from the A and B relays of all the registers from the windings of relays 19–DC3 and 19–DC3A to the winding of relay 16–DC3B through break contacts 1306. However, since this series check circuit is now open at contacts of relay 21B and at contacts of the A relay of the I register, relay 16–DC3B does not operate at this time.

The operation of the A relay of the I register, which is similar to relay 21A of the A register, completes a circuit for operating the switching or read relays in the I register so that the windings of the register relays including ground from the locking contacts are connected to the corresponding leads of the X multiple. The circuit for operating these switching or read relays extends from ground through contacts 1912 of relay 15–REG and contacts 1908 of relay 16–CXUP and through operated contacts on the A relay of the I register and then to battery through the windings of the switching relays of the I register. The operation of these switching or read relays applies ground to the leads of the X multiple in accordance with the particular register relays operated in each denominational order of the I register representing the number recorded in the I register. Ground is also applied to the RY lead which causes relay 21–RY to operate. Since the Y multiple is not used during the execution of the order in question, the operation of relay 21–RY performs no useful function at this time.

The operation of relay 21B closes a number of contacts, including contacts 2120, which connects the down-check circuit of the A register to the DC1B lead to check the condition of the register relays of the A register to insure that all the relays are released so that this register will be in proper condition to properly register the number to be transferred from the I register to this register. This down-check circuit extends from the winding of relay 16–DCB through contacts 1608 of relay 18–TR, contacts 1517 over the DC1B lead to contacts 2109 of the A register and then through break contacts of each of the register relays of the A register shown in Fig. 21 to ground. If all of the register relays of the A register are released, a series circuit through all of these contacts extends to the winding of relays 16–DCB, as described above, and causes this relay to operate. The operation of relay 16–DCB completes a circuit for the operation of the switching relays of the A register. This circuit extends from ground through contacts 1608, 1610, operated contacts 1611 of relay 16–DCB over the RXB lead, then through the operated contacts 2110 and the 21B relay to battery through windings of each of the switching relays 21–EUR and 21–AR through 21–JR. These switching or read relays of the A register extend the windings of each of the register relays of register A to the corresponding conductors of the X multiple. Thus, relay 21–EUR, in operating, closes the contacts 2113, 2114, etc., connecting the windings of relay 21 N, 21–N, 21 E, 21–EU00, 21–EU5 and 21–EU0 through 21–EUT, inclusive, to corresponding leads of the X multiple. Likewise relay 21–AR in operating connects the windings of relay 21–A00, 21–A5 and 21–A0 through 21–A5 to the corresponding leads of the X multiple. Likewise, the other switching relays connect the corresponding contacts with connecting windings of the other register relays of the A register to the X multiple.

Upon the connection of windings the register relays of both the I register and the A register to the X multiple the number recorded in the I register is transferred to the A register by way of ground from the LK relay in the I register and the locking contacts of the operated register relays of the I register to battery through the corresponding relays of the A register over the conductors of the X multiple and the contacts of the switching relays of the A and I registers. The corresponding relays of the A register thereupon operate and lock operated under the control of the locking relay 21–LK.

The operation of one relay in each of the subgroups of register relays of the A register completes an up-check circuit from ground extending through the up-check contacts of these relays. For example, the circuit extends from ground through an operated contact of either the 21–(+)N relay or the 21–(−)N relay and then through either the E or the −E relay, then either the 21–EU00 or 21–EU5 relay and then through the operated contacts of one of the relays EU0 through 21–EU4 and then through two relays of the relays required to register each of the digits in the succeeding denominational orders of the number. Upon completion of this up-check circuit within the A register, a circuit is completed for the operation of relay 16–UP, which circuit extends from battery through the winding of relay 16–UP, the operated contacts 1611, 1612 and break contacts 1613, break contacts 1307 to the UP lead extending to the registers and then through the operated contacts 2111 of relay 21B of the A register to ground through the series up-check circuit described above. The operation of relay 16–UP actuates contacts 1608, which contacts interrupt the ground supplied to the read leads RXA, RXB and RY for operating the switching relays of both the I and A registers allowing these switching relays to release and interrupt the connections between the register relays to both of these registers and the X multiple. The operation of relay 16–UP closes contacts 1518 and thus completes a circuit for the operation of relay 16–DC1B, which circuit extends from battery through the winding of relay 16–DC1B, the operated contacts 1614 of relay 18–TR and break contacts 1512 of relay 15–CLRB, the operated contacts 1518 of relay 15–UP to ground through the contacts 1519 of relay 18–TR.

The operation of relay 16–DC1B completes a circuit for the operation of relay 15–OC4 from battery through the winding of relay 15–OC4, the operated contacts 1520, relay 16–UP, contacts 1521 of relay 16–DC1B to ground through the operated contacts 1512 of relay 46–3T. The operation of relay 15–OC4 actuates contacts 1605 which contacts interrupt ground connected to the G4 lead and thus permit relay 21B to release.

The operation of relay 16–UP completes a circuit for operation of the locking relay of the register I by operating contacts 1522, which circuit extends from ground through the operated contacts 1522 of relay 16–UP, the operated contacts 1523 of relay 18–TR, the operated contacts 1524 of relay 15–CLRA, the operated contacts 1615 of relay 18–TR, contacts 1602 over CLRA lead extending to all the registers and then through the operated A relay of the I register to the LK relay of the I register, thus operating this relay. The operation of the LK relay

in the I register removes locking ground from all of the register relays of this register thus erasing the number registered in this register and clearing the register relays of this register so that they will be available for registering other numbers when desired. The release of all of the register relays of the I register will complete a down-check circuit within the I register, which circuit will extend through the break contacts of all of the register relays of this register and then through the operated contacts of the A relay of this register to the DC1A lead and then through break contacts **1504** and the operated contacts **1508** of relay **15**–CLRA to battery through the winding of relay **15**–DC1A thus causing this relay to operate and indicate that the number has been cleared from the I register. Operation of relay **15**–DC1A closes contacts **1509** which completes a down-check circuit through contacts on each of the switching relays of the I register from ground through the break contacts of the read or switching relays of the I register and the operated contacts of the A relay in the I register, over the DC2A lead and then through contacts **1509** of relay **15**–DC1A and then to battery through the winding of relay **15**–OC1. Relay **15**–OC1 operates at this time and actuates contacts **1902** which contacts remove ground from the G1 lead **1903** and which interrupts the operating circuit of the A relay in the I register, thus permitting this relay to release.

The release of the A relay in the I register, together with the previous release of relay **21**B, as described above, again completes the down-check circuit through A and B relays of all of the registers, which circuit now extends from ground through contacts of the A and B relays of these registers, the operated contacts **1903** of relay **15**–5UP, the operated contacts of relay **19**–DC3A, break contacts **1306** to battery through the winding of relay **16**–DC3B, which relay now operates and indicates that the control relays of all of the registers have been restored to normal.

Relay **16**–DC3B, in operating, completes a circuit for maintaining itself operated under control of relay **19**–DC3 from battery through the winding of relay **16**–DC3B closed contacts **1616** of relay **16**–DC3B to ground through the operated contacts **1615** of relay **19**–DC3.

The operation of relay **15**–DC1A, in addition to completing a circuit for the operation of relay **15**–OC1, as described above, also completes a circuit for the operation of relay **15**–OC5, which circuit extends from battery through the winding of relay **15**–OC5, the normal contacts **1514** of relay **44**–5E1, the operated contacts **1515** of relay **44**–TR1 to ground through the operated contacts **1905** of relay **16**–DC1B and the operated contacts **1906** of relay **16**–DC1A. Relay **15**–OC5, in operating, completes the circuit for maintaining itself operated under control of contacts **1502** of relay **15**–5UP. The operation of relay **15**–OC5 actuates contacts **1805** which contacts now disconnect ground from the G5 lead and permit relay **15**–CLRA to release.

The operation of relay **15**–DC1A also closes contacts **1615**, which contacts complete a circuit for the operation of relay **16**–CDC2 from battery through the winding of relay **16**–CDC2, the operated contacts **1618** of relay **16**–DC1B, contacts **1617** of relay **15**–DC1A, contacts **1619** of relay **18**–TR and contacts **1620** and **1621** of relays **15**–OC3 and **15**–OC1, respectively. Relay **16**–CDC2, in operating completes a circuit for the operation of relay **15**–OC2, which circuit extends from battery through the winding of relay **15**–OC2, the operated contacts **1525** of relay **16**–CDC2 to ground through the operated contacts **1526** of relay **16**–UP. Relay **15**–OC2, in operating, completes a circuit for maintaining itself operated under control of relay **15**–5UP from battery through the winding of relay **15**–OC2, closed contacts **1527** of relay **15**–OC2 to ground through the closed contacts **1502** of relay **15**–5UP.

The operation of relay **15**–OC2, together with the previous operation of relays **15**–OC1, **15**–OC3, **15**–OC4 and **15**–OC5, completes a circuit for the operation of relay **18**–CTR1 in an obvious circuit shown in Fig. 18. The operation of relay **18**–CTR1 completes a circuit for maintaining itself operated from battery through its winding, the operated contacts **1807** of relay **45**–CD and the locking contacts **1806** of relay **18**–CTR1. The operation of relay **18**–CTR1 removes ground from the control circuit of the steering relays shown in Figs. 11 and 12 and permits the steering relays of this circuit to be restored to their normal condition as described herein.

The operation of relay **18**–CTR1 also removes ground from the operating circuit of relay **45**–5UP thus permitting this relay to release. Release of relay **45**–5UP completes an obvious circuit for the operation of relay **45**–CO1, which relay operates and opens contacts **4655** thus preventing discharges through any of the tubes in Fig. 46 as a result of any switching transients which may arise upon the release of the relays of Fig. 46.

The operation of relay **18**–CTR1 also opens contacts **4653**, which contacts interrupt the locking circuit of all of the order relays of Fig. 46 thus permitting previously operated relays of Fig. 46 to release. Under the assumed conditions, relays **46**–1I, **46**–2S, **46**–3T, **46**–4A and **46**–5B will all release at this time. The release of these relays in turn interrupts the operating circuit of relays **45**–1RC through **45**–5RC, inclusive, thus permitting these relays to release. Release of all of the relays **45**–1RC through **45**–5RC, together with the release of relay **45**–5UP, interrupts the locking circuit of relay **45**–CO, which relay releases and in turn releases relay **45**–CO1 which relay restores the battery supply to the tube circuits of Fig. 46.

The release of the relays in Fig. 46 causes relays **44**–RO and **44**–TR1 to release.

Concurrently with the release of the relays in Figs. 44, 45 and 46, previously operated relays in the routine control circuits are likewise released. The release of relay **45**–5UP interrupts the operating circuit of relay **15**–5UP, which relay releases and opens contacts **1502** which in turn permits the release of relays **15**–OC1 through **15**–OC5, inclusive. In addition, contacts **1901** are opened with the result that relays **19**–DC3 and **19**–DC3A release and in turn release relays **15**–DC1A, **16**–UP, **16**–DCB, **16**–DC1B and **16**–CDC2.

Thereafter, the release of relay **45**–CO, described above, interrupts the locking circuit of relay **18**–CTR1, which relay releases and restores the circuits to their normal condition where they are ready to respond to a succeeding order registered in the order relays of Fig. 46. The release of these relays completes a down-check circuit for the operation of relay **13**–DCP which relay causes the advance of certain of the circuits to enter this next order on the order relays of Fig. 46.

Order A × B C $\overline{CC}$

Assume now for purposes of illustration that another order has been entered upon the order relays of Fig. 46, which order comprises the symbols A × B C $\overline{CC}$. This order directs the computer to multiply the number stored in the A register by the number stored in the B register and place the result in the C register and release or clear the number recorded in the A and B registers. The following order relays of Fig. 46 will be operated to set up this order, namely, relays **46**–1A, **46**–2R, **46**–3B, **46**–4C and **46**–5A.

The above series of five order relays of Fig. 46 may be set up from any of the various sources of orders in the normal manner of setting up such orders. The manner of setting up the orders is described elsewhere herein and will not be repeated here. In response to the operation of one and only one of the relays in each of the five columns of order relays of Fig. 46, as described above, relays **45**–1RC through **45**–5RC are operated and these

relays in turn complete a circuit for the operation of relay 45–5UP. Relay 45–5UP, in operating, completes a circuit for operating relay 46–CO, which relay locks operated under control of all the relays 45–1RC through 45–5RC, inclusive.

The operation of relay 46–1A closes contacts 2103 which prepare a circuit for the operation of relay 21A as will be described hereinafter. The operation of relay 46–2R closes contacts 4406 and which contacts prepare a circuit for the operation of relay 44–2R1 as will be described hereinafter. The operation of relay 46–2R also closes contacts 4405 which contacts complete an obvious circuit for the operation of the routine order relay 44–RO.

The operation of relay 46–3B closes contacts 2903 which prepares a circuit for the operation of the B relay of the B registers as will be described hereinafter.

The operation of relay 46–4C closes contacts 2904 which partially prepares a circuit for the operation of the B relay of the C register as will be described hereinafter.

The operation of relay 46–5A closes contacts 4403 which contacts complete an obvious circuit for the operation of relay 44–TR1 and relay 44–TR1 in operating in part prepares a circuit for maintaining itself operated under control of contacts 1401 of relay 15–5UP which relay operates as described hereinafter.

The operation of relay 46–5A also closes contacts 4404 which completes an obvious circuit for the operation of relay 44–5A1 and relay 44–5A1 in turn partially prepares the circuit for the operation of relays 15–CLRA and 15–CLRB, the operation of which relays will be described presently.

The operation of relay 45–5UP indicates that a complete order has been entered upon the order relays of Fig. 46, and in turn completes a circuit for the operation of relay 15–5UP from ground through the operated contacts 4501 of relay 7–RG1 and operated contacts 4504 of relay 45–5UP, over conductor 4506 through contacts 1501 and 1304 to battery through the winding of relay 15–5UP. The operation of relay 15–5UP prepares numerous locking circuits for relays of the routine control portion of the computer and initiates operation of the circuits and apparatus for the execution of the order, as described herein.

The operation of relay 15–5UP causes contacts 1801 to close, which contacts connect ground to the G5 lead, designated 1803, through the break contacts 1805 of relay 15–OC5. Ground thus applied to lead 1803 extends through the operated contacts 1528 of relay 46–5A1 to the winding of relay 15–CLRA and through contacts 1529 of relay 46–5A1 to the winding of relay 15–CLRB causing both of these relays to operate. Operation of relay 15–CLRA actuates contacts 1508 which contacts connect winding of relay 15–DC1A to down-check lead DC1A extending to the register circuits. The operation of relay 15–CLRB actuates contacts 1512 which contacts partially prepare a circuit for the down-check of relays of the B register.

The operation of either of the relays 15–CLRA or 15–CLRB completes an obious circuit for the operation of relay 15–CLRM.

Relay 15–CLRM in operating closes its locking contacts and completes a circuit for maintaining itself operated under control of contacts 1542 of relay 15–5UP. Relay 15–CLRM in operating transfers lead CXUP from the calculator section from the winding of relay 16–CXUP to the winding of relay 16–XUPM and also transfers lead CYUP from the calculator from the winding of relay 16–CYUP to the winding of relay 16–YUPM.

The operation of relay 15–5UP also connects ground to G2 lead, designated 1802, through contacts 1801 and through the break contacts 1809 of relay 15–OC2 which ground extends over lead 62 through Figs. 19, 20, 35, 38, 41 and 44 to the closed contacts 4406 of relay 46–2R and then to battery through the winding of relay 44–2R1 thus causing the operation of relay 44–2R1. Operation of relay 44–2R1 closes contacts 2501 which contacts apply ground to the calculator conductor which conditions the calculator circuits to multiply the numbers entered in the X and Y registers of the calculator section. Operation of relay 44–2R1 closes contacts 1530 which contactcs complete an obvious circuit for the operation of the 15–REG relay in the routine control circuit. The operation of this relay conditions the routine order control circuit to properly respond to the regular routine orders employing the calculator section of the computer.

The operation of relay 15–REG, for example, closes contacts 1912 which contacts partially prepare circuits for the operation of relays in the storage register circuits. The operation of relay 15–REG closes contacts 1530 which complete an obvious circuit for the operation of the 15–CALC relay. The operation of relay 15–REG closes contacts 2206 and 2207 which contacts apply ground to the G1 and G2 leads to the calculator. The operation of relay 15–REG also closes its locking contacts 1549 which contacts complete a circuit for maintaining relay 15–REG operated under control of contacts 1615 of relay 19–DC3 when this relay operates as will be described.

The operation of relay 15–CALC also partially prepares numerous circuits extending to the calculator portion of the computer which circuits are described more fully herein when they are finally completed.

The route control circuits first check the control relays of the register circuits to insure that the various circuits are in a condition for proper response to the order to be executed. First the down-check circuit through the contacts of the A and B relays of each of the register circuits is employed to operate relay 19–DC3 through the operated contacts 1913 of relay 15–5UP, when all these control relays are released, indicating that none of the registers are connected to any of the circuits of the computer. The operation of relay 19–DC3 closes contacts 1901, which contacts apply ground to the G1 lead through break contacts 1902 of relay 15–OC1. As a result, a circuit is completed for the operation of relay 21A from battery through the winding of relay 21A, operated contacts 2103 of relay 46–1A, the break contacts 1902 and operated contacts 1901 to ground.

The operation of relay 19–DC3 also connects ground to the G3 lead by closing contacts 1810, which ground extends through the break contacts 1811 and over the G3 lead, through the operated contacts of relay 46–3B to the B relay of the B register causing the operation of this B relay.

The operation of either or both the A relay of the A register, relay 21A, and the B relay of the B register interrupts the ground connected to the left-hand winding terminal of relay 19–DC3 and to the right-hand winding terminal of relay 19–DC3A, thus causing the operation of relay 19–DC3A and at the same time maintaining relay 19–DC3 operated.

The operation of relay 21A closes contacts 2117 which contacts complete a circuit for operating the switching or read relays EUR, AR through JR of the A storage register which circuit extends from ground through the operated contacts 1912 of the 15–REG relay, the break contacts 1908 of the 16–CXUP relay, the RXA lead, contacts 2117 to battery through the winding of relays EUR, AR through JR, inclusive, in parallel. The operation of these relays close contacts 2113, 2114, 2115, etc. and connect ground through the operated contacts 2118 of relay 7–RG1 and through the break contacts 2109, 2110, 2111, 2112, etc. of relay 21LK, then through the locking contacts of the operated storage register relays of the register and through the operated contacts of relays EUR, AR through JR to conductors of the X multiple, thus causing the number stored in the A register to be read out over the X multiple.

Likewise, the operation of the B relay of the B register, which relay is similar to relay 21B of the A register,

completes a circuit from ground through the operated contacts **1912** of relay **15**–REG, break contacts of relay **1907** of relay **16**–CYUP, the RY lead, operated contacts of the B relay of the B register to battery through the winding of the RY relay of the B register. The B register is not shown in detail but it is similar in every respect to the A register shown in detail in Fig. 21. The operation of the RY of the B register applies ground to the contacts of the storage relays of the register which contacts are connected to the Y multiple, thus causing the number stored in the B register to be read out over the Y multiple. In other words, the operated storage relays of the registers cause ground to be applied through contacts of the switching or read relays to the corresponding conductors of the Y multiple thus indicating the number stored in the Y multiple.

The X and Y registers of the calculator are provided with a down-check circuit which circuit is completed when the register relays of these registers are released. When all of the register relays of both the X and Y registers of the calculator section are fully released ground is applied to the DC1 lead which extends through contacts **1531** to the winding of relay **15**–CDC1. Relay **15**–CDC1 in operating closes its locking contacts **1532** thus maintaining itself operated under control of contacts **1533** of relay **15**–CALC. The operation of relay **15**–CDC1 causes contacts **1624**, **1625**, **1626** and **1627** to be closed which closed contacts extend ground to the RX, REX, RSX, RY, REY and RSY conductors which conductors extend to the calculator shown in Fig. 25 which causes the numbers on the X and Y multiples to be read or recorded by the X and Y registers of the calculator. The circuit for applying ground to the RX, REX, RSX, RY, REY and RSY leads extends from ground through the operated contacts **1628** of relay **19**–DC3 through break contacts of the **15**–OC1 relay and **15**–OC3 relay, break contacts of the **16**–YUPM, **16**–CYUP, **16**–XUPM, **16**–CXUP and **15**–CDC1 relays to the respective conductors extending to the calculator.

When the numbers have been fully recorded in the X and Y registers of the calculator section of the computer, the respective leads CXUP and CYUP are grounded thus causing the operation of relays **16**–XUPM and **16**–YUPM. The circuit for operating the **16**–XUPM relay extends from battery through the winding of relay **16**–XUPM, operated contacts **1661** of relay **15**–CLRM, break contacts **1308**, the operated contacts **1630** of relay **15**–CALC to ground over the CXUP lead extending to the calculator section shown in Fig. 25. The circuit for applying ground to the leads in the calculator section is described in detail in the above-identified patent to Williams so that said description is not repeated here.

The circuit for operation of the relay **16**–YUPM extends from battery through the winding of relay **16**–YUPM, operated contacts **1631** of relay **15**–CLRM, operated contacts **1632** of relay **15**–CALC to the CYUP lead extending to the calculator section shown in Fig. 25.

The operation of relay **16**–XUPM actuates contacts **1633** which contacts interrupt the ground supplied over leads RX, REX and RSX to the computer and allow the switching or read relays of the X register of the computer to release and disconnect the register relays of this register from the X multiple. Likewise, the operation of relay **16**–YUPM actuates contacts **1634** which contacts remove ground from leads RY, REY and RSY extending to the computer and thus allow the read or switching relays of the Y register to release and disconnect the register relays of this register from the conductors of the Y multiple.

Thereafter, the computer performs the necessary operations of shifting, addition, etc., as well as shifting the result when required, performing round-off operations and such other operations as are required to obtain the desired answer as a result of the computations performed by the computer.

If the computing operation requires a longer interval of time than is allowed by the alarm and time-out circuits thus indicating some trouble condition or inability to proceed through the necessary steps to arrive at a satisfactory answer, contacts **1501** will be actuated under control of the alarm circuit which contacts cause relay **15**–5UP to release. The release of this relay interrupts the numerous locking circuits for the various relays as described above and causes the routine control circuits to be restored to their initial or normal condition. However, the order relays of Fig. 46 are not released and neither are the various relays directly controlled by these order relays released. Consequently, at a slightly later interval of time when contacts **1553** are closed under control of the alarm circuits to initiate a second attempt to arrive at a satisfactory answer, relay **15**–5UP will reoperate and initiate the execution of the same order set up on the order relays of Fig. 46 in the same manner as described above. If the second attempt is unsuccessful then the alarm circuits will interrupt the operation of the computer on the entire problem and stop the computer or advance it to another problem if such other problem is available and ready for the computer.

However, assume now that the computing section satisfactorily progresses through all of the steps required and arrives at an answer within the time prescribed either upon a first or a second attempt. Upon arriving at the conclusion of the calculating operations, the calculator applies ground to the lead XYG indicating that the calculating section is ready to read out the answer or results of the calculations performed therein. The application of ground to the XYG lead causes relay **16**–XYG to operate which relay closes contacts **1641** and applies ground through the respective contacts **1642** of relay **16**–XUPM and **1643** of relay **16**–YUPM to the windings of relays **16**–CXUP and **16**–CYUP respectively causing the operation of these relays.

The operation of relay **16**–CXUP closes contacts **1552** which contacts together with the operated contacts **1550** of relay **15**–CLRM short-circuits the contacts **1501**, thus cancelling or preventing the second trial if the alarm circuits time out after the operation of relay **16**–CXUP.

The operation of relay **16**–CXUP opens contacts **1908** which contacts remove ground from the RXA lead which lead as described above now extends through operated contacts **2117** of relay **21**A to the winding of the switching or read-out relays **21**–EUR and **21**–AR through **21**–JR. The release of the red or switching relays **21**–EUR and **21**–AR through **21**–JR disconnects the windings of the register relays of the A register from the corresponding conductors of the X multiple. Likewise, the operation of relay **16**–CYUP opens contacts **1907** which contacts remove ground from the RY lead and thus permit the release of the RY relay in the B register. The release of this relay disconnects ground from the contacts of the register relays in the B register extending to conductors of the Y multiple. Thus, the connection between the A register and the X multiple and between the B register and the Y multiple is interrupted.

The operation of relay **16**–CXUP closes contacts **1535** which contacts apply ground to the CLRA lead extending to the register circuits. A circuit for operating the relay **21**–LK over the CLRA lead now extends from battery through the winding of relay **21**–LK, the operated contacts **2104** of relay **21**A, the CLRA lead extending to Fig. 16 and then through contacts **1602** of relay **19**–ENCA, operated contacts **1635** of relay **16**–CXUP, operated contacts **1524** of relay **15**–CLRA, operated contacts **1535** of relay **16**–CXUP to ground through the operated contacts **1534** of relay **16**–XYG. The operation of relay **21**–LK in the above-described circuit opens the locking contacts **2109**, **2110**, **2111**, **2112**, etc., in the A register permitting all of the register relays which were previously operated to release. Likewise, the operation of relay **16**–CYUP

applies ground to the CLRB lead for operating the LK locking relay in the B register. The circuit for operating this LK relay extends from ground through the operated contacts **1534** of relay **16**–XYG, the operated contacts **1544** of relay **16**–CYUP, operated contacts **1554** of relay **15**–CLRB, operated contacts **1637** of relay **16**–CYUP, the break contacts **1636** of relay **19**–ENCB and over the CLRB lead, through contacts of the B relay of the B register to battery through the winding of the LK relay of the B register. The LK relay of the B register operates and interrupts the locking circuit of all of the register relays of the B register which were previously operated, thus releasing all of these relays.

The routine control circuits now make a down-check of the register relays of both the A and B registers and also of the switching or read relays of both of the A and B registers.

The release of all the register relays in the A register completes a down-check circuit through a set of break contacts on each of the register relays connected in a series circuit from ground through contacts **2107** of relay **21A** and over the DC1A lead which extends to Fig. 15 and then through contacts **1504** of relay **19**–ENCA and operated contacts **1508** of relay **15**–CLRA to battery through the winding of relay **15**–DC1A. When all of the register relays of the A register are released, relay **15**–DC1A will operate and close its locking contacts for maintaining itself operated under control of relays **19**–DC3 and **16**–CXUP and **16**–CYUP.

The operation of relay **15**–DC1A closes contacts **1509** which contacts connect the winding of relay **15**–OC1 to the DC2A lead extending to the register circuits. This lead extends through contacts **2119** of relay **21A** to a down-check circuit extending serially through break contacts on each of the switching or read relays to ground. Upon the release all of the switching relays of the A register in response to the opening of contacts **1908** as described above a circuit is therefore completed for operating relay **15**–OC1 which relay in operating closes its locking contacts **1506** and thus completes a locking circuit for maintaining itself operated under control of contacts **1502** of relay **15**–5UP. The operation of relay **15**–OC1 actuates its contacts **1902** and removes ground from the G1 lead, **1903**, and thus interrupts the circuits of relay **21A** permitting relay **21A** to release.

In a similar manner the release of the register relays of the B register complete a circuit extending serially through break contacts on each of the register relays of the B register and then through operated contacts of the B relay of the B register to the DC1B lead which extends from the B register to Fig. 15 and then through contacts **1517** of relay **19**–ENCB operated contacts **1512** of relay **15**–CLRB and operated contacts **1638** of relay **16**–CYUP to battery through the winding of relay **16**–DC1B. Relay DC1B operates when this circuit is completed and closes its locking contacts **1640** for maintaining itself operated under control of contacts **1615** of relay **19**–DC3 and also under control of contacts of relays **16**–CXUP and **16**–CYUP.

In operating relay **16**–DC1B closes its contacts **1536** which contacts connect battery through the winding of relay **16**–OC3 to the conductor DC2B extending to the register circuits. This conductor extends through operated contacts of the B relay of the B register to a down-check circuit extending serially through the break contacts of each of the switching or read relays of the B register circuit to ground. When this down-check circuit is completed, relay **15**–OC3 operates and closes contacts **1537** for maintaining relay **15**–OC3 operated under control of contacts **1502** of relay **15**–5UP. The operation of relay **15**–OC3 actuates contacts **1811** and removes ground from the G3 lead thus interrupting the operating circuit of the B relay of the B register, permitting this B relay to release.

The operation of both relays **15**–DC1A and **16**–DC1B completes a circuit for the operation of relay **15**–OC5 which circuit extends from battery through the winding of relay **15**–OC5, the break contacts **1514** of relay **44**–5E1, operated contacts **1515** of relay **44**–TR1 to ground through the operated contacts **1905** of relay **16**–DC1B and contacts **1906** of relay **15**–DC1A. Relay **15**–OC5 in operating closes contacts **1538** for maintaining itself operated under control of contacts **1502** of relay **15**–5UP. The operation of relay **15**–OC5 actuates contacts **1805** and removes ground from the G5 lead, **1803**, thus interrupting the operating circuits of relay **15**–CLRA and **15**–CLRB which permits these relays to release.

Thus, the numbers previously stored in both the A and B register were transferred to the X and Y registers of the calculator and after the calculator had satisfactorily progressed through the necessary steps to arrive at an answer, the register relays and the switching or read relays and the control relays of both the A and B registers released and the release of all these relays checked by the routine control circuits.

The routine control circuits also check the release of the read or switching relays in the X and Y registers of the calculator.

The release of the switching relays in the X and Y registers of the calculator in response to the actuation of contacts **1633** of relay **16**–CXUP and contacts **1634** of relay **16**–CYUP causes the circuits of these registers in the calculator to apply ground to the DC2 lead extending from the calculator to Fig. 16 and then through contacts **1639** of relay **15**–CALC, contacts **1663** of relay **16**–CYUP, contacts **1640** of relay **16**–CXUP, contacts **1617** of relay **15**–DC1A, contacts **1618** of relay **16**–DC1B to battery through the winding of relay **16**–CDC2. The completion of this circuit causes relay **16**–CDC2 to operate and close its locking contacts for maintaining itself operated under control of contacts **1615** of relay **19**–DC3 and also contacts of relays **16**–CXUP and **16**–CYUP. The operation of relay **16**–CDC2 actuates contacts **1539** which contacts permit relay **15**–CALC to release. The release of relay **15**–CALC interrupts numerous circuits extending to the calculator by opening its contacts. The operation of relay **16**–CDC2 also closes contacts **1525** and prepares a circuit for the operation of relay **15**–OC2, the operation of which will be described hereinafter.

The release of relay **21A** and B relay of the B register as described above again completes a down-check circuit through a break contact on each of the control relays A and B in each of the register circuits which circuits now extend from battery through the winding of relay **16**–DC3B, break contacts **1306**, operated contacts **1909** of relay **19**–DC3A, operated contacts **1913** of relay **15**–5UP to ground through the series circuit through break contacts of each of the control relays of all the storage registers. Relay **16**–DC3B operates when the above-described circuit is completed and in operating closes locking contacts **1616** which maintain relay **16**–DC3B, operated under control of contacts **1615** of relay **19**–DC3. The operation of relay **16**–DC3B actuates contacts **1652** which contacts connect ground received from the calculator circuit over lead DC2 in response to a closure of the down-check circuit through the read or switching relays of the X and Y registers of this calculator to the G4 lead and also to the read lead returning to the calculator and to the RN lead.

First considering the circuit from the DC2 lead over the G4 lead, the operation of contacts **1652** as described above completes a circuit for the operation of the B relay of the C register which circuit extends from battery through the winding of the B relay of the C register then through Figs. 21, 20, 17, 32 and 29 and then through contacts **2907** of relay **44**–RO and contacts **2904** of relay **46**–4C to the G4 lead which lead extends from Fig. 29 through Figs. 14, 17, 20, 19 and through the operated contacts **1652** to ground on the DC2 lead. The opera-

tion of the B relay of the C register extends the down-check circuit through the register relays of the C register to lead DC1B. The application of ground to lead DC1B from the register down-check circuit of the C register completes a circuit for the operation of relay 16–DC1B, which circuit extends from battery through the winding of relay 16–DC1B and the operated contacts 1662 of relay 16–DC3B and break contacts 1517 of relay 19–ENCB to ground received over the DC1B lead from the down-check circuit of the register relays of the C register as described above. The operation of relay 16–DC1B causes contacts 1663 of relay 16–DCB to close and complete a circuit for maintaining relay 16–DCB operated under control of contacts 1615 of relay 19–DC3.

The operation of relay 16–DCB closes contacts 1611 which contacts apply ground through the break contacts 1608 of relay 16–UP and contacts 1910 of relay 16–UP1 and operated contacts 1611 of relay 16–DCB to the RXB lead extending to the register circuits. The RXB lead extends through operated contacts of the B relay of the C register to the winding of the read or switching relays of the C register. The above-described circuit from ground connected to contacts 1608 to the switching or read relays of the C register causes these relays to operate and connect the respective windings of the register relays of the C register to the corresponding conductors of the X multiple, thus conditioning these relays to receive and store the number from the X multiple.

Meantime, the ground received over the DC2 lead from the down-check circuit of the X and Y registers of the calculator section is also applied through contacts 1652 of relay 16–DC3B to the RN lead through contacts 1605 of relay 15–OC4, normal contacts 1664 of relay 22–RTX and the operated contacts 1665 of relay 16–DC3B to the RN lead extending to the calculator. Ground connected to this RN lead causes the calculator to read out the results of the computation in a normal manner over the X multiple. In addition, ground from the DC2 lead through contacts 1652 also extends through contacts 1651 of relay 15–OC4, operated contacts 1650 of relay 16–DC3B and contacts 1649 of relay 16–CXUP to the read lead extending to the calculator section. Ground thus applied to the read lead to the calculator section causes the calculator to read out the number representing the results of the computations performed by the calculator over the X multiple. This number then is stored in the storage relays of the C register which are at this time connected to the X multiple as described above.

Upon the completion of the storing of the number upon the register relays of the C register an up-check circuit which extends through contacts of each subgroup of the register relays of the C register is completed. This up-check circuit then extends through operated contacts of the B relay of the C register to the UP lead which lead extends to Fig. 16 and then through break contacts 1307 of Fig. 13 and through the operated contacts 1666 of relay 16–DC3B, contacts 1655 of relay 18–RPTO, operated contacts 1656 of relay 15–REG, contacts 1667 of relay 16–DCB to battery through the winding of relay 16–UP1. Upon the completion of this up-check circuit, relay 16–UP1 operates and closes its locking contacts 1658 for maintaining itself operated under control of contacts 1659 of relay 15–OC4 and contacts 1628 of relay 19–DC3. The operation of relay 16–UP1 actuates contacts 1610 which contacts remove ground from the RXB lead extending to the switching or read relays of the C register thus permitting these switching or read relays of the C register to release and disconnect the respective windings of the register relays of the C register from the corresponding conductors of the X multiple. It should be noted that the register relays of the C register which were operated in response to the number received from the X multiple which number in turn was applied to the X multiple by the calculator section are locked operated and maintained operated under control of the LK relay of the C register. Thus, the register relays of the C register are disconnected from the X multiple at this time with the result of the calculations performed by the calculator stored upon them.

The operation of relay 16–UP1 also actuates contacts 2503 and 2504 which removes ground from the G1 and G2 leads extending to the calculator section which permits the calculator to restore to normal.

The operation of relay 16–UP1 also closes contacts 1645 which contacts complete a circuit for the operation of relay 15–OC2 which circuit extends from battery through the winding of relay 15–OC2, the operated contacts 1525 of relay 16–CDC2 to ground through the operated contacts 1545 of relay 16–UP1. Relay 15–OC2 operates in the above-described circuit and closes its operating contacts 1527 for maintaining itself operated under control of contacts 1502 of relay 15–5UP.

The operation of relay 15–OC2 actuates contacts 1809 which contacts remove ground from the G2 lead and thus interrupt the operating circuit of relay 44–2R1. Relay 44–2R1 in releasing opens contacts 1530.

The operation of relay 15–OC2 actuates contacts 1660 which contacts remove the locking ground from the windings of relay 16–XUPM, 16–YUPM, 16–CXUP and 16–CYUP, thus permitting these relays to release. The calculator in returning to normal in response to the removal of ground from the G1 and G2 leads, described above, connects ground to the ADV lead which extends to Fig. 15. Ground applied to the ADV lead causes the operation of relay 15–OC4 through the operated contacts 1546 of relay 16–UP1. Relay 15–OC4 in operating closes its locking contacts for maintaining itself operated under control of contacts 1502 of relay 15–5UP. Relay 15–OC4 in operating actuates contacts 1605, 1651, 1659, interrupting locking circuits and removing ground from conductors extending to the calculator section.

The operation of relay 15–OC4 together with the previous operation of relays 15–OC1, 15–OC2, 15–OC3 and 15–OC5 complete a circuit shown in Fig. 18 for the operation of relay 18–CTR1. The operation of relay 18–CTR1 actuates contacts 1105 and restores the steering and progress circuits shown in Figs. 11 and 12 in their normal condition. The operation of relay 18–CTR1 actuates contacts 1116 which contacts interrupt the operating circuit of relay 45–5UP, thus permitting this relay to release. The release of relay 45–5UP causes the release of relay 15–5UP which relay releases and in turn interrupts the locking circuits of the relays of the routine control circuits of Figs. 15 and 16 and permits these relays to release. The operation of relay 18–CTR1 also actuates contacts 4653 which contacts interrupt the locking circuits of the order relays of Fig. 46 and permit these relays to release. The release of the relays of the routine control circuit shown in Figs. 15 and 16 completes a down-check circuit through contacts of these relays for operating relay 13–DCB which relay causes the advance of certain of the circuits from which orders are received so that a succeeding order will be set up on the order relays of Fig. 46. After the release of the order relays of Fig. 46, as well as the release of the control relays of Figs. 44 and 45, relay 18–CTR1 also releases, thus restoring the circuits to their normal condition where they are ready to execute the succeeding order set up on the order relays of Fig. 46.

Order B ÷ A S $\overline{HH}$

Assume now that the order B ÷ A S $\overline{HH}$ is set up on the order relays of Fig. 46 from any of the sources employed to set these order relays. This order is employed to direct the computer equipment to take the number stored in the B register and divide it by the number stored in the A register and leave the result in the X register of the computer holding the numbers in the B and A registers stored therein for future use by the computer. This number is entered into the com-

puter by causing relays 46–1B, 46–2Q, 46–3A, 46–4S and 46–5D to operate. The operation of relay 46–1B causes contacts 2201 to close and extend a circuit from the winding of the A relay of the B register to the G1 lead for the operation of the A relay of the B register when ground is applied to this lead. The operation of relay 46–2Q closes contacts 4407 which contacts complete an obvious circuit for the operation of the routine order relay 44–RO. Routine order relay 44–RO closes numerous control contacts as will be described hereinafter.

The operation of relay 46–2Q also closes contacts 4408 which contacts connect the winding of relay 44–2Q1 to the G2 lead.

The operation of relay 44–3A causes contacts 2905 to close and in turn connects the winding of relay 21B to the G3 lead.

The operation of relay 46–5D causes contacts 4409 to close and complete an obvious circuit for the operation of relay 44–TR1.

The operation of relay 44–TR1 together with the closure of contacts 2202 complete a circuit for the operation of relay 22–RTX from ground through the closed contacts 2203 of relay 44–TR1, closed contacts 2202 of relay 46–4S, contacts 2204 of relay 44–TR1 to battery through the winding of relay 22–RTX.

The operation of each of these order relays described above in Fig. 46 completes a circuit for maintaining itself operated as described herein and in addition the operation of one of these relays of each column as assumed above completes circuits for the operation of the respective relays 46–1RC through 44–5RC. These relays in turn complete a circuit for the operation of relay 45–5UP as described hereinbefore. Relay 45–5UP completes a circuit for the operation of relay 45–CO which relay in turn locks operated under control of relays 45–1RC through 45–5RC.

In addition, relay 45–5UP completes a circuit for the operation of relay 15–5UP and the operation of relay 15–5UP starts the execution of the order by the computer.

Relay 15–5UP applies ground to numerous contacts of the routine control circuit of the computer so that numerous relays when they operate will be maintained operated until the order is executed or dismissed. The first operations of the computer in executing the order are to check the various control circuits of the storage register, first to insure that both the A and B relays provided in each of the registers are released and then that one or more of these relays operates in response to the execution of the order. Thus, the operation of relay 15–5UP closes contacts 1801 which contacts apply ground to the G2 lead and G5 lead. Application of ground to the G5 lead at this time produces no useful results since none of the relays having contacts connected to this lead are operated. The application of ground to the G2 lead as described hereinbefore completes a circuit for the operation of relay 44–2Q1 which relay in operating closes contacts 1543 which contacts complete an obvious circuit for the operation of relay 15–REG. Relay 15–REG in operating closes contacts 1530 which contacts complete an obvious circuit for the operation of relay 15–CALC. The operation of relay 15–CALC together with the closure of contacts 2502 of relay 44–2Q1 prepare the calculator for performing the required computation.

The operation of relay 15–5UP also closes contacts 1913 which contacts extend the down-check lead through a break contact on each of the A and B relays of each of the storage registers to the winding of the down-check relay DC3 through the break contact 1909 of relay 19–DC3A. If the down-check circuit is complete indicating that none of the control relays of the storage registers is operated, relay DC3 operates and closes contacts 1910 and 1810. Contacts 1910 apply ground to lead G1 which ground causes the operation of the A relay of the B register. Likewise, the operation of contacts 1810 applies ground to the G3 lead and in turn causes the operation of relay 21B of the A register. The operation of either or both of these relays removes a short-circuit from around the winding of relay DC3A which relay operates and locks operated in series with relay 19–DC3 thus indicating that one or both of these control relays have operated.

The operation of the A relay of the B register extends the winding of the switching or reading relays of the B register to the RXA conductor which extends to Fig. 10 and then through contacts 1908 to relay 16–CXUP to ground through the operated contacts 1912 of relay 15–REG. The completion of this circuit causes the switching or reading relays of the register to connect the winding and locking contacts of the register relays of the B register to corresponding conductors of the X multiple. As a result, ground is applied to those conductors of the X multiple corresponding to the register relays of the B register operated to represent the number registered therein.

Likewise, the operation of relay 21B causes conductor 2121 to close and extend the winding of relay 21RY to the RY lead which extends to Fig. 19 and then through the break contacts of relay 16–CYUP to ground through contacts 1912 of relay 15. The operation of relay 21RY connects contacts from the storage relays of the A storage register to corresponding conductors of the Y multiple which cause the respective conductors of the Y multiple to be grounded in accordance with the register relays of the A register which are operated to represent the number stored in the A register. Thus, the number stored in the B register is read out on the X multiple and the number stored in the A register is read out on the Y multiple.

The operation of relay 15–REG as described above causes contacts 1531 to operate and connect the winding of relay 15–CDC1 to the DC1 lead extending to the calculator. Ground is applied to the lead DC1 if and when all of the register relays of the X register and the Y register of the calculator are released and in their normal condition. When ground is applied to this lead, relay 15–CDC1 operates and closes its locking contacts 1532 which complete an obvious circuit for maintaining relay 15–CDC1 operated under control of contacts 1533 of relay 15–CALC.

The operation of relay 15–CDC1 together with the operation of relay 15–CALC applies grounds to the RX, REX, RSX, RY, REY and RSY leads extending to the calculator circuit. The circuits of the RX, REX and RSX may be traced from ground through the operated contacts 1628 of relay 19–DC3, break contacts 1645 of relay 15–OC1, contacts 1646 of relay 16–XUPM, contacts 1633 of relay 16–CXUP, contacts 1635 of relay 15–CDC1 to the RSX lead and contacts 1624 of relay 15–CDC1 and contacts 1541 of relay 15–CALC to the RX lead and contacts 1542 to the REX lead. Ground extends to the RY, REY and RSY leads through a similar series of contacts through the break contacts 1647 of relay 15–OC3 instead of contacts 1645 of relay 15–OC1. Ground applied to the RX, REX, RY and REY leads causes the switching relays of the X and Y registers of the calculator to be operated and connects the windings of the register relays of these registers to the corresponding conductors of the X and Y multiples so that upon the reading out of the numbers stored in the B and A registers the corresponding number is read into and stored upon the register relays of the X and Y registers, respectively, of the calculator.

When the number is completely read into the X register of the calculator the calculator grounds the lead CXUP which lead extends through the operated contacts 1630 of relay 15–CALC, the break contacts 1308 and the

break contacts 1629 of relay 15–CLRM to the winding of relay 16–CXUP.

Likewise, when the number is fully transferred to the Y register of the calculator the calculator applies ground to the CYUP lead which lead extends through contacts 1632 of the operated relay 15–CALC, the break contacts 1631 of relay 15–CLRM to battery through the winding of relay 16–CYUP. Inasmuch as neither the 15–CLRA relay nor the 15–CLRB relay is operated by relay 46–5D, relay 15–CLRM is not operated. Consequently, relay 16–CXUP and relay 16–CYUP operate as soon as ground is applied to the corresponding leads CXUP and CYUP by the calculator section of the computer.

The operation of relay 16–CXUP causes contacts 1633 to open and the operation of relay 16–CYUP causes contacts 1634 to open. The opening of contacts 1633 and 1634 interrupts the ground applied to leads RX, REX, RSX, RY, REY and RSY extending to the calculator and thus permits the reading or switching relays which extend the connections from the X and Y multiples to the register relays of the X and Y registers of the calculator to release thus interrupting these connections. The operation of relay 16–CXUP and relay 16–CYUP also causes the respective contacts 1908 and 1907 to be opened which contacts remove ground from the RXA lead and the RY lead extending to the registers. The removal of ground from the RXA lead interrupts the switching or read relays of the B register, thus permitting these relays to release. The removal of ground from the RY lead interrupts the operating circuit of relay 21–R4, thus opening the connections between the contacts of the register relays of the A register and the Y multiple. However, it should be noted that the register relays of both the B and A registers are maintained operated at this time because the locking relay of these registers has not been operated.

The calculator then performs the ordered computations which under present conditions will be dividing a number in the B register which number was transferred to the X register of the calculator by the number in the A register which number was transferred to the Y register of the calculator.

In performing these operations the calculator section also performs the necessary shift operations both at the beginning of the computations and at the completion of the computations and also performs the necessary round-off functions as may be required.

If trouble is encountered in performing the computations the caluculator section operates as described hereinelsewhere, clears itself and restores the routine control circuits to their initial condition without releasing the order relays of Fig. 46 whereupon the computer will again attempt to perform the operation indicated by the order entered upon the order relays. If, on the second attempt, the calculator still fails to satisfactorily perform the directed computation, a trouble indication is given and the operation of the computer on the particular problem involved is stopped.

If, however, the calculator successfully performs the computations required as well as the required auxiliary operations the calculator will ground the lead XYG and also the read lead both of which extend to Fig. 16, thus indicating that the calculation has been satisfactorily performed and that the calculator is ready to read out the results of the computation.

The operation of relay 16–XYG closes contacts 1534 which contacts complete circuits for the operation of relays 15–DC1A and 16–DC1B. The circuit for operating relay 15–DC1A extends from battery through the winding of relay 15–DC1A, the break contacts 1508 of relay 15–CLRB, the operated contacts 1535 of relay 16–CXUP to ground through the operated contacts 1534 of relay 16–XYG. Relay 15–DC1A in operating closes contacts 1509 which contacts extend to the winding of relay 15–OC1 to the DC2A lead which extends to the registers. Under the assumed conditions, with the A relay of the B register operated, the DC2A lead extends through the operated contacts on the A relay of the B register and then through a down-check circuit of the switching relay of this register to ground. If and when the switching relays release in response to the removal of ground from the RXA lead as described above, the above-traced down-check circuit will be completed and cause the operation of relay 15–OC1 which relay in operating locks under control of contacts 1502 of relay 15–5UP. Relay 15–OC1 in operating opens contacts 1902 which contacts remove ground from the G1 lead, 1903, which extends through the operated contacts 2201 to the winding of the A relay of the B register, thus permitting this relay to release.

The circuit for the operation of relay 16–DC1B is traced from battery through the winding of relay 16–DC1B, the operated contacts 1638 of relay 16–CYUP, the break contacts 1512 of relay 15–CLRB, the operated contacts 1544 of relay 16–CYUP to ground through the operated contacts 1534 of relay 16–XYG. Relay 16–DC1B in operating closes its locking contacts 1640 for maintaining itself operated under control of relay 19–DC1B. Relay 16–DC1B in operating closes contacts 1536 which connect the winding of relay 15–OC3 to the DC2B lead extending to the register circuits. Under the assumed conditions, this lead extends through the operated contacts 2122 of the 21B relay of the A register and then through the down-check circuit through the contacts of the read or switching relays in the A register circuit. Inasmuch as the switching or read relays of the A register are released at this time the down-check circuit will be completed through their contacts and thus complete a circuit for the operation of relay 15–OC3 which relay operates and in operating closes its locking contacts 1537 for maintaining itself operated under control of contacts 1502 of relay 15–5UP.

Relay 15–OC3 in operating also operates contacts 1811 which contacts remove ground from the G3 lead extending through contacts 2905 and 2906 to the winding of relay 21B, thus permitting relay 21B to release.

The release of the read or switching relays in the X and Y registers of the calculator section applies ground to a DC2 lead extending to Fig. 16. The application of ground to the DC2 lead together with the operation of relay 15–DC1A complete a circuit for the operation of relay 16–CDC2 which circuit extends from the DC2 lead to the operated contacts 1639 of relay 15–CALC, the operated contacts 1620 and 1640 of relay 16–CYUP, the operated contacts 1617 of relay 16–CXUP, contacts 1618 of relay 15–DC1A to battery through the winding of relay 16–CDC2. Relay 16–CDC2 in operating closes its locking contact for maintaining itself operated under control of contacts 1615 of relay 19–DC3.

The operation of relay 16–CDC2 opens contacts 1539 which contacts release relay 15–CALC which relay thereupon releases and restores its contacts to an unoperated condition.

The release of the A relay of the B register together with the release of relay 21B of the A register again completes a down-check circuit through the control A and B relays of all the register circuits which complete a circuit for the operation of relay 16–DC3B which circuit may be traced from battery through the winding of relay 16–DC3B, through the break contacts 1306, the operated contacts 1909 of relay 19–DC3A, the operated contacts 1913 of relay 15–5UP to ground through the down-check circuits of the A and B relays of all of the register circuits. The operation of relay 16–DC3B extends the ground received from the down-check lead DC2 to the calculator to the G4 lead and also through contacts 1651, operated contacts 1650 of relay 16–DC3B and contacts 1649 of relay 16–CXUP to the READ lead to the computer and also from the contacts 1652 of the 16–DC3B

relay, contacts **1605**, operated contacts **1652** of relay **22**–RTX, operated contacts **1653** of relay **16**–DC3B to the RTX lead causing the calculator to enter the results of the computation into the X register of the calculator section. At this time the A relay in the calculator remains locked up after the execution of the present order has been completed to provide a simulated down-check path to the DC1 lead of the calculator to be used in starting the execution of the next routine order in which the first number is to be used in the calculations which should be the number left in the register by the present order.

When the result of the computation has been entered into the X register of the calculator and then ground applied by the calculating circuit to the CXUP lead which this time extends through the operated contacts **1654** of relay **16**–DC3B instead of contacts **1630** of relay **15**–CALC as described above when ground was applied to the CXUP lead for the first time, a circuit from the CXUP lead extends through the break contacts **1655** and the operated contacts **1656** of relay **15**–REG, contacts **1657** of relay **22**–RTX to battery through the winding of the **16**–UP1 relay.

The operation of relay **16**–UP1 closes its locking contacts **1658** and completes a circuit for maintaining itself operated under control of contacts **1628** of relay **19**–DC3 and contacts **1659** of relay **15**–OC4.

Relay **16**–UP1 in operating also closes contacts **1545** and completes a circuit for the operation of relay **15**–OC2 which circuit extends from ground through operated contacts **1545**, operated contacts **1525** of relay **16**–CDC2 to battery through the winding of relay **15**–OC2. Relay **15**–OC2 in operating closes locking contacts **1527** for maintaining itself operated under control of contacts **1502** of relay **15**–5UP.

Relay **15**–OC2 in operating opens contacts **1660** thus allowing relays **16**–CXUP and **16**–CYUP to release. Relay **15**–OC2 in operating also opens contacts **1809** thus removing ground from lead G2 and causing relay **44**–2Q to release which in turn opens contacts **1543** and causes relay **15**–REG to release. The operation of relay **16**–UPI operates contacts **2503** and **2504** which contacts remove ground from the G1 and G2 leads to the calculator. The calculator applies ground to the ADV lead extending to Fig. 15 which ground in turn extends through the operated contacts **1546** of relay **16**–UP1 to the winding of relay **15**–OC4 to battery causing relay **15**–OC4 to operate and lock operated under control of contacts **1502** of relay **15**–5UP.

The operation of relay **15**–OC4 interrupts the locking ground for relay **16**–UP1, thus permitting this relay to release after relay **15**–REG releases as described above. The operation of relay **15**–OC4 was the last one of the **15**–OC1 through **15**–OC5 relays to operate indicating complete execution of each portion of the order. As a result an obvious circuit is shown in Fig. 18 for the operation of relay **18**–CTR1 which relay in turn operates under control of contacts **1806** of relay **18**–TRC1 and contacts of relay **45**–CO. Relay **18**–CTR1 interrupts the locking circuit of the order relays of Fig. 46 which relays release and in turn release relays **45**–1RC and **45**–5RC. The operation of relay **18**–TRC1 also interrupts the operating circuit of relay **45**–5UP and allows this relay to release and release the control relays associated with the order relays of Fig. 46 as described herein. Relay **45**–5UP in operating interrupts the locking circuit of relay **15**–5UP which relay releases and interrupts numerous locking circuits described herein for relays in the routine control circuit allowing these relays to release. The release of the various relays of the routine control circuit completes a down-check circuit through these relays for the operation of relay **13**–DCP from battery through the winding of relay **13**–DCP, break contacts **1309** and then through a series circuit of the contacts on each of the relays in the routine control circuit to ground. Relay **18**–CTR1 releases upon release of relay **15**–5UP and relays **15**–OC1 through **15**–OC5. The release of relay **18**–CTR1 and the operation of relay **13**–DCP restores the routine control circuits to normal and advances a circuit supplying information so that the next order will be entered upon the order relays of Fig. 46.

Assume now that the order S — A C $\overline{HC}$ is entered upon the order relays of Fig. 46 to any one of the sources from which orders may be entered upon these relays with the result that relays **46**–1S, **46**–20, **46**–3A, **46**–4C and **46**–5C are operated.

This order causes the number recorded in the A storage register to be subtracted from a number entered in the X register of the calculator section which number was entered in said X register as a result of said previous computation by the calculator section of the computer. The difference between these two numbers is to be stored in the C storage register and register A is to be cleared thus removing the number stored therein.

The operation of relay **46**–20 closes contacts **4410** which contacts connect the winding of relay **44**–201 to the G2 lead. The operation of relay **46**–20 closes contacts **4411** which contacts complete an obvious circuit for the operation of relay **44**–RO indicating that a routine order is to be executed. The operation of relay **46**–3A closes contacts **2123** and connects the winding of relay **21**B to the G3 lead for later operation as will be described. The operation of relay **46**–4C closes contacts **2904** and these contacts together with the operation of contacts **2907** of relay **44**–RO connect the winding of the B relay of the C register to the G4 lead. The operation of relay **46**–5C closes contacts **4412** which contacts complete an obvious circuit for the operation of relay **44**–TR1. The operation of relay **46**–5C also closes contacts **1547** which contacts connect the winding of relay **15**–CLRB to the 5G lead.

As described herein, the entering of a complete order upon the order relays of Fig. 46 causes relay **45**–5UP to operate which relay in turn causes relay **56**–CO to operate and relay **15**–5UP to operate. The operation of relay **15**–5UP initiates the execution of the order by the computer equipment. The operation of relay **15**–5UP closes contacts **1801** which contacts apply ground to leads G2 and G5. The application of ground to lead G2 completes a circuit for the operation of relay **44**–2O1 which relay closes contacts **1548** and completes an obvious circuit for the operation of relay **15**–REG indicating that a regular type of computation is to be performed by the computer. This relay grounds leads G1 and G2 designated **2503** and **2504**, respectively, in Fig. 25. The operation of relay **44**–2O1 also closes contacts **2505** which contacts condition the computer to subtract the number entered in the Y register from the number entered in the X register of the computer. The operation of relay **15**–REG also completes a circuit for the operation of relay **15**–CALC, the operation of which relay partially prepares other circuits for controlling the entering of numbers into the registers in the calculating section of the computer. The application of ground to lead G5, **1803**, completes a circuit through the operated contacts **1547** of relay **46**–5C for the operation of relay **15**–CLRB which relay operates and closes contacts **1541** which contacts complete an obvious circuit for the operation of relay **15**–CLRM which relay then locks under control of contacts **1542** of relay **15**–5UP.

Relay **15**–CLRM in operating transfers the CXUP lead from the winding of the **16**–CXUP relay and connects this lead to the **16**–XUPM relay. Likewise, the operation of relay **15**–CLRM disconnects the CYUP lead from relay **16**–CYUP and connects this lead to relay **16**–YUPM.

The next step in executing the order is to check the A and B relays of each of the storage registers to insure that these relays are all released. If these relays are all released, then a down-check circuit which extends

serially through a break contact on each of these relays is completed and this circuit extends through the operated contacts **1913** and the break contacts **1909** to the windings of relays **19**–DC3 and **19**–DC3A. When relay **19**–DC3 operates, relay **19**–DC3A does not operate at this time because it has ground connected to both of its winding terminals. Relay **19**–DC3 locks operated under control of contacts **1901** of relay **15**–5UP. Relay **19**–DC3 in operating closes contacts **1910** which contacts apply a ground to the G1 lead and the break contacts **1902** of relay **15**–OC1. Relay **19**–DC3 in operating also closes contacts **1810** which contacts connect ground to the G3 lead through the break contacts **1811** of relay **15**–OC3. The application of ground to lead G3 completes a circuit for the operation of relay **21**B from battery through the winding of relay **21**B and contacts **2123** of relay **46**–3A to ground through the break contacts **1811** of relay **15**–OC3 and the operated contacts **1810** of relay **19**–DC3.

The operation of relay **15**–CALC closes contacts **1630** which contacts extend a lead CXUP from the calculator through contacts **1630**, contacts **1308**, operated contacts **1661** of relay **15**–CLRM to the winding of relay **16**–XUPM to battery. Relay **16**–XUPM in operating completes an obvious circuit for maintaining itself operated under control of contacts **1660** of relay **15**–OC2 and contacts **1628** of relay **19**–DC3. Inasmuch as a number is already recorded in the X register of the calculator section, the calculator has placed ground on this CXUP lead which ground causes the operation of relay **16**–XUPM as described above.

In the operation of relay **21**B as described above in response to the application of ground to lead G3 by contacts **1810** of relay **19**–DC3, the ground is removed from the common connection between the windings of relays **19**–DC3A and **19**–DC3, thus permitting relay **19**–DC3A to operate and holding relay **19**–DC3 operated. The operation of relay **21**B also completes a circuit for the operation of lead Y of relay **21**–RY in the A storage register. This circuit extends from battery through the winding of relay **21**–RY, the operated contacts **2121** of relay **21**B, over the RY lead and thence through contacts **1907** of relay **16**–CYUP to ground through the operated contacts **1912** of relay **15**–REG. Relay **21**–RY in operating closes contacts indicated in Fig. 21 which applies ground to the contacts of the register relays of the A storage register which contacts are connected to corresponding conductors on the Y multiple. Thus, the operation of relay **21**–RY applies ground to the appropriate conductors of the Y multiple in accordance with the register relays of the A register which are operated to represent the number stored therein. In other words, the number stored in the A register is now represented by grounds connected to selective leads of the Y multiple. A down-check is indicated on the Y registers in the calculator section by ground on the DC1 lead from the calculator section which lead extends to Fig. 15. Under the assumed conditions, with a number stored in the X register as a result of a previous computation, the ground on the DC1 lead indicates that the relays of the Y register are normal but it does not so indicate for the X relays since these relays cannot be all normal and have a number entered in them or upon them. The operation of relay **15**–REG together with the application of ground to the DC1 lead by the register section completes an obvious circuit from the DC1 lead to contacts **1531** of the **15**–REG relay to battery through the winding of relay **15**–CDC1. Relay **15**–CDC1 in operating closes contacts **1624**, **1625**, **1626** and **1627** which contacts apply ground to the RX, REX, RSX, RY, REY and RSY leads to the calculator section which conditions the calculator register Y to receive the number from the X multiple read out from the A register as described above. When the number has been fully entered into the Y register of the calculator section, ground is applied by the calculator to lead CYUP thus causing the operation of relay **16**–YUPM in a circuit extending from battery through the winding of relay **16**–YUPM, the operated contacts of relay **15**–CLRM to the CYUP lead extending to the calculator section. Relay **16**–XUPM locks operated under control of relay **15**–OC2 and contacts **1628** of relay **19**–DC3. The operation of relay **16**–YUPM actuates contacts **1648** and removes ground from the RY, REY, and RSY leads to the calculator, thus releasing the switching or read relays for connecting the Y register relays with the Y multiple, thus leaving stored upon the register relays of the Y register the number that was previously stored in the A register.

The calculating section then proceeds to perform the necessary operations for subtracting the number thus entered in the Y register from the number previously entered in the X register. In addition, to perform the computations indicated, it is necessary for the calculator section to first shift the numbers so that they will be properly aligned for subtraction. It is also frequently necessary after the computations have all been performed to perform other functions such as shifting the number into the standard form for printing out purposes. Likewise, it is frequently desirable to perform round-off functions where it is desirable to have the accuracy of a predetermined number of significant figures. When all of these functions have been satisfactorily performed by the calculating section of the computer, ground is applied to the XYG lead which causes the operation of relay **16**–XYG, the operation of which relay indicates that the calculating section has satisfactorily performed the computation required by the order. If the calculating section fails to satisfactorily perform these functions, it is possible to recycle the calculator as described herein in which case a second attempt will be made to perform the calculation. Upon the satisfactory completion of the calculation operation relay **16**–XYG operates and causes contacts **1624** to operate which contacts complete obvious circuits for the operation of relays **16**–CXUP and **16**–CYUP. The operation of these relays completes an obvious circuit for the operation of relay **18**–RTC.

The operation of relay **16**–CXUP completes a circuit for the operation of relay **15**–DC1A which circuit extends from battery through the winding of relay **15**–DC1A, the break contacts **1508** of relay **15**–CLRA, the operated contacts **1635** of relay **16**–CXUP to ground through the operated contacts **1534** of relay **16**–XYG. Relay **15**–DC1A in operating closes its locking contacts for maintaining itself operated under control of contacts **1615** of relay **19**–DC3.

The operation of relay **15**–DC1A also closes contacts **1509** which contacts complete a circuit for the operation of relay **15**–OC1 from battery to the winding of relay **15**–OC1, closed contacts **1509** of relay **15**–DC1A, lead 1S which extends to Fig. 22, thence through contacts **2205** of relay **44**–TR1, operated contacts **2206** of relay **46**–1S to ground over the G1 lead through contacts **1902** of relay **15**–OC1 and the operated contacts **1910** of relay **19**–DC3. Relay **15**–OC1 in operating first closes its locking contacts **1506** for maintaining itself operated under control of contacts **1502** of relay **15**–5UP. Relay **15**–OC1 in operating also opens contacts **1902** which remove ground from the G1 lead.

The operation of relay **16**–CYUP actuates contacts **1907** which contacts remove ground from the RY lead extending to the **21**–RY relay of the A register, thus permitting this relay to release and disconnect ground from the contacts of the storage relays of the A register extending to the Y multiple. The operation of relay **16**–CYUP also connects ground to the CLRB lead which circuit extends from ground through the operated contacts **1534** of relay **16**–XYG, the operated contacts **1544** of relay **16**–CYUP, the operated contacts **1535** of relay **15**–CLRB, the operated contacts **1637** or relay **16**–CYUP,

the break contacts 1663 which lead CLRA extends to the winding of relay 21–LK through the operated contacts 2124 of relay 21B. Relay 21–LK operates in this above-described circuit and interrupts a locking ground applied to the various storage relays of the A storage register, thus permitting these relays to release and restoring the register relays to their normal condition. Upon the release of the storage relays of the A register under these conditions a down-check circuit is completed through the series circuit extending through a set of break contacts on each of the register relays of the A register and then through contacts 2120 of relay 21B to the DC1B lead which lead now extends to Fig. 15 and then through the break contacts 1517 of relay 19–EMCB and operated contacts 1512 of relay 15–CLRB, operated contacts 1638 of relay 16–CYUP to battery through the winding of relay 16–DC1B.

The operation of relay 16–DC1B closes its locking contacts 1640 which contacts maintain relay 16–DC1B operated under control of contacts 1615 of relay 19–DC3. Relay 16–DC1B in operating also closes contacts 1905 which contacts complete a circuit for the operation of relay 15–OC1 which circuit extends from battery through the winding of relay 15–OC1, the break contacts 1514 of relay 44–5E1, contacts 1515 of relay 44–TR1, operated contacts 1905, relay 16–DC1B to ground through the operated contacts 1906 of relay 16–DC1A. Relay 15–OC5 in operating closes its locking contacts 1538 which maintain relay 15–OC5 operated under control of contacts 1502 of relay 15–5UP.

Relay 16–DC1B closes a down-check circuit for checking the release of the read or switching relays of the A register which circuit extends from ground through a contact on each of the read or switching relays, then through contacts 2222 of relay 21B, thence over DC2B lead to Fig. 15, thence through contacts 1536 of relay 16–DC1B to battery through the winding of relay 15–OC3. If all of the read and switching relays are released and the down-check series circuits through their contacts are completed, thus causing relay 15–OC3 to operate. Relay 15–OC3 in operating actuates contacts 1811 which contacts remove ground from the G3 lead and thus interrupt the operating circuit of relay 21B of the A register which relay thereupon releases. The release of relay 21B of the A register then completes a down-check circuit to contacts of the control relays A and B of each of the register circuits. When all of these relays are released, the down-check circuit is completed through their contacts, the operating contacts 1913 of relay 15–5UP, the operated contacts 1909 of relay 19–DC3, the break contacts 1306 and through the winding of relay 16–DC3B to battery. Relay 16–DC3B operates in this circuit when all of the A and B control relays of the registers are released and in operating closes its locking circuit 1616 which maintains relay 16–DC3B operated under control of contacts 1615 of relay 19–DC3 and also contacts of the 16–CXUP relay and contacts of the 16–CYUP relay. A down-check is also made on the read or switching relays of the X and Y registers of the calculator section of the computer. This down-check circuit extends from battery through the winding of relay 16–CDC2, operated contacts 1618 of relay 15–DC1A, contacts 1617 of relay 16–CXUP, contacts 1640 of relay 16–CYUP, contacts 1620 of relay 16–DC1B, contacts 1639 of relay 15–CALC to ground over the DC2 lead from the calculator. The calculator applies ground to this lead when and only when all of the switching or read relays of the X and Y registers of the calculator section are released. Relay 16–CDC2 in operating locks operated under control of contacts 1615 of relay 19–CD3, contacts of relay 16–CXUP and relay 16–CYUP.

The operation of relay 16–DC3B as described above actuates contacts 1652 which contacts apply ground from the down-check of the switching relays of the calculator section connected to lead DC2, to the G4 lead and then through the operated contacts 2901 of relay 44–4A, contacts 2902 of relay 44–RO to battery through the winding of relay 21B to operate the B relay of the C storage register. The operation of the B relay of the C storage register connects the down-check circuit over a serial path through contacts of each of the register relays of the C register and then through operated contacts of the B relay of the C register to the DC1B lead extending to Fig. 15 and then through contacts 1517, contacts 1662 of the 16–DC3B relay to battery through the winding of relay 16–DCB, providing, of course, that all of the register relays of the C register are released. The operation of relay 16–DCB closes contacts 1611 which apply ground to contacts 1608 of relay 16–UP and contacts 1610 of relay 16–UP1, contacts 1611 of relay 16–DCB and then over the RXB lead to the C register and then through contacts of the operated B relay of the C register to the read-out or switching relay of the C register. The operation of the switching relays of the C register connect the windings of the register relays of the C register to corresponding conductors of the X multiple so that the C register is in condition to read in and store the numbers supplied to the X multiple for recarding the representations of the number presently to be applied to said X multiple.

The operation of contacts 1652 of relay 16–DC3B also connects ground to the read lead through contacts 1651 of relay 15–OC4 and contacts 1649 of relay 16–CXUP. Ground is also applied from the same source, namely, the down-check circuit of the switching or read relays of the X and Y registers of the computer section and through the operated contacts 1615 of relay 16–DC3B, the break contacts 1605 of relay 15–OC4, the break contacts 1652 of relay 22–RTX, the operated contacts 1665 of relay 16–DC3B to the RN lead extending to the computer section. Ground on the RN lead extending to the calculator section indicates to the calculator section that the number is to be read out in a normal manner over the X multiple while the ground on the read relay initiates the operation of reading out the results of the computation. This number is read out over the X multiple and causes register relays of the C register to be operated and locked operated under control of the LK relay of the C register. When the number is fully registered in the C register, an up-check circuit through contacts on the register relays of the C register is completed and a circuit then extends through contacts of the B relay of the C register to the UP lead which extends from the register circuits to Fig. 16 and then through the operated contacts 1656 of relay 15–RG and the operated contacts 1658 of relay 16–DCB to battery through the winding of relay 16–UP1. The operation of relay 16–UP1 opens contacts 1610 which contacts interrupt a circuit extending over the RXB lead to the register circuits and then through the B relay of the register to the read or switching relays of this register which relays thereupon release. The operation of relay 16–UP1 closes contacts 1545 which contacts complete a circuit from ground through these contacts 1545 of relay 16–UP1 and contacts 1625 of relay 16–CDC2 to battery through the winding of relay 15–OC2. Relay 15–OC2 thereupon operates and closes its contacts 1527 which contacts maintain this relay operated under control of contacts 1502 of relay 15–5UP. The operation of relay 16–UP1 also actuates contacts 2503 and 2504, thus interrupting the ground connected to the G1 and G2 leads extending to the calculator section of the computer. The release of these grounds causes the calculator to release and apply ground to the ADV lead which lead extends to contacts 1546 of relay 16–UP1 and then to battery through the winding of relay 15–OC4. The operation of relay 15–OC4 completes a circuit for maintaining itself operated under control of contacts 1502 or relay 15–5UP. The operation of relay 15–OC4 opens contacts 1651 and 1605 and removes

ground supplied over the read lead and over the RN lead to the computer section.

With all of the relays 15–OC1 through 15–OC5 operated, a circuit is completed for the operation of relay 18–CTR1 which relay in operating interrupts the locking ground for all of the order relays of Fig. 46, thus permitting these relays to release. Relay 18–CTR1 also interrupts the operating circuit of relay 45–5UP which relay releases and in turn restores the circuits associated with the order relays to be returned to their normal or idle condition. The release of relay 45–5UP causes relay 15–5UP to release which relay interrupts the locking circuits of the various relays of the routine control circuits and permits these relays to release. The release of all of the routine control relays completes a down-check circuit for the operation of relay 13–DCP which relay operates and advances the operation of the source of information so that it will advance and supply an additional order. Relay 18–CTR1 remains operated until all of the order relays of Fig. 46 are operated at which time the operating circuit of this relay is interrupted, thus permitting the relay to release and restore the circuits to their initial condition where they are ready to execute another order.

Order A √ T C $\overline{CH}$

When it is desired to obtain the square root of a number, this number must be read into the computer over the X multiple. Consequently, the first portion of the order designates the location of the number of which it is desired to obtain the square root. Thus, it is assumed that it is desired to obtain the square root of the number stored in the A storage register and to place the result or answer in the C register and clear the A register. The order relays of Fig. 46 which are operated in response to this order comprise relays 46–1A, 46–2N, 46–3T, 46–4C and 46–5B. Relay 46–1A in operating closes contacts 2103 which select the A register and connect the A relay of the A register to the G1 lead. The operation of relay 46–2N closes contacts 4413 and completes an obvious circuit for the operation of the routine order relay 44–RO. The operation of relay 46–2N also closes contacts 4413 which connect the winding of relay 44–2N1 to the G2 lead. The operation of relay 46–3T which is the dummy or by-pass relay in the third column which is operated in response to the dummy or by-pass code in the third position of the order causes contacts 1512 to close and complete an obvious circuit for the operation of relay 15–OC3. Inasmuch as the third portion of the order is by-passed, relay 15–OC3 is at once operated. Consequently, ground is not applied to the G3 lead during the execution of the above exemplary order illustrating the method of executing the square root order. The operation of relay 46–4C causes contacts 2904 to close and these contacts together with the operation of contacts 2907 by the operation of relay 44–RO connect the winding of the B relay to the G4 lead. The operation of relay 46–5B closes contacts 4402 which contacts complete an obvious circuit for the operation of relay 44–TR1. The operation of relay 46–5B closes contacts 1516 which connect the winding of the relay 15–CLRA to the G5 lead. It should be noted from the fifth portion of the order that the number recorded in the A register is to be released and the register restored to its initial or normal condition.

As in the execution of the previous orders the first portion of the checking of the various circuits in response to the above-described square root order is substantially the same, when the order is completely entered on the order relays of Fig. 46 and one and only one relay in each of the columns is operated, relays 45–1RC through 45–5RC are operated which relays in turn operate relay 45–5UP and this relay in turn operates relay 45–CO and interrupts and closes other circuits described herein. In addition, the operation of relay 45–5UP completes a circuit for the operation of relay 15–5UP which relay operates and applies ground to numerous locking contacts to maintain the various relays operated once these relays have been operated as long as relay 15–5UP remains operated. For example, the closure of contacts 1502 of relay 15–5UP applies ground to the locking contacts 1537 of relay 15–OC3 thus locking relay 15–OC3 operated under control of contacts 1502 of relay 15–5UP.

The operation of relay 15–5UP closes contacts 1801 which contacts apply ground to the G1 and G5 leads. The application of ground to the G5 leads causes the operation of relay 15–CLRA through the operated contacts 1516 of relay 46–5B. The operation of relay 15-CLRA closes contacts 1540 which completes an obvious circuit for the operation of relay 15–CLRM which relay then closes its locking contacts for maintaining itself operated under control of contacts 1542 of relay 15–5UP. The operation of contacts 1801 of relay 15–5UP also applies ground to the G2 lead, thus completing a circuit for the operation of relay 44–2N1. The operation of relay 44–2N1 closes contacts 1555 which contacts complete an obvious circuit for the operation of relay 15–REG. The operation of relay 15–REG closes contacts 1530 which operate relay 15–CALC and relay 15–CALC closes a number of circuits to the calculating section of the computer. The operation of relay 15–REG also closes contacts 2206 and 2207 which contacts apply ground to the G1 and G2 leads of the calculator section. Ground applied to these G1 and G2 leads together with ground through the operated contacts 2508 of relay 44–2N1 prepares the calculator circuits for extracting the square root of the number to be entered in the X register as described herein.

The operation of relay 44–2N1 closes contacts 1812 and completes an obvious circuit for the square root relay 18–SQR. Relay 18–SQR in operating completes a circuit for the operation of relay 16–DC1B from battery through the winding of relay 16–DC1B, the operated contacts 1605 of relay 18–SQR, the break contacts 1512 of relay 15–CLRB to ground through the operated contacts 1513 of relay 18–SQR. Relay 16–DC1B in operating closes its locking contacts 1640 for maintaining itself operated under control of contacts 1615 of relay 19–DC3, when relay 19–DC3 operates as described herein.

The operation of relay 15–5UP closes contacts 1913 which contacts extend a down-check circuit through the break contacts of each of the A and B relays of each of the register circuits to the winding of relay 19–DC3 which relay operates upon the completion of this down-check circuit. Relay 19–DC3 in operating closes locking contacts 1904 for maintaining itself operated under control of contacts 1901 of relay 15–5UP. Relay 19–DC3 in operating closes contacts 1901 which apply ground to contacts 1902 of relay 15–OC1 to the G1 lead, 1903, extending to the contacts 2103 of relay 46–1A. The operation of relay 21A in response to the completion of the above-described circuit removes ground from the down-check circuit through its break contacts and thus removes ground from the common winding terminal of relays 19–DC3A and 19–DC3, thus permitting relay 19–DC3A to operate in series with relay 19–DC3. The operation of relay 19–DC3A causes contacts 1909 to be actuated and transfer the down-check lead from the common winding terminal of relays 19–DC3 and 19–DC3A to a circuit extending through the winding of relay 19–DC3B.

The operation of relay 21A as described above completes a circuit for the operation of the switching or read relays 21–EUR and 21–AR through 21–JR from battery through the winding of these relays and the operated contacts 2117 of relay 21A to the RXA lead which extends to Fig. 19 and then through contacts 1908 of relay 16–CXUP and the operated contacts 1912 of re-

lay 15–REG. Ground is also applied at this time to the RY lead but since the third element of the order was the dummy or by-pass code T, none of the B relays of any of the registers would be operated so that the application of ground to the RY lead at this time produces no useful results. The operation of the switching or read relays of the A register connects the windings of the respective register relays of the A register to conductors of the X multiple, thus reading out of the A register the numbers stored therein and applying the number to conductors of the X multiple. As pointed out herein before ground is applied to conductors of the X multiple corresponding to the operated register relays of the A register, said ground being obtained through the locking contacts of these relays.

In the meantime, a down-check was made on the X and Y registers of the calculator section which causes ground to be applied to the DC1 lead from the calculator circuit extending through contacts 1531 of relay 15–REG to battery through the winding of relay 15–CDC1. If the above-described down-check circuits through the X and Y registers of the calculator section are completed, relay 15–CDC1 operates and locks operated under control of relay 15–CALC.

The operation of relay 15–CDC1 closes contacts 1624, 1625, 1626 and 1627. The closure of contacts 1624 and 1625 applies ground to contacts 1628 of relay 19–DC3 through the break contacts 1645 of relay 15–OC1, break contacts 1646 of relay 16–XUPM, break contacts 1633 of relay 16–CXUP to the RSX lead and through contacts 1624 of relay 15–CDC1 and contacts 1541 of relay 15–CALC to the RX lead and contacts 1542 of relay 15–CALC to the REX lead extending to the X register of the computer. Inasmuch as relay 15–OC3 has operated as described above in response to this order, contacts 1647 are open so that ground is now applied to the corresponding leads RY, REY and RSY extending to the Y register of the computer section. The application of ground to the RX, REX and RSX leads extending to the X register of the calculator causes the operation of the switching or read relays. These relays in turn connect the windings of the register relays of the X register to the corresponding conductors of the X multiple and cause the respective register relays of the X register to be operated in accordance with the conductors of the X multiple which have ground connected to them through the locking contacts of the register relays of the A register as described above.

When the number has been fully read into the X register of the calculator section, this register causes the calculator to ground the CXUP lead which lead extends through the operated contacts 1630 of relay 15–CALC, break contacts 1308, operated contacts 1661 of relay 15–CLRM to battery through the winding of relay 16–XUPM. Relay 16–XUPM in operating actuates contacts 1633 which contacts remove ground from the RX, REX and RSX leads extending to the X register of the calculator and thus allow the switching relays in the X register of the calculator to release and disconnect the register relays from the conductors of the X multiple, of course, leaving those relays locked operated which were operated in response to the number represented on the X multiple from the A register. The calculator then proceeds to extract the square root of the number entered in the X register as described above. The process of the calculator of extracting the square root is described in detail in the above-identified Williams patent. Consequently, the operation of the calculator and extracting of the square root need not be repeated herein. After the necessary shift and round-off functions are completed the calculator prepares to read out the number by grounding the XYG lead.

If, for any reason, the calculator is unable to satisfactorily complete the extraction of the square root within a prescribed time, the alarm circuits function and cause contacts 1501 to operate which releases relay 15–5UP. The release of this relay causes the routine control circuits and the calculator circuits to be restored to their initial or idle condition but does not release the order relays of Fig. 46 having the above-described order entered upon them. Thereafter, the alarm circuits close contacts 1553 and cause the routine control circuits to advance through the various steps described above on a second trial. If the calculator is still unable to obtain a satisfactory answer in the prescribed time, the alarm circuits will then function and interrupt the operation of the computer.

When the calculator section has performed the necessary routine steps to extract the square root of the number and put this number in suitable form for reading out the XYG lead is grounded which causes the operation of relay 16–XYG and relay 16–XYG in operating closes contacts 1641 which contacts complete a circuit for the operation of relay 16–CXUP from battery through the winding of relay 16–CXUP, closed contacts 1642 of relay 16–XYPM to ground through the operated contacts 1641 of relay 16–XYG. Inasmuch as there was a T in the third place of the order relay 16–YUPM was not operated and relay 16–CYUP likewise was not operated at this time. The operation of relay 16–CXUP opens contacts 1908 which remove ground from the RXA lead, thus permitting the switching or read-out relays of the A register to release. As a result, the connections between the register relays of the A register and the respective conductors of the X multiple are interrupted. The operation of relay 16–XYG together with the operation of relay 16–CXUP connects ground to the CLRA lead in a circuit extending from ground through the operated contacts 1534 of relay 16–XYG and contacts 1535 of relay 16–CXUP, contacts 1534 of the operated relay 15–CLRA, contacts 1635 of relay 16–CXUP, the break contacts 1602 of relay 19–ENCA to the CLRA lead extending to the register circuits. This lead also extends through the operated contacts of relay 21A of the A register to battery through the winding of the 21LK relay. The operation of relay 21LK in the above-described circuit interrupts the locking contacts for the register relays of the A register which were operated to represent the number stored in there which now release, clearing the register of said number.

The release of all of the register relays of the A register completes the down-check circuit to break contacts on each of these register relays which down-check circuit extends through the operated contacts 2107 of relay 21A and then over the DC1A lead to Fig. 15. In Fig. 15, a circuit then extends from the DC1A lead through contacts 1504 of relay 19–ENCA and the operated contacts 1508 of relay 15–CLRA to battery through the winding of relay 15–DC1A. Relay 15–DC1A operates when this down-check circuit is completed and in operating connects the DC2A lead through contacts 1509 through the winding of relay 15–OC1. The DC2A lead extends to the register circuits and through contacts 2108 of relay 21A to a down-check circuit which extends serially through a set of break contacts on each of the switching relays of the A register when these relays have fully released. Upon the completion of this down-check circuit a circuit is completed for the operation of relay 15–OC1 as described above. Relay 15–OC1 in operating closes the locking contacts 1506 for maintaining itself operated under control of contacts 1502 of relay 15–5UP.

The operation of relay 15–OC1 opens contacts 1902 and thus removes ground from the G1 lead, 1903. As a result relay 21A of the A register releases and again completes the down-check circuits through all of the A and B registers of the storage registers.

The operation of relay 15–DC1A as described above closes contacts 1617 and completes a circuit for the operation of relay 16–CDC2. The circuit for the operation of this relay may be traced from ground applied to the

DC2 lead by the down-check circuit extending through the read relays of the X and Y registers of the calculator section, through contacts **1619** of relay **15**–CALC, contacts **1668** of relay **18**–SQR, contacts **1640** of relay **16**–CXUP, contacts **1617** of relay **15**–DC1A and contacts **1618** of relay **16**–DC1B to battery through the winding of relay **16**–CDC2. Relay **16**–CDC2 closes its locking contacts for maintaining itself operated under control of contacts **1615** of relay **19**–CD3 and also closed contacts **1525** at this time to prepare a circuit for the operation of relay **15**–OC2. The operation of relay **16**–CDC2 opens contacts **1539** which contacts cause the release of relay **15**–CALC.

The operation of relay **15**–CD1A as described above together with the previous operation of relay **16**–DC1B completes a circuit for the operation of relay **15**–OC5 from battery through the winding of relay **15**–OC5, the break contacts **1514** of relay **44**–5E1, contacts **1515** of relay **44**–TRI to ground through the operated contacts **1905** of relay **16**–DCB and contacts **1906** of relay **15**–DC1A. Relay **15**–OC5 in operating actuates contacts **1805** and thus removes ground from the G5 lead permitting relay **15**–CLRA to release.

The release of relay **21**B as described above which completes a down-check circuit through the A and B relays of each of the register circuits completes a circuit for the operation of relay **16**–DC3B from battery through the winding of relay **16**–DC3B to the break contacts **1306**, the operated contacts **1909** and **1913** to ground through the down-check circuit. Relay **16**–DC3B operates when the above-described circuit is completed and closes contacts **1666** for maintaining itself operated under control of contacts **1615** of relay **19**–DC3. At this point it should be noted that all of the relays of the A register have been released and their release checked by the operation of relay **15**–DC1A, relay **15**–OC1 and the operation of relay **16**–DC3B. At this time a circuit is completed from the down-check lead DC2 of the calculator section where ground is applied to this DC2 lead in response to the restoration of the switching relays of the X and Y registers which relay is released as described above. Upon the operation of relay **16**–XUPM due to contacts **1633** removing ground from leads RX, REX and RSX extending to the calculator section. The application of ground to the DC2 lead by the completion of the down-check circuit through the X and Y registers together with the operation of relay **16**–DC3B which closes contacts **1652** applies ground to the G4 lead in the routine control circuits described herein and also to the RN lead extending to the calculator and the read lead also extending to the calculator section. The ground from the DC2 lead from the calculator through contacts **1552** extends over the G lead through contacts **1929** of relay **46**–4C and contacts **2907** of relay **44**–RO through the winding of the B relay of the C register circuit which relay operates at this time and connects the down-check circuit of this register to the DC1B lead which lead now extends to Fig. 15 and then through contacts **1517** of relay **19**–ENCB and the operated contacts **1662** to battery through the winding of relay **16**–DCB.

Relay **16**–DCB closes contacts **1663** for maintaining itself operated under control of contacts **1650** of relay **19**–DC3. Relay **16**–DCB in operating closes contacts **1611** which contacts extend a ground from contacts **1608** and **1610** over lead RXB extending to the registers and then through operated contacts of the B relay of the C register to the windings of the read or switching relays of the C register. The operation of the read or switching relays in the C register over the above-described circuit connects the windings of the respective register relays to the corresponding conductors of the X multiple thus preparing the circuits of the C register to receive any number which may be entered therein.

In the meantime, the application of ground from the DC2 lead from the calculator section through contacts **1652**, contacts **1605**, contacts **1664** and **1665** to the RN lead extending to the calculator section actuates the calculator to read the number out in a normal manner. The connection of ground to the read relay from contacts **1652** to contacts **1651**, **1650** and **1649** causes the calculator to read out the root which was extracted over the X multiple. This number is then transmitted over this multiple to the storage or register relays of the C register. The storage relays of the C register are thus operated over the X multiple in accordance with the square root of the number and the corresponding relays representing this number operated and locked operated, thus storing the results of the computations in the C register. Upon the completion of the storing of the number in the C register an up-check circuit through the C register is completed through contacts of the B relay of the C register to the UP lead which lead extends to Fig. 16 and then through contacts **1307**, contacts **1666** of relay **16**–DC3B, contacts **1655**, contacts **1656** of relay **15**–REG, contacts **1667** of relay **16**–DCB to battery through the winding of relay **16**–UP1. Relay **16**–UP1 in operating opens contacts **1610** which contacts remove ground from the RXB lead, thus permitting the read or switching relays of the C register to release and disconnect the windings of the storage relays of this register from the conductors of the X multiple leaving the number previously recorded in the register relays stored thereupon.

The operation of relay **16**–UP1 as described above closes contacts **1545** and thus completes a circuit for the operation of relay **15**–OC2 from battery through the winding of relay **15**–OC2, the operated contacts **1525** of relay **16**–CDC2 to ground through the operated contacts **1545** of relay **16**–UP1. Relay **15**–OC2 in operating closes contacts **1527** for maintaining itself operated under control of contacts **1502** of relay **15**–5UP. Relay **15**–OC2 in operating opens contacts **1809**, thus removing ground from the G2 conductor, **1802**, and in turn releasing relay **44**–2N1. This relay releases and causes the release of relay **18**–SQR.

The operation of relay **16**–UP1 also opens contacts **2503** and **2504**, thus interrupting ground applied to the G1 and G2 leads to the calculator section. The calculator section is restored to its normal condition by removal of ground from leads G1 and G2. As a result the calculator applies ground to the ADV lead which extends to Fig. 15 and then through contacts **1546** of relay **16**–UP1 through the winding of relay **15**–OC4 to battery. Relay **15**–OC4 operates in this circuit and closes its locking contact for maintaining itself operated under control of contacts **1502** of relay **15**–5UP.

The operation of relay **15**–OC4 together with the previous operation of relays **15**–OC1, **15**–OC2, **15**–OC3 and **15**–OC5 completes a circuit for the operation of relay **18**–CTR1 as shown in Fig. 18. The operation of relay **18**–CTR1 opens contacts **1105** which contacts restore the steering circuits of Figs. 11 and 12 to their normal condition. The operation of relay **18**–CTR1 opens contacts **1116** which contacts open the circuit for relay **45**–5UP, thus permitting this relay to release. The operation of relay **18**–CTR1 also opens contacts **4653**, thus interrupting the locking circuits of all of the previously operated order relays of Fig. 46. The release of relay **45**–5UP causes the release of relay **15**–5UP and this relay in turn causes the release of relay **19**–DC3. The release of relays **45**–5UP, **15**–5UP and **19**–DC3 causes the circuits of the order relays of the control circuits therefor and the relays of the routine control circuits all to be restored to their normal condition. As a result of the release of the order relays of Fig. 46 and the relays in the control circuits thereof shown in Figs. 44 and 45, relay **18**–CTR1 releases. The release of all of the relays of the routine control circuits completes a down-check circuit for operation of relay **13**–DCP which relay causes the advance of certain circuits which supply orders to the order relay, thus initiating the entry of another order upon these order relays.

The foregoing four orders illustrate the manner in which members may be transferred from storage registers to the calculator section and the results of the computations stored in another storage register. They also illustrate how the calculator section is prepared for the various types of calculations and how it is otherwise controlled. While only a limited number of orders has been described herein, numbers have been transferred from a limited number of registers to the calculator section and the results of the computations stored in only a limited number of the storage registers, it is to be understood that the numbers may be transferred to the calculator section from any and all of the various register circuits and that the results of the computations may be stored in any of the storage register circuits including the tape storage circuits or the results of the computations may be employed to actuate a printer to print the number as one of the partial or complete answers for the problem. Since the operation of the circuits in transferring numbers to and from the various registers and to and from the calculator operate in substantially the same manner as described above with reference to the exemplary orders required for purposes of illustration, it is unnecessary to describe in detail the many numerous permutations of orders for obtaining numbers from different registers and storing the results of the computations in other registers.

It should be noted that inasmuch as the release of a number stored in a register takes place before the results of the computations are read out that it is possible to read a number from a storage register to the calculator section and release the number stored in the storage register and then store the results of the computations in the same storage register. Furthermore, the above orders describe the operation of multiplication, division, subtraction and square root. The calculator is also arranged to perform addition and the operation of the circuits in response to orders directing the calculator to perform addition are substantially the same as described above except that different order relays are operated which order relays condition the calculator to perform addition instead of one of the other types of computation. Any of the various types of computations may be employed in combination with receiving the necessary number from any of the various registers including the tape storage registers, the problem tapes as well as the third or C tape when it is employed either as a problem tape or in place of the B storage tape.

Order T B 0 1 $\overline{HH}$

Certain of the orders are employed to select different formula numbers such as the order T B 0 1 $\overline{HH}$ which is employed to select the first formula of the B level. The first portion of the order being T as a by-pass or dummy, the second portion B selects the second level. If it is desired to select an order in the first level, the second portion of the order would be represented by the code A, the third level by the code C and the fourth level by the code D. The third and fourth portions of the order are employed to identify the number of the formula in the particular level and the fifth portion is again a by-pass which is in the form of $\overline{HH}$.

In entering this order from the order relays of Fig. 46, relays **46–1T** is operated, relays **46–2B**, **46–3A**, **46–4B** and **46–5D** are operated and locked operated in the normal manner from any suitable source of orders such as described herein.

Upon the entry of a complete order of which one and only one relay of each column is operated the corresponding relays **45–RC1** through **45–RC5** are operated which relays complete a circuit for the operation of relay **45–5UP**. This relay controls a number of circuits such as the operation of relay **45–CO** which remains operated under control of relays **45–1RC** through **45–5RC**.

In addition, relay **46–1T** causes contacts **2208** to close relay **46–2B**, causes contacts **4415** to close and complete an obvious circuit for the operation of relay **44–FOR**, the operation of which relay prepares routine control circuits for setting up the proper formula in the proper formula level. Relay **46–3A** causes contacts **4905** to close and the operation of relay **46–4B** causes contacts **2908** to close. The operation of relay **46–5D** closes contacts **4412** and completes an obvious circuit for the operation of relay **44–TR1** which relay closes numerous contacts as described herein. The operation of relay **46–5D** also causes contacts **1914** to close.

The operation of relay **45–5UP** as described herein in addition to controlling circuits from the director also completes a circuit for the operation of relay **15–5UP**. Inasmuch as this detailed circuit has been described several times herein elsewhere, it is not necessary to trace the circuit again. The operation of relay **15–5UP** applies ground to numerous locking contacts of the relays of the routine control circuit as described herein.

Relay **15–5UP** in operating closes contacts **1801** which contacts apply ground through contacts **1809** of relay **15–OC2** to the **G2** lead which lead extends from Fig. 18 to Figs. 19 and 20 and Figs. 35, 32, 38, 41 and 44. Under the assumed conditions with relay **46–2B** operated, contacts **3501** will be closed so that the ground on lead **G2** extends to the winding of relay **35B** of the B level of the formula director circuit, thus operating relay **35B**. Relay **35B** in operating opens contacts **3503** and thus interrupt a locking circuit for relays **B00** through **B59** and permits any of these relays which may have been previously operated to release. The operation of relay **35B** also opens contacts **3601** which interrupt the operating circuit of relay **36–BF1** and prevent the operation of this relay at this time. The operation of relay **35B** closes contacts **3602** which contacts complete a circuit for the operation of relay **36–BF** which relay closes its locking contacts **3603** and maintains itself operated under control of the contacts **3504** of relay **36–RLS** and over conductor **3201** to ground through contacts **3202** of relay **7–RG1**. Relay **36–BF** in operating actuates contacts **3604** which contacts interrupt a circuit for operating relay **33–AF1** and partially prepare a circuit for the operation of relay **36–BF1**. The operation of relay **36B** closes contacts **3605** and the operation of these contacts connects a down-check circuit through the relays **B00** to **B59** through the winding of relay **36–B1**. Relay **36–B1** operates in response to the closure of contacts **3605** and the completion of the down-check circuit through break contacts of relays **36–BS** and **36–BS1**, through relays **36–BS17** and **35–B00** through **35–B39**. Relay **36–B1** in operating connects the windings of relays **35–T0** through **35–T3** to the conductors extending to the contacts of relay **44–FOR** shown in the upper left-hand corner of Fig. 29.

The operation of relay **35B** closes contacts **3901** and completes an obvious circuit for the operation of relay **39RLS** which relay releases any of the formula relays **38–C00** through **38–C59** which may have been previously operated. The operation of relay **30–RLS** in operating contacts **3801** also interrupts the locking circuit of relay **39–CF**, thus permitting this relay to release and restore contacts **3902**. Likewise, the operation of relay **35B** also closes contacts **3606** which contacts connect ground to the RD lead extending to the winding of relay **42–RLS**, thus causing the operation of relay **42–RLS**. Relay **42–RLS** releases any of the D formula relays **41–D00** through **41–D59** which may have been previously operated.

In addition, the operation of contacts **4101** of relay **42–RLS** interrupts the locking circuit of relay **42–DF**, thus permitting this relay to release, if any of the D formula relays were operated when relay **36B** was operated as described above.

It is thus obvious that in operating, a relay for selecting a formula in any level releases the relays which select formulas in lower levels. Circuits similar to the

above-described circuits provide for releasing the relays of the B, C and D formula levels if any of them are operated when the formula in the A level is selected.

The operation of contacts **1801** also applies ground to the G5 lead through the break contacts **1805** of relay **15–OC5** but this lead does not extend to any contacts of the **46–5D** relay so that the application of ground to this lead performs no function at this time. The operation of contacts **1801** of relay **15–5UP** also applies ground to the G4 lead in a circuit extending from ground through the operated contacts **1801** of relay **15–5UP**, the operated contacts **1813** of relay **44–FOR**, break contacts **1606** of relay **19–COMP**, break contacts **1605** of relay **15–OC4** and then over lead **1607** through Figs. 19, 20, 17 and 14 to Fig. 29 and then through contacts **2908** of relay **46–4B**, operated contacts **2902** of relay **44–FOR** and then over the W1 lead extending to all levels of the formula director circuit. In addition, relay **15–5UP** closes contacts **1913** which contacts connect ground from a down-check circuit extending through break contacts of each of the A and B relays of each of the register circuits to the common winding terminal of relays **19–DC3** and **19–DC3A**, thus completing a circuit for the operation of relay **19–DC3**. Relay **19–DC3** in operating closes the locking contacts **19–DC4** for maintaining relay **19–DC3** operated and for later operating and maintaining relay **19–DC3A** operated under control of contacts **1901** of relay **15–5UP**. Relay **19–DC3** does not operate at this time because ground is connected to both of its winding terminals.

However, the operation of relay **19–DC3** closes contacts **1901** and applies ground through the break contacts **1902** of relay **15–OC1** to the G1 lead which lead extends to the contacts **2208** of relay **46–1T**. The closure of ground to the G1 lead by the operation of contacts **1901** completes a circuit for the operation of relay **15–OC1** from a ground on the G1 lead as described above and through the contacts **2208** of relay **46–1T**, operated contacts **2207** of relay **44–TR1** and then over the T1 lead to battery through the winding of relay **15–OC1** which relay operates and closes its locking contacts **1506** for maintaining itself operated under control of contacts **1502** of relay **15–5UP**. Relay **15–OC1** in operating opens contacts **1902** and thus removes ground from the G1 lead.

The operation of relay **19–DC3** as described above also closes contacts **1810** which contacts apply ground through the break contacts **1811** of relay **15–OC3** to the G3 lead which lead extends through Figs. 19, 20, 17, 14, 29, 32, 35, 38 and 41. The ground thus applied to the G3 lead completes a circuit for the operation of relay **35–T0** from the ground on the G3 lead through the operated contacts **2905** of relay **46–3A**, operated contacts **2910** of relay **44–FOR** and then over the T0 lead of Fig. 35 and then through contacts **3502** to battery through the winding of relay **35–T0**.

The operation of relay **35–T0** connects relays **35–B00** through **35–B09** to the units leads U0 through U9 and under the assumed conditions completes a circuit for the completion of relay **35–B01** which circuit extends from battery through the winding of relay **35–B01**, contacts **3505**, the U1 lead extending to Fig. 29, contacts **2909** of relay **44–FOR**, contacts **2908** of relay **46–4B**, the G4 lead designated **1607** extending through Figs. 14, 17, 20 and 19 to ground through the operated contacts **1813** of relay **44–FOR** and contacts **1801** of relay **15–5UP**.

The operation of relay **35–B01** completes a circuit for the operation of relay **35–UPCB** through a one and one only check circuit of relays **35–B00** through **35–B59** shows at the top of Fig. 35. The operation of relay **35–UPCB** closes contacts **3506** which contacts complete a circuit for the operation of relay **19–DCR** which circuit extends from battery through the winding of relay **19–DCR**, the operated contacts **1910** of relay **44–FOR**, conductor **1914** which conductor extends from Fig. 19 through Figs. 20, 35 and then through contacts **3506** of relay **35–UPCB** to ground. Relay **19–DCR** in operating closes contacts **1556**, **1557**, **1558**, **1559** and **1560** which contacts connect ground to the windings of the respective relays **15–OC1**, **15–OC2**, **15–OC3**, **15–OC4** and **15–OC5**, thus causing the operation of all these relays.

The operation of relay **15–OC2** removes ground from the G2 lead, thus permitting relay **35B** to release. Relay **35B** in releasing interrupts a locking circuit for relay **35–B1**, thus permitting relay **36–B1** to release. The release of relay **35B** also interrupts the operating circuits of relays **39–RLS** and **42–RLS** which relays then release. However, the previously operated formula relays in the C and D levels are not reoperated. The operation of relay **15–OC3** removes ground from the G3 lead, thus permitting relay **35–T0** to release. The operation of relay **15–OC4** removes ground from the G4 lead and the removal of ground from the G4 lead together with the release of relay **35–T0** interrupts the operating circuit of relay **35–B01**. However, the release of relay **35B** described above completes a locking circuit for maintaining relay **35–B01** operated from battery through the winding of relay **35–B01**, contacts **3507**, break contacts **3503** of relay **35B**, normal contacts **3504** of relay **36–RLS** to ground through the operated contacts **3202** of relay **7–RG1**. Thus, relay **35–B01** and relay **36–BF** are locked operated at this time under control of contacts **3504** of relay **36–RLS** and contacts **3202** of relay **7–RG1**. The operation of relays **15–OC1** through **15–OC5**, inclusive, completes a circuit for the operation of relay **18–CTR1** which relay opens contacts **1105**, **1116** and **4653** causing the release of the order relays of Fig. 46, the release of the steering relays in Figs. 11 and 12 and the release of relay **45–5UP**. Relay **45–5UP** causes relay **15–5UP** to release and this relay in turn causes the release of the relays in the routine control circuits including relays **15–OC1** through **15–OC5**. When the relays in the routine control circuit release they complete a down-check circuit for operating relay **13–DCP**. The release of the relays **45–IRC** through **45–5RC** permit relay **45–CO** to release and this relay in turn interrupts the locking circuit of relay **18–CTR1** which relay then releases.

Formula director

The exemplary computer embodying the present invention comprises the formula director having four different levels of formulas semipermanently wired into the computer. As described herein these levels are called the A, B, C and D levels and the D level has the more simple formula for routines built into it. The routines in the C level are more complicated than those in the D level and the routines in the B level are more complicated than those in the C or D level, while the routines in the A level are still more complicated than the routines in the B level. As described herein a fifth level may be provided by the use of the C tape and the special orders controlling it. Circuit-wise the "C" tape when in use for providing routine orders is located between the "A" formula level and the problem tape. At present, it is assumed that the formula B01 is selected and the operation of the system in response to this selection of this formula will be described by way of example. In addition a routine order set up on a step of any formula in any level except the D level may choose a formula in a lower level and when that formula is completed the control is restored to the formula of a higher level. The system is also arranged so that the formula of the lower level may select a formula of the same level or of a higher level. In this case the formula selecting a formula in the higher level or the same level is cancelled or discharged upon the selection of the second formula in the same level or the formula of a higher level. The manner in which these control circuits operate in response to various formulas

selecting other formulas will be described in detail in the following description of the operation of the formula directing circuits. As described herein each of the formulas is selected by means of an order which is set up on the order relays of Fig. 46 and then executed by the routine control circuit shown principally in Figs. 15, 16, 18 and 19. As described herein with reference to the order T B 0 1 $\overline{HH}$ at the completion of the execution of an order selecting a formula such as formula B01 the routine control circuits are restored to normal and relay 13–DCP is operated by the down-check circuit of the routine control circuit. At this time the relay designating the selected formula is locked operated together with the F1, UPC and S relays of the particular formula 01. Thus for the formula B01 relay 35–B01 is locked operated and relay 36–BF, relay 36–BF1, relay 35–UPCB and relay 36–BS are operated. Upon the release of relay 18–CTR1 of the routine control circuit at the end of the order selecting the formula B01 together with the operation of relay 13–DCP in response to the completion of the down-check circuit through the relays of the routine control circuit, a circuit is completed for the operation of relay 45–STP which circuit extends from battery through the winding of relay 45–STP, the operated contacts 4507, contacts 4508, relay 11–KEY and then through break contacts on each of the relays 45–IRC, 45–2RC, 45–3RC, 45–4RC and 45–5RC, contacts 4502 of relay 31–TST and then over the LK lead which extends to Figs. 42, 39, 36, 33, 30, 29, 14, 13, 12 and 11 to ground through contacts 1116 of relay 18–CTR1 and contacts 1106 of relay 7–RG1. Relay 45–STP in operating at this time closes contacts 3301, 3302, 4514 and 4515.

The operation of contacts 4515 of relay 45–STP completes a circuit for the operation of relay 45–FR from ground through the operated contacts 4516 of relay 8–ST4, contacts 4515 of relay 45–STP, break contacts 4518 of relay 45–5UP to battery through the winding of relay 45–FR. Relay 45–FR in operating closes its locking contacts 4517 which complete a locking circuit extending from battery through the winding of relay 45–FR, operated contacts 4517, break contacts 4504 of relay 45–5UP to ground through contacts 4501 of relay 7–RG1.

The operation of relay 45–FR closes contacts 4417 and 4418 and opens contacts 4420. The closure of contacts 4417 partially prepares a circuit for the operation of relay 44–AL and 44–AL1. The closure of contactcs 4418 of relay 45–FR together with the closure of contacts 4419 of relay 45–STP apply ground to the TMA lead extending to the alarm circuit. Ground applied to the TMA lead causes the alarm circuit to initiate the operation of the timing circuits which allow a predetermined time interval for the order relays and related control circuits and relays to function.

The operation of contacts 3302 of relay 45–STP completes a circuit for the operation of relay 36–BS1 from ground through the operated contacts 3607 of relay 36–BS1 from ground through the operated contacts 3607 of relay 35–UPCB, through a series set of break contacts on relay 36–BS17 through relay 36–BS1, the operated contacts 3608 of relay 36–BS, the operated contacts 3609 of relay 36–BS, the operated contacts 3610 of relay 36–BF1, the operated contacts 3302 of relay 45–STP, the operated contacts 3611 of relay 36–BF1, operated contacts 3612 of relay 36–BS to battery through the winding of relay 36–BS1. Relay 36–BS1 operates and closes its contacts 3613 which contacts in closing complete a circuit for maintaining relay 36–BS1 operated from ground, through contacts 3607 of relay 35–UPCB and then through the series set of break contacts of relay 36–BS17 through relay 36–BS2 and the operated contacts 3613 of relay 36–BS1 to battery through the winding of relay 36–BS1, thus maintaining relay 36–BS1 operated. At this time the ground from the armature of contacts 3613 extending to the winding of relay 36–BS1 also extends through the operated contacts 3612 of relay 36–BS and operated contacts 3611 of relay 36–BF1, the operated contacts 3302 of relay 45–UP, the operated contacts 3610 of relay 36–BF1 and the operated contacts 3609 of relay 36–BS for maintaining relay 36–BS operated. It should be noted that the operating circuit of this relay is opened at the break contacts 3613. However, the above-described circuit is completed so long as relay 45–STP remains operated. Thus, relays 36–BS and 36–BS1 are operated at this time.

The closure of contacts 3301 of relay 45–STP as described above completes a circuit for the operation of relay 36–ST1 from battery through operated contacts of relay 35–B01 (not shown in drawing) similar to contacts 3535 of relay 35–B00, through the winding of relay 36–TS1, the break contacts 3614 of relay 36–ST1, the operated contacts 3615 of relay 36–BF1 to ground through the operated contacts 3301 of relay 45–STP.

The operation of relay 36–ST1 actuates its contacts 3614 for maintaining itself operated. Relay 36–ST does not operate at this time because it has ground connected to both of its winding terminals. Relay 36–ST1 in operating actuates contacts 3613 and 3617. The actuation of contacts 3613 completes a circuit for the operation of relay 36–S1 which circuit extends from battery through contacts 3618 of relay 36–B01, the winding of relay 36–S1, contacts 3619 of relay 36–BS1, contacts 3620 of relay 36–BS, contacts 3621 of relay 36–BF1 to ground through the operated contacts of relay 36–S1. The operation of relay 36–S1 together with the actuation of contacts 3617 connect ground through a seris of five coils, one in each column of Fig. 47 to the odd conductor 3620 extending to the impulse generator. This ground circuit may be traced from the ground at the lower right-hand corner of Fig. 46, then through one coil in each column of the order coils in Fig. 46 and then to the eighteenth B terminal on the left-hand edge of Fig. 46 which terminal is cross-connected to contacts 3701 of relay 36–S1 and then through the operated contacts 3702 of relay 35–B01, contacts 3703 of relay 36–BF1, the operated contacts 3617 of relay 36–ST1 and then to the odd impulse generator and through the right-hand contacts of key 3111, contacts of key 3120, the operated contacts 3122 of relay 31–CO1 and then through contacts 3126 to condenser 3130. Ground applied to this condenser transmits a positive pulse through it which initiates a discharge through the odd tube 3141 which in turn operates the odd relay 31–ODD. Relay 31–ODD operates in this circuit and actuates contacts 3126 which applies ground to the upper terminal of condenser 3138 through the inductance coil 3136. Condenser 3138 discharges to the ground at the lower right-hand corner of Fig. 47 through the above-described circuit over the odd conductor which extends through one coil in each of the five columns of coils in Fig. 46. Due to the inductance of coil 3136, the condenser discharge over the above-described circuit is oscillatory in nature having a frequency determined by the constants of the inductance of the coil and the capacity of the condenser. This oscillatory current flowing through the conductor threaded through five coils causes a sufficient voltage to be induced in the second lower winding of each of the coils to initiate a discharge through the associated gas discharge tube. The discharge through this tube in turn causes the corresponding order relays of Fig. 46 to operate and lock operated under control of contacts 4653 of relay 18–CTR1. Upon the operation of one of the order relays in each column of Fig. 46 a complete order is entered upon these relays which order is then executed in the manner described herein. This order may comprise any one of the numerous orders described herein or other similar types of orders. The order is determined solely by the coils through which the conductor connected to terminal B01 of Fig. 46 is threaded.

If any one or more of the order relays fails to operate in response to the pulse of alternating current from the pulse generator applied to the conductor extending through

the five order coils such as described above and the control circuits fail to function because one or more of the relays 45–1RC through 45–5RC fail to operate, as a result, the circuit described herein for operating relay 45–5UP is not completed so relay 45–5UP fails to operate. Consequently, the time-out circuit functions and causes the operation of relay 44–TM at the end of the interval of time allowed for the operation of the order relays and control circuits including the operation of relay 45–5UP. The operation of relay 44–TM causes contacts 4421 to close and complete a circuit for the operation of relay 44–AL from battery through the winding of relay 44–AL, the break contacts 4422 of relay 44–AL1, the operated contacts 4417 of relay 44–FR, the break contacts 4423 of relay 44–TCO to ground through the operated contacts 4421 of relay 44–TM. Relay 44–AL in operating connects ground to the right-hand terminal of relay 44–AL by closing contacts 4424 which circuit extends through contacts 4425 of relay 44–TMO to ground in the alarm circuit. Relay 44–AL1, however, does not operate at this time because it now has ground connected to both of its winding terminals. The operation of relay 44–AL closes contacts 3132 and completes a circuit for the operation of relay 31–CO through the operated contacts 3132 of relay 44–AL, the break contacts 3133 of relay 44–AL1 to battery through the winding of relay 31–CO. The operation of relay 31–CO opens contacts 3134 of relay 31–CO which causes relay 31–CO1 to release. The release of relay 31–CO causes contacts 3121 and 3122 to release and disconnect the even and odd pulse generators from the even and odd leads respectively extending to the formula director circuits. As a result, the pulse generators are restored to their normal condition with a positive charge on the upper terminals of condensers 3137 and 3138.

The operation of relay 44–AL closes contacts 4426 which apply ground through the break contacts 4427 of relay 44–AL1 to the TMA' lead extending to the alarm circuit. As a result, relay 44–TM is released by the alarm circuit in a short interval of time of the order of two and one-half seconds, for example, after the application of ground to the TMA' lead. As a result, contacts 4421 of relay 44–TM open and remove the short-circuit from around the winding of relay 44–AL1. Relay 44–AL1 opens contacts 4427 and removes ground from the TMA' lead. Relay 44–AL1 also opens contacts 4422 thus interrupting the operating circuit of relays 44–AL and 44–AL1. Relays 44–AL and 44–AL1, however, remain operated in a circuit extending from battery through the winding of relay 44–AL, the winding of relay 44–AL1, the operated contacts 4424 of relay 44–AL, the break contacts 4425 of relay 44–TMO to ground in the alarm circuit.

The operation of relay 44–AL1 also opens contacts 3133, thus releasing relay 31–CO and the release of relay 31–CO in turn causes contacts 3134 to reclose and reoperate relay 31–CO1. Relay 31–CO1 in reoperating recloses contacts 3121 and 3122, thus reconnecting the even and odd generators to the even and odd leads extending to the formula director circuits. Upon the reclosure of these contacts the impulse circuit which previously transmitted a pulse over the selected conductor extending through five of the coils again transmits a pulse over this conductor in an effort to operate all five of the order relays associated with the coils through which the conductor extends. If upon this second try, all five order relays do not operate, then the alarm circuits time out and stop the operation of the computer. If, however, upon the application of either the first or second pulse to this selected conductor all five order relays operate, then the circuits as described herein are completed for the operation of relays 45–1RC through 45–5RC and for the operation of relay 45–5UP. The operation of relay 45–5UP indicates that the order has been fully entered upon the order relays and closes contacts 3135 of relay 45–5UP. The operation of relay 31–CO causes relay 31–CO1 to release and disconnect the pulse generators from the even and odd leads in the manner described herein. The operation of relay 45–5UP also operates contacts 4504 and 4505. The operation of relay 45–5UP also operates contacts 4504, 4505 and 4518. The operation of contacts 4518 interrupts the operating circuit and the operation of contacts 4504 interrupts the locking circuit of relay 45–FR, thus permitting this relay to release. The release of either or both of the relays 45–STP and 45–FR removes ground from the TMA lead extending to the alarm circuit, thus cancelling the alarm and time-out features since the circuits have operated satisfactorily up to this point. If the circuits had previously recycled so that it was necessary to apply a second alternating-current pulse to the selected conductor before all five of the order relays are operated, this information is also recorded in a special counter or register in the time-out circuit.

The operation of relay 45–5UP also operates and interrupts the locking circuit of relay 45–STP and relays 45–1RC through 45–5RC operate and interrupt the operating circuit of relay 45–STP. As a result relay 45–STP releases and opens contacts 3302 and contacts 3301. The opening of contacts 3302 interrupts the above-described locking circuit for relay 36–BS, thus permitting relay 36–BS to release and restore its contacts 3612 and contacts 3620. The opening of contacts 3620 of relay 36–BS at this time interrupts the operating circuit of relay 36–S1, thus permitting relay 36–S1 to release. In the meantime, relay 36–BS1 is operated.

The release of relay 45–STP opens contacts 3301 which contacts remove the circuit from around the winding of relay 36–ST, thus permitting this relay to operate and close its contacts 3621.

The formula control circuits then remain in the position described during the execution of the order called for by the first step in the formula B01.

At the completion of the execution of this order in a manner similar to that set forth herein relay 13–DCP is again operated and relay 18–CTR1 again released with the result that relay 45–STP is again operated. The operation of relay 45–STP again closes contacts 3302 and contacts 3301. The closure of contacts 3302 at this time completes a circuit for the operation of relay 36–BS2 which circuit extends from ground through the operated contacts 3607 of relay 35–UPCB, the break contacts of relays 36–BS17 through 36–BS2, the operated contacts 3622 of relay 36–BS1, the break contacts 3609 of relay 36–BS, the operated contacts 3610 of relay 36–BF1, the operated contacts 3302 of relay 45–STP, the operated contacts 3611 of relay 36–BF1, the break contacts 3612 of relay 36–BS, operated contacts 3622 of relay 36–BS1 to battery through the winding of relay 36–BS2. Relay 36–BS2 in operating actuates contacts 3623 which contacts first complete a locking circuit for continuing the operation of relay 36–BS2 and maintaining this relay operated and also for maintaining relay 36–BS1 operated and then interrupting the operating circuit of relay 36–BS1. The locking circuit for maintaining relay 36–BS2 operated may be traced from ground through the operated contacts 3607 of relay 35–UPCB, through break contacts of relays 36–BS17 through 36–BS3 and then through the operated contacts 3623 of relay 36–BS2 to battery through the winding of relay 36–BS2. The ground thus connected to the winding of relay 36–BS2 for maintaining this relay operated also extends through the operated contacts 3622 of relay 36–BS1, the break contacts 3612, operated contacts 3611, operated contacts 3302 of relay 45–STP, operated contacts 3610, break contacts 3609 of relay 36–BS, operated contacts 3622 and contacts 3613, both of relay 36–BS1 to battery through the winding of relay 36–BS1. At this time relays 36–BS1 and 36–BS2 are operated.

The closure of contacts 3301 of relay 45–STP con-

nects ground to the upper winding terminal of relay 36–ST1, thus short-circuiting this relay and permitting it to release. Ground is, however, maintained on the lower winding terminal of relay 36–ST, thus causing relay 36–ST to remain operated. With relay 36–ST operated and relay 36–ST1 released, a circuit is completed for the operation of relay 36–S2, which circuit extends from battery through the operated contacts 3618 of relay 35–B01 to the winding of relay 36–S2, the operated contacts 3624 of relay 36–BS2, contacts 3625 of relay 36–BS1, the operated contacts 3626 of relay 36–BF1, the operated contacts 3627 of relay 36–ST to ground through the break contacts 3630 of relay 36–ST1. The operation of relay 36–S2 together with the release of relay 36–ST1 connect the conductor connected to the terminal B18 on the left-hand side of Fig. 46 to the conductor 3619 extending to the even impulse generator. The conductor connected to the B18 terminal extends through a coil in each column of the order of coils of Fig. 46 to ground so that the application of a pulse of alternating current to this conductor induce a voltage in this conductor to which this conductor is threaded which voltage initiates through the corresponding tubes and sets up another order upon the order relays of Fig. 46. In response to setting up a complete order on these relays the routine control circuits operate as described above and interrupt both the operating and locking circuits of relay 45–STP which relay thereupon releases and opens contacts 3302 and contacts 3301. The opening of contacts 3302 interrupts the above-described holding circuit for relay 36–BS1, thus permitting this relay to release and open contacts 3625 and thus release relay 36–S2. The release of contacts 3301 removes ground from the lower winding terminal of relay 36–ST, thus permitting this relay to release so that now both relays 36–ST and 36–ST1 are released.

The second order of the B01 routine is then executed by the control circuits in a manner similar to the execution of the orders described herein. At the completion of the second order the routine control circuits and the formula control circuits shown in Figs. 35 and 36 are caused to advance another step and thus set up another order and the above process repeated in accordance with the various orders called for by the respective steps of this particular order.

Assume, for example, that the fifth step of the B01 order causes the order T D 18 $\overline{HH}$ to be set up on the order relays of Fig. 46. Upon the entering of the above complete order on the order relays the operation of the routine control circuit is initiated in substantially the same manner as described hereinbefore with respect to the order T B 0 1 $\overline{HH}$ except that relay 46–2D is operated instead of relay 46–2B, relay 46–3B instead of relay 46–3A and relay 46–4I is operated instead of relay 46–4B. As a result the operation of relay 45–5UP causes relay 15–5UP to operate which relay in turn applies ground to the leads G2 and G5 as described above and completes a circuit for the operation of relay 19–DC3 over the down-check lead through the A and B relays of all of the storage registers. The operation of relay 19–DC3 applies ground to the G3 lead and the operation of relay 44–FOR in response to the operation of contacts 4416 of relay 46–2D closes contacts 1813 and applies ground to the G4 lead. As a result relay 41D operates in response to the application of ground to the G2 lead in a circuit extending from battery through the winding of relay 41D, the operated contacts 4102 to the G2 lead and through Figs. 38, 35, 20, 19, 18, the break contacts 1605 of relay 15–OC4 to ground through the operated contacts 1813 of relay 44–FOR and contacts 1801 of relay 15–5UP. Relay 41D in operating opens contacts 4103 which interrupt the locking circuits of all the D formula relays. As assumed above, however, these relays are already released. The operation of relay 41D also opens contacts 4201, thus preventing the operation of relay 42–DF1. The operation of relay 41D also closes contacts 4202 and completes an obvious circuit for the operation of relay 42–DF. Relay 42–DF in operating locks operated under control of contacts 4101 of the 42–RLS relay to ground on the RG lead extending through Figs. 38, 35, and 32 to ground through the operated contacts 3202 of relay 7–RG1. The operation of relay 41D also closes contacts 4203 which contacts connect the winding of relay 42–D1 through a down-check circuit which extends through break contacts on each of the relays DS, DS1 to DS14 and through the series circuit through the break contacts on each of the relays D00 through D59, inclusive, to ground. Upon the completion of the above-described circuit, relay 42–D1 operates and completes a circuit for maintaining itself operated from ground through the contacts 4204 of relay 41D and contacts 4205 of relay 41–D1 to battery through the winding of relay 42–D1. Relay 42–DF in operating closes contacts 4104 which contacts complete an obvious circuit for the operation of relay 41–DF2 and relay 41–DF2 in turn actuates the contacts 4206 which extend through the winding of relay 42–RLS to contacts 4207 and the alarm circuit 4208.

The operation of relay 42–D1 connects the windings of relays 41–T0 through 41–T5 to the respective tens leads T0 through T5. These relays then extend through Figs. 38, 35 and 32 to the contacts of relay 44–FOR. Under the assumed conditions the application of ground to the G3 lead together with the operation of relay 42–D1 and the operation of relay 44–FOR and relay 46–3B complete a circuit for the operation of relay 41–T1. The circuit for operating relay 41–T1 extends from battery through the winding of relay 41–T1, operated contacts 4105 of relay 42D and then over the T1 lead through contacts 2911 of relay 44–FOR, contacts 2903 of relay 46–3B, then over the G3 lead to ground through the break contacts 1811 of relay 15–OC3 and the operated contacts 1810 of relay 19–DC3. The operation of relay 42–T1 completes a circuit for maintaining itself operated from battery through its winding and its operated contacts 4106 to ground through the operated contacts 4415 of relay 44–TR1 and the operated contacts 4409 of relay 46–5D. A second holding ground is also connected to the winding of relay 41–T1 and a circuit extended from battery through the winding of relay 44–T1, the operated contacts 4106 of relay 44–T1 to ground through the operated contacts 1401 of relay 15–5UP.

The operation of relay 41–T1 connects the windings of relays D10 through D19 to the respective units leads U0 through U9. The operation of relay 41–T1 together with the operation of relay 44–FOR and the operation of relay 46–4I and the application of ground to the G4 lead complete a circuit for the operation of one of the D formula relays D10 through D19. Under the assumed conditions, relay D18 will be operated over the above-described circuit. The operation of one and one only of the D formula relays, namely, D–18, under the conditions assumed above, completes a circuit for the operation of relay 41–UPCD to battery through the winding of relay 41–UPCD to ground to one and one only of the check circuits of the contacts of relays D00 through D59 which check circuit is shown at the upper right-hand portion of Fig. 41. The operation of relay 41–UPCD dismisses the progress circuit at the end of the selection of relay D18 and as a result, relays 41–T1 and 42–D1 all release leaving relays 41D, 41–UPCD, 41–DF2 and 41–DF operated. The release of relay 41D also completes a circuit for the operation of relay 41–DF1 which circuit extends from battery through the winding of relay 41–DF1, break contacts 4201 of relay 41D, contacts 4209 of relay 42–DF to ground over the RG lead, 3201, through the operated contacts 3202 of relay 7–RG1. Relay 42–DF1 connects the stepping relays

42–ST and 42–ST1 to the contacts 3301 of the stepping relay 45–STP and also connects the circuit of the D formula stepping relays shown in Fig. 42 to the contacts 3302 of relay 45–STP and also to the contacts of the stepping relays 42–ST and 42–ST1. Then upon the release of the routine control circuits as described herein relay 45–STP is operated which relay causes the order called for by the first step in the D18 formula to be set up on the order relays of Fig. 46 and this order in turn executed in the manner described herein. Thereafter, the stepping relays of Fig. 42 are caused to advance and set up the succeeding order and then progress from step to step causing each of the succeeding orders called for by the particular step of this relay to be set up and executed and then the next order set up, etc. It should be noted that when the D relay formula was selected by the fifth step of the formula B01, the B level of the formula director circuit remained in the fifth step and was not released. Should any step of the D18 formula call for another D formula, this formula would be selected in the same manner as described above. It should be noted, however, that upon the operation of the 41D relay previously operated, relay 41–D18 is released due to the operation of contacts 4103 of relay 41D interrupting the locking circuit of the previously operated D formula relay, i. e., 41–D18 under the assumed conditions after which the succeeding D formula relay causes the stepping circuit to advance step by step through the various steps called for by this formula causing the proper order to be set up on the order relays and then executing in the manner described herein. After the original formula D18 has progressed through all its steps assuming that no other formula is called for by any of the steps of this formula the control is then returned to the higher level which called for the D18 formula, namely, the B formula. Operation of the circuits for returning the control to the higher level may be initiated in several different ways.

So far as the circuits and their mode of operation are concerned, any one of the formulas in any of the levels may have as many steps as may be desired. However, in order to reduce the amount of apparatus necessary in one specific exemplary embodiment of the invention sufficient equipment was provided for the formulae of the respective levels so each of the formulae A00 to A19 comprises a maximum of twenty steps. In other words, each of these formulas could set up a maximum of twenty orders on the order relays. Each of the formulas A20 through A39 comprises a maximum of eight steps. Each of the formulas B00 through B29 may comprise a maximum of seventeen steps while formulas B20 to B39 comprise a maximum of eleven steps. Formulas C00 through C19 may specify a maximum of fourteen different orders or steps. Formulas C20 through C39 each may comprise eight steps and formulas C40 through C59 may comprise six steps. Formulas D00 through D19 comprise fourteen steps and formulas D20 through D59 are arranged so that they may include seven steps. The above listing of the various steps for the various formulas is wholly arbitrary and a matter of supplying the necessary equipment. However, inasmuch as one specific exemplary embodiment of the invention was equipped in this manner the accompanying drawings have been drawn to show or indicate sufficient equipment to provide the above number of steps in the above-identified formulas.

Thus assuming that all of the steps are required in formula D18 and that the stepping circuit shown in Fig. 42 is progressed through all fourteen steps and causes the fourteen orders of this formula to be set up on the order relays of Fig. 46 and executed by the computing equipment in the manner set forth herein. At the completion of the execution of the fourteen order or step from the formula D18 the 45–SPT relay operates. The operation of relay 45–SPT at this time closes contacts 3302 which contacts now complete a circuit for the operation of relay 42–RHLO from battery through the winding of relay 42–RHLO, the operated contacts 4212 of relay 42–DS14, the break contacts of relays 42–DS13 through 42–DS1, operated contacts 4213 of relay 42–DF1, the operated contacts 3302 of relay 45–SPT, the operated contacts 4214 of relay 42–DF1, break contacts of relay 42–DS, break contacts of relays 42–DS1 through 42–DS13 and operated contacts of relay 42–DS14. Relay 42–RHLO in operating in the above-described circuit causes contacts 4509 through 4513 to close.

Order T G T T $\overline{HH}$

Thus, at the completion of the execution of the last order on any formula, provided all of the steps attached to the particular one are used, the code T G T T $\overline{HH}$ is set up on the order relays. The purpose of this order is to cause the formula director circuit to return to a higher level. In case it is not necessary or desirable to use all of the steps of a formula then the order T G T T $\overline{HH}$ may be inserted by threading a wire through the proper coils after all the required orders of a formula. The operation of relay 46–3T causes contacts 1512 to close which contacts complete an obvious circuit for the operation of relay 15–OC3 which relay in operating closes contacts 1537 and thus prepares a locking circuit for maintaining itself operated under control of contacts 1502 when relay 15–5UP operates. The operation of relay 46–4T causes relay 44–4T1 to operate by closing contacts 4416 and relay 44–4T1 in turn closes contacts 1507. Relay 46–5D in operating closes contacts 4409 which contacts complete an obvious circuit for the operation of relay 44–TR1. Relay 44–TR1 in operating closes contacts 1506 and these contacts together with the operated contacts 1507 of relay 44–4T1 complete an obvious circuit from ground through contacts 1505 of relay 44–5E1 to battery through the winding of relay 15–OC4. Relay 15–OC4 in operating in turn closes its locking contacts and thus partly prepares a locking circuit for maintaining itself operated under control of contacts 1502 of relay 15–5UP. As described hereinbefore upon the entering of a complete order on one of the relays of each column of the order relays of Fig. 46 such as described above for the order T G T T $\overline{HH}$, the control circuits function and cause relay 45–5UP to operate and this relay in turn causes relay 15–5UP to operate. Relay 15–5UP causes contacts 1913 to close and complete a down-check circuit through the control A and B relays of each of the storage register circuits for the operation of relay 19–DC3. Relay 19–DC3 in operating closes contacts 1901 and applies ground to the G1 lead, 1903, through break contacts 1902 of relay 15–OC1. The operation of relay 15–5UP closes contacts 1801 which contacts apply ground to the G2 and G5 leads. The application of ground to lead G2 completes a circuit for the operation of relay 19–RHL to battery through the winding of relay 19–RHL, the operated contacts 1915 of relay 46–2G and over the G2 lead, 1801, to ground through the break contacts 1809 of relay 15–OC2 and the operated contacts 1801 of relay 15–5UP. Meantime, the operation of relay 46–1T together with the operation of relays 44–TR1 and 19–DC3 close a circuit for the operation of relay 15–OC1 from battery through the winding of relay 15–OC1 over the T lead which extends from Fig. 15 through Figs. 16, 17, 20, 21 and 22 through the operated contacts 2207 of relay 44–TR1, operated contacts 2208 of relay 46–1T to the G1 lead which extends through Figs. 22, 21, 20 and 19 to ground through the break contacts 1902 of relay 15–OC1 and the operated contacts of relay 19–DC3.

The operation of relay 19–RHL described above completes a circuit for the operation of relay 42–RLS from battery through the winding of relay 42–RLS, the operated contacts 4206 of relay 42–DF2 to ground through

the operated contacts 4207, of relay 19–RHL. The operation of relay 42–RLS actuates contacts 4102. The actuation of contacts 4102 removes ground from the locking contacts of all of the relays D00 through D59 which relays select the respective D formulas. Thus, under the assumed conditions the actuation of contacts 4101 interrupts a locking circuit of relay 41–D18, thus permitting the release of relay 41–D18. The actuation of contacts 4101 also interrupts the locking circuit of relay 42–DF which relay in turn releases and interrupts the operating and locking circuits of relay 41–DF1. Relay 41–DF1 in releasing opens contacts 4215, 4213, 4214, 4210 and 4216, thus disconnecting the stepping circuit of the D level formulas from the control circuits of the 45–STP relay. The release relay 41–D18 interrupts the operating circuit of relay 41–UPCD through the one and one only check circuit shown at the top of Fig. 41. The release of relay 41–UPCD opens contacts 4217, thus interrupting the locking circuit of any of the relays 42–DS and 42–DS1 through 42–DS14, thus causing any of these relays to release. Under the assumed conditions, relay 42–DS14 will release. In addition, the release of relay 41–D18 opens corresponding contacts supplying battery to the relays 42–S1 through 42–S14, thus permitting any of these relays to be released. Under the assumed conditions, relay 42–S14 will release at this time.

The release of relay 41–UPCD in opening contacts 4217 also interrupts the above-described operating circuit for relay 42–RHLO, thus permitting this relay to release.

The release of relay 42–DF1 causes contacts 2201 to release and complete a circuit for the operation of relay 19–DCR from battery through the winding of relay 19–DCR, the closed contacts 1916 of relay 19–RHL and then over a conductor extending from Figs. 19 through Figs. 16, 17, 14, 29 and 22 and through the operated contacts 2202 of relay 42–RLS to ground through the normal break contacts 2201 of relay 42–DF1. The operation of relay 19–CDR completes a circuit for maintaining itself operated under control of relay 15–5UP and in addition applies ground in obvious circuits for the operation of relays 15–OC1, 15–OC2, 15–OC3, 15–OC4 and 15–OC5, thus indciating the completion of the execution of the order T G T T $\overline{HH}$. The operation of relays 15–OC1, 15–OC2, 15–OC3, 15–OC4 and 15–OC5 each in operating removes ground from the respective G1, G2, G3, G4 and G5 leads, thus interrupting the operating circuit of relay 19–RHL. Relay 19–RHL in turn releases and interrupts the operating circuit of relay 42–RLS which relay in turn releases and releases relay 41–DF2. As a result, all of the relays of the D formula level have now been restored to their normal or unoperated condition.

The operation of all of the relays 15–OC1 through 15–OC5 together with the operation of relay 15–5UP described above completes an obvious circuit for the operation of relay 18–CTR1 which relay opens contacts 1105, 1116 and 4653 thus permitting the release of the order relays, the relays of Figs. 44 and 45 controlled by the order relays and the release of the steering relays and related circuits in Figs. 11 and 12 and release of numerous relays of Figs. 15, 16, 18 and 19. The operation of relay 18–CTR1 in releasing the numerous relays described above also releases relay 45–5UP and this relay in turn releases the operated relay 15–5UP which relays release and interrupt the locking circuits of the other relays of the routine control circuits, thus permitting these relays to release and complete the down-check circuit for the operation of the down-check relay 13–DCP. The release of relay 45–5UP together with the release of relay 45–CO when all of the order relays are released interrupts a locking circuit of relay 18–CTR1 which relay releases and restores the routine control circuits to their normal condition.

Upon the release of relay 42–DF described above a circuit is reestablished for the operation of relay 36–BF1. It will be recalled that relay 36–BF1 has remained operated all during the time the D formula was in control of setting up the order relays. Relay 36–BF1 maintains itself operated at this time in a circuit extending from battery through the winding of relay 36–BF and the operated contacts 3603 of relay 36–BF, break contacts 3504 of relay 36–RLS to ground through the operated contacts 3302 of relay 7–RG1. Consequently, upon the release of relay 42–DF, relay 36–BF1 was reoperated and the reoperation of this relay reestablishes connections between the stepping relay circuits of the B level formula shown in Fig. 36 and the contacts 3301 and 3302 of relay 45–STP. Consequently, upon the release of relay 18–CTR1 and the operation of relay 13–DCP a circuit is completed for the operation of relay 45–STP. The operation of this relay again closes contacts 3301 and 3302 which cause the stepping relays of the B level formula director to advance to the next or sixth step or position where they will control the setting up of another order in the order relays of Fig. 46 in the same manner as described herein for setting up these order relays for any of the other steps of the B level or any of the steps of the C level or of any other level.

It is thus evident that any one of the formula levels can pick a lower formula level and during the time the lower formula level is under control the stepping of the circuits of the higher formula level is suspended. When the lower formula level has progressed through all the steps, the control is returned to the higher formula level and this level advanced step by step from the position where the control is given over to the lower formula level.

As indicated hereinbefore, the circuits of a specific embodiment of the present invention have been arranged so that certain of the formulas in each level have more steps than others. For example, the formulas D00 through D19 are arranged to have a maximum of fourteen steps while the formulas D20 through D59 are arranged to have only a maximum of seven steps. When one of these higher orders of the D level formulas is selected, it should be noted that upon the eighth step of this formula when relays 42–DS7 and 42–DS8 are operated for the operation of relay S8 on the eighth step, a short-circuit is also completed through contacts of the corresponding relays 42–D20 through 42–D59 for the operation of relay 42–RHLO. In addition, contacts 4218 of relay 42–DS8 are operated which contacts together with the operation of relay 42–RHLO cause the order T G T T $\overline{HH}$ to be set up and restore the control to a higher level. Thus, when the seven steps of these D formulas D20 through D59 have selected a group of order relays and this order is executed upon the next step the control is returned to a higher order which order first picked or seelcted the D formula, i. e., D18 under the assumed conditions. It is also possible to return the control to a higher level without progressing through each and every step of any of the formulas or any of the levels merely by setting up the return to the higher level order by threading the higher level order through the proper coils and energizing this higher level from the impulse director in response to the formula circuit advancing to the step which controls the setting up of this order. It is pointed out hereinbefore that should the lower level formula select a higher level formula, then all formulas including the selecting of the lower formula level are cancelled and the relays of these lower levels restored to normal upon the selection of a higher level formula. Consequently, at the termination of the higher selected formula it is impossible to go back and complete the steps of a lower level formula. If it is necessary to use a lower level formula again, then the higher level formula must set up the order selecting the lower level formula in the same manner as described herein when a D formula was selected by a formula in the B level.

Order A E A T $\overline{HH}$

Provision has been made to employ any of of the numbers recorded in any of the registers to control or select a desired formula. Inasmuch as the numbers recorded in the various registers all may have ten places of denominational orders and since it is only necessary to employ three places or denominational orders to select any formula in the exemplary embodiment set forth herein, arrangements have been made for selecting certain of the places of the number to control the selection of a formula. Any suitable or desirable mode of selection of the digits of the number may be employed as may be desired. However, in the exemplary embodiment set forth herein provision has been made to select either the first three places or denominational orders of the number to control the selection of the formula or the second three denominational places or orders of the number or the third three denominational places of the number may be employed to select any one of the formulas. The above order A E A T $\overline{HH}$ will cause the first three places or denominational orders of the numbers stored in the A register to control the selection of a formula in accordance with the identity of the digit or character in each of these places of the number. Had it been desired to select the number stored in some other register, then the code or designation of this order register would be substituted for the first A in the above order. Likewise, if three places or denominational orders of the number in the A register or any other register are to be employed to select the formula, then a B will be substituted for the second A in the above order. Similarly, if the third three places or denominational orders of the number are to be employed to select the formula then the second A of the above order will be replaced by C.

Assuming now that the above-described order is entered on the order relays of Fig. 46 in any suitable manner the order relays **46–1A**, **46–2E**, **46–3A**, **46–4T** and **46–5D** are all operated. The operation of relay **46–1A** and only this relay in the first column causes relay **45–1RC** to operate and in addition closes contacts **2103** which contacts connect the winding of relay **21A** to a conductor extending to the routine control circuits as will be described herein. The operation of relay **46–2E** closes contacts **1917** which contacts partly prepare a circuit for the operation of relay **19–RFN**. The operation of relay **46–2E** also closes contacts **1561** which contacts complete an obvious circuit for the operation of relay **15–OC4**. Relay **15–OC4** in operating closes its locking contacts for maintaining itself operated under control of contacts **1502** of relay **15–5UP** when this relay becomes operated as described hereinafter. The operation of relay **46–3A** closes contacts **2905** which contacts partly prepare a circuit for the operation of relays **29AB** and **29BC**. The operation of relay **46–4T** completes a circuit for the operation of relay **44–4T1** which relay in turn closes contacts **1507** and partly prepares a circuit for the operation of relay **15–OC4**. The operation of relay **46–5D** closes contacts **4409** and completes an obvious circuit for the operation of relay **44–TR1**. Relay **44–TR1** in operating together with the operation of relay **44–4T1** described above completes a second circuit for the operation of relay **15–OC4**.

The operation of the above set of five order relays of Fig. 46, one of which is in each of the columns of the relays of Fig. 46 causes the circuits of Fig. 45 to operate as described above and complete a circuit for the operation of relay **45–5UP** which relay in operating interrupts the locking circuits of relays **45–STP** and **45–FR** as described herein. In addition the operation of relay **45–STP** actuates contacts **4504** which contacts complete a circuit described herein for the operation of relay **15–5UP**. Relay **15–5UP** in operating closes the above-described circuit for maintaining relay **15–OC4** operated and in addition closes numerous other contacts which apply ground to locking contacts of numerous of the

relays of the progress control circuits shown in Figs. 14, 15, 16, 18, and 19, etc. In addition the operation of relay **15–5UP** closes contacts **1801** which contacts apply ground to a conductor **5G**. However, inasmuch as none of the relays **46–5A**, **46–5A1**, **46–5B**, **46–5C** or **46–5E** are operated and since relay **46–2T** is not operated and relay **16–T2A** is not operated at this time the application of ground to the **G5** lead produces no useful functions at this time. The operation of contacts **1801** apply ground to the **G2** lead, **1802**, which lead extends through contacts **1917** of relay **46–2E** to the winding of relay **19–RFN**, thus causing the operation of relay **19–RFN**. Relay **19–RFN** in operating closes contacts **2912**, **2913**, **2914** which contacts partly prepare circuits for the operation of relays **29AB**, **29BC**, **29DC**, **29EF**, **29GH** and **29HI**. The operation of relay **19–RFN** also closes other contacts which partly prepare other circuits which circuits will be described hereinafter.

The operation of relay **15–5UP** also closes contacts **1913** which contacts extend a circuit from the common point between the windings of relays **19–DC3** and **19–DC3A** through break contacts on each of the A and B relays of each of the storage register circuits to ground. If this down-check circuit through all of the A and B relays of the storage and other registers is completed, relay **19–DC3** operates as described herein but relay **19–DC3A** does not operate because it has ground connected to both of its winding terminals. The operation of relay **19–DC3** closes the locking contacts **1904** for maintaining itself operated and later operates relay **19–DC3A** as described herein. Relay **19–DC3** in operating closes contacts **1901** which contacts apply ground through the break contacts **1902** of relay **15–OC1** to the **G1** lead, **1903**, which ground now extends through the operated contacts **2103** to the winding of relay **21A**, thus causing the operation of relay **21A**. The operation of relay **21A** removes ground from the center point between the winding of relay **19–DC3A** and relay **19–DC3**, thus permitting relay **19–DC3A** to operate while maintaining relay **19–DC** operated. The operation of relay **21A** also completes a circuit for the operation of relays **21–EUR** and **21–AR** through **21–JR**, the operation of which relays completes a circuit for the operation of these relays extending from battery through the windings of these relays, the operated contacts **2117** of relay **21A** and over the RXA lead which extends to Fig. 19 and then through contacts **1908** of relay **16–CXUP** and operated contacts **1918** of relay **19–RFN** to ground. The operation of relays **21–EUR**, **21–AR** through **21–JR**, inclusive, extends the windings of the register relays of the A register to the corresponding conductors of the X multiple. The storage relays of the A register which are operated will have a locking ground connected through their locking contacts to the winding terminals which ground also extends over the conductors of the X multiple, thus indicating the magnitude of the number stored in the A register.

The operation of relay **19–DC3** as described above also closes contacts **1810** which contacts apply ground through break contacts **1811** of relay **15–OC3** to the **G3** lead which lead extends from Fig. 18 through Figs. 19, 20, 17 and 14 to Fig. 29 and then through the operated contacts **2903** of relay **46–3A** and the operated contacts **2912** of relay **19–RFN** to battery through the windings of relays **29AB** and **29BC**. Relays **29AB** and **29BC** in operating close contacts between the X multiple and the windings of relays **20–H00**, **20–H5** and **20–H0** through **20–H4**. Relay **29AB** in closing these contacts connects the windings of these relays to the conductors of the X multiple which convey the identity or magnitude of the digit in the first denominational order of the number transmitted over this multiple. Likewise, relay **29BC** closes contacts between the windings of relays **20–U00**, **20–U5** and **20–U0** through **20–U4**, inclusive, and conductors of the X multiple over which the identity or magnitude of the digit in the third denominational position or order is

transmitted. Likewise, the combined operation of relays 29AB and 29BC connects the windings of relays 20–T00, 20–T5 and 20–T0 through 20T4 to conductors of the X multiple over which the identity or magnitude of the digit in the second denominational order is transmitted. Thus, the various relays of Fig. 20 are operated in accordance with the identity of the digits in the first three denominational orders of the number read out over the X multiple. As described above, this number is read out from the A register due to the operation of relay 21A and relays 21–EUR, 21–AR through 21–JR. If it had been desired to employ the digits in the second three denominational orders of the numbers stored in the A register at this time, the second portion of the order would have been a B instead of an A symbol as described above. Under these circumstances, the relays of Fig. 20 would be operated in accordance with the other two of the digits of the number stored in the designated register in the second three denominational positions. Likewise, if a C had been employed in the third position of the order, then the last three denominational places of the numbers stored in the A or otherwise designated register would be employed to operate the relays of Fig. 20.

Assume for purposes of illustration that the first three digits of the number stored in the A register at this time comprises digits 226, then the relays 20–H00 and 20–H2 will be operated as will be relays 20–T00, 20–T2, 20–U5 and 20–U3.

The operation of relays 20–H00 and 20–H2 causes the respective contacts 4107 and 3802 to be operated and complete a circuit for the operation of relay 38C of the C level of the formula director. The operation of relay 38C actuates contacts 3803 which contacts interrupt the locking circuit of all of the relays 38–C00 through 38–C59 which relays select and designate the respective formulas of the C level of the formula director. The release of all of the C selecting relays 38–C00 through 38–C59 completes a down-check circuit shown in the upper portion of Fig. 38 through the operated contacts 3903 to the winding of relay C1, thus causing the operation of relay 39–C1. The operation of relay 39–C1 completes a circuit for maintaining itself operated under control of the contacts 3904 of relay 38C. The operation of contacts 3904 of relay 38C also completes a circuit for the operation of relay 42–RLS to release any D formula relay as described herein if such a D formula relay 41–D00 through 41–D59 is operated at this time. The operation of relay 38C also closes contacts 3905 which contacts complete an obvious circuit for the operation of relay 39–CF. The operation of relay 39–CF upon the release of relay 42–DF had it been previously operated partially prepares a circuit for the operation of relay 39–CF1.

The operation of relay 20–T00 closes contacts 3203 and the operation of relay 20–T2 causes contacts 3204 to close which contacts together with the operation of relay 39–C1 complete a circuit for the operation of relay 38–T2.

The operation of relay 38–T2 closes locking contacts 3804 for maintaining itself operated in a circuit extending from battery through the winding of relay 38–T2, operated contacts 3804, then over the locking conductor which extends from Fig. 38 to Figs. 35, 32 and 17 to ground through the operated contacts 1401 of relay 15–5UP. The operation of relay 38–T2 also connects the windings of relays 38–C20 through 38–C28, inclusive, to the respective units conductors extending to the contacts of the units relays shown in Fig. 32. Thus, the operation of relay 20–U5 closes contacts 3205 and the operation of relay 20–U3 closes contacts 3206 with the result that the operation of these relays together with the operation of relay 38–T2 complete a circuit from ground through the operated contacts 3205, the operated contacts 3206 and through operated contacts of relay 38–T2 to the winding of relay 38–C28, thus causing this relay to operate and select the formula No. C28 of the C level. Relay 38–C28 in operating closes its locking contacts and completes a circuit for maintaining itself operated under control of contacts 3807 of relay 39–C1. Relay 38–C28 is not shown in detail on the drawings. This relay is one of the relays indicated in the series of relays 38–C00 through 38–C59. The operation of relay 38–C28 completes a circuit through the chain circuit in the upper portion of Fig. 38 for the operation of relay 38–UPCC. A circuit for the operation of relay 38–UPCC is completed if one and only one of the relays 38–C00 through 38–C59 is operated. The operation of relay 38–UPCC closes contacts 3806 and the closure of these contacts together with the closure of contacts 3805 by relay 38–T2 connects ground over a circuit extending from Fig. 38 through Figs. 35, 20 and 19 and through contacts 1919 of relay 29BC to battery through the winding of relay 19–FUP. Relay 19–FUP in operating closes contacts 1920 which contacts complete a circuit for the operation of relay 19–DCR from battery through the winding of relay 19–DCR, the operated contacts 1914 of relay 46–5D to ground through the operated contacts 1920 of relay 19–FUP. Relay 19–DCR in operating closes its locking contacts for maintaining itself operated under control of relay 15–5UP. The operation of relay 19–DCR closes contacts 1556, operating relay 15–OC1. Relay 15–OC1 in operating closes a locking circuit for maintaining itself operated under control of contacts 1502 of relay 15–5UP. Relay 15–OC1 in operating also actuates contacts 1902, thus interrupting the ground connected to lead G1, 1903, which in turn causes relay 21A to release. The release of relay 21A interrupts the operating circuit of the read relays 21–EUR, 21–AR through 21–JR, thus disconnecting the windings of the storage relays of the storage register from the X multiple.

The operation of relay 19–DCR also closes contacts 1527 which contacts complete an obvious circuit for the operation of relay 15–OC2 which relay operates and actuates contacts 1819, thus removing ground from the G2 lead, 1802, which interrupts the operating circuit of relay 19–RFN, thus permitting this relay to release.

The operation of relay 19–DCR also closes contacts 1558 which contacts complete an obvious circuit for the operation of relay 15–OC3 and the operation of relay 15–OC3 actuates contacts 1811 which contacts remove ground from the G3 lead. Either the release of relay 19–RFN or the removal of ground from the G3 lead or both of them interrupts the operating circuits for relays 29AB and 29BC, thus permitting these relays to release. The release of relays 29AB and 29BC interrupts the connections between the relays of Fig. 20 and the X multiple. The release of these relays thus together with the release of the read relays 21–EUR, 21–AR and 21–JR causes the relays of Fig. 20 which were previously operated to release, thus restoring the relays of Fig. 20 to normal and disconnecting the X multiple.

The operation of relay 19–DCR also closes contacts 1560 which contacts complete an obvious circuit for the operation of relay 15–OC5. The operation of relay 15–OC5 together with the operation of relays 15–OC1, 15–OC2, 15–OC3 and 15–OC4 complete a circuit for the operation of relay 18–CTR1 which relay in operating opens contacts 1105, 1106, and 4653, thus interrupting the locking circuits for the steering circuits of Figs. 11 and 12 and interrupting the locking circuits of the order relays of Fig. 46. The operation of contacts 1116 also interrupts the operating circuit of relay 45–5UP. Relay 45–5UP releases and releases relay 15–5UP which relay restores the relays of the control circuits shown in Figs. 14, 15, 16, 17, 18, 19 and 20 and the release of the relays in Figs. 44, 45 and 46 in turn permit relay 18–CTR1 to release. The release of relay 18–CTR1 together with the operation of relay 13–DCP in response to the completion of the down-check circuit through the routine

control relays of Figs. 15 and 16 as shown in the center portion of Fig. 13 is employed to advance the circuit so that the next order will be set up on the order relays or such action taken by the computer as may be called for by the various circuits as described herein.

Special orders

Provision has been made in the computer for responding to special orders to rearrange the component circuits of the computer. These special orders cause various functions to be performed by the computer and in addition cause certain apparatus to be switched in or out of use, to be interchanged or to be restored to a predetermined condition. In the exemplary embodiment set forth herein provision has been made for recognizing and responding to fifteen separate and distinct special orders. It is to be understood, of course, that any number of special orders may be provided as may be required in a particular computer or as may be required to solve any specified type of problem.

By way of example, the special orders provided in the exemplary embodiment of the invention set forth herein comprise orders 00 through 14 as follows:

Special Order Number	Remarks
00	This order is used to condition the circuits and apparatus of the computer for single tape operation. This type of operation is used when the needs of the problem require only one storage tape.
01	This order is used to condition the computer for solving problems requiring storage in both the A and B storage tapes.
02	This order is employed to reverse the reading and hunting functions between the A and B tapes. This order is useful in two-tape operation since by its use the formulae which are designed to employ one or the other of the tapes for a given function may be employed in combination with the other tape for the same function.
03	This order reverses the perforating in the A and B tapes. The order 01 must be in effect before orders 02 and 03 can be called for. To restore the circuits to their normal condition and thus cancel the reverse perforations in the tapes, order 01 is employed.
04	This order is employed to direct the control circuits on a signal to return to a higher level from the A formula level to read the next order on the problem tape.
05	This order conditions the computer so that upon a return to a higher level signal from a formula of the A level the control circuits consider the problem to be ended and cause all the registers in the calculator and formula to be cleared and restored to normal and the A tape reset to a predetermined position which is usually its initial condition. In response to this order the computer will then advance to the next order from the problem tape.
06	This order is employed to shut down the computer and performs the same function as the release keys provided for the operating or service station of the computer.
07	This order is employed to reset tape A to fresh tape so that the tape storage apparatus will be in condition to record additional information.
08	This order is employed to reset tape B to fresh tape.
09	This order is employed to clear all of the storage registers A to L, inclusive.
10	This order is employed to disconnect the tape C transmitter from the problem control circuit and connect the regular problem tape transmitter thereto.
11	This order is employed to disconnect the problem tape transmitter from the problem control circuit and connect the tape C transmitter thereto.
12	This order is employed to disconnect the C tape transmitter from the storage tape control circuit and connect the storage tape transmitter B thereto.
13	This order is employed to disconnect the storage tape transmitter B from the storage tape control circuit B and connect the tape C transmitter thereto.
14	This order is the same as order 13 except that in addition it causes the computer to disconnect the reperforating normally associated with the storage tape B and connect in its place a reperforator which is associated with tape C.

It is thus evident that these orders may be employed to arrange the circuits of the computer in different manners so that they will be more adaptable to solving different types of problems. Thus, in problems of lesser complexity the computer may be arranged to employ only one storage tape in the solution of a problem. At the same time the necessary information relative to another problem may be entered into the other storage tape from another problem tape. By thus providing this type of overlap operation the time required to solve the problem is reduced and the operating efficiency of the computer is increased.

In order to employ these special orders, it is necessary to enter the proper orders into the computer by setting up appropriate order relays of Fig. 46 in any one of the manners in which these relays may be operated such as from a problem tape, from a key-set, from any of the formulas from the formula director circuit, etc. These orders take the form of T F 0 1 $\overline{HH}$, for example.

Order T F 0 1 $\overline{HH}$

As pointed out above this order is employed to condition the circuits of the computer for two-tape operation wherein it is desired to record information to be employed in the solution of the problem in both the storage tape A and the storage tape B. The following order relays of Fig. 46 are operated in response to any of the above orders of these order relays: **46–1T**, **46–2F**, **46–3A**, **46–4B** and **46–5B**. Relay **46–1T** closes contacts **2208** which contacts partly prepare a circuit for the operation of relay **15–OC1**. The operation of relay **46–1T** also causes contacts **1921** to close. These contacts, however, perform no useful function with respect to the order being described. The operation of relay **46–2F** causes contacts **4428** to close and complete an obvious circuit for the operation of relay **44–SO**. The operation of the special order relay **44–SO** causes contacts **2915** through **2924** and **2525** through **2934** to close and partially prepare circuits for the operation of other selecting relays as described herein. The operation of relay **46–2F** also closes contacts **1814** which contacts partly prepare other circuits described herein. The operation of relay **46–3A** causes contacts **1815** and contacts **2905** to close and partly prepare circuits for the operation of various selecting relays as described herein. The operation of relay **46–4B** causes contacts **1816** and contacts **2908** to close and partly complete circuits as will be described herein. The operation of relay **46–5D** closes contacts **4409** which complete an obvious circuit for the operation of relay **44–TR1** which relay operates and partly prepares circuits for the operation of the selecting relays as described herein. The operation of relay **46–5D** also closes contacts **1914**. These contacts, however, perform no useful function in response to the orders selecting the special order relay **01**.

The entry of the complete order on the order relays of Fig. 46 as described herein causes the operation of relay **45–5UP** as well as other of the control relays and the operation of relay **45–5UP** causes the operation of relay **15–5UP** over circuits traced herein. The operation of relay **15–5UP** connects ground to numerous locking contacts of the routine control circuits and also closes contacts **1801**. Contacts **1801** apply ground through the break contacts **1805** to lead **1803**, G5, but since relay **46–5D** has no contacts connected to this lead, the application of ground to this lead produces no useful results at this time. The operation of contacts **1801** of relay **15–5UP** also applies ground to the G2 lead, **1801**, but since the contacts of relay **46–2F** are not connected to this lead the application of ground thereto by the operation of contacts **1801** produces no useful results at the present time. The operation of contacts **1801** together with the operation of contacts **1817** of relay **44–SO** connect ground to the G4 lead for the operation of one of the special order relays as will be described herein. The operation of relay **15–5UP** also closes contacts **1913** which contacts connect a common terminal of the windings of relays **19–DC3** and **19–DC3A** to a down-check circuit extending through break contacts on each of the A and B relays of the storage registers of the computer. If these registers are normal, a down-check circuit is completed which causes the operation of relay **19–DC3**. Relay **19–DC3** closes the locking contact **1904** for maintaining itself

operated under control of contacts **1901** of relay **15–5UP**. Relay **19–DC3A** does not operate at this time because ground is connected to both of its winding terminals. The operation of relay **19–DC3** closes contacts **1901** which contacts apply ground to the G1 lead, **1930**. The application of ground to the G1 lead completes a circuit for the operation of relay **15–OC1** which circuit extends from battery through the winding of relay **15–OC1** over the 1T conductor extending through Figs. 15, 16, 17, 20, 21 and 22, the operated contacts **2207** of relay **44–TR1**, the operated contacts **2208** of relay **46–1T** to ground connected to the G1 lead through the break contacts **1901** and **1902** and the operated contacts **1901** of relay **19–DC3**, the G1 lead extending from Fig. 22 through Figs 21, 20 and 19 to the break contacts **1902** of relay **15–OC1**. Relay **15–OC1** operates and first closes its locking contacts **1506** maintaining itself operated under control of contacts **1502** of relay **15–5UP**.

The operation of relay **19–DC3** also closes contacts **1810** which contacts apply ground to lead G3 through the break contacts **1811**. The application of ground to lead G3 completes a circuit for the operation of relay **29–SOT0** which circuit extends from battery through the winding of relay **29–SOT0**, through contacts **1915** of relay **44–SO**, the operated contacts **2905** of relay **46–3A**, the G3 lead which extends from Fig. 29 through Figs. 14, 17, and 20 to ground through the break contacts **1811** of relay **15–OC3** and the operated contacts **1810** of relay **19–DC3**. The operation of relay **29–SOT0** closes contacts **2935** through **2944** which contacts together with the operated contacts of relay **44–SO** extend circuits for the operation of the special order relays **00** through **09** to contacts of the fourth column of relays of Fig. 46. Under the assumed conditions the closure of contacts **2936** of relay **29–SOT0** completes a circuit for the operation of relay **14–01** which circuit extends from battery through the winding of relay **14–01** and then over a conductor extending through Figs. 17, 32 through 29 and then through operated contacts **2936** of relay **29–SOT0**, contacts **2926** of relay **44–SO**, the operated contacts **2908** of relay **46–4B** to ground over the G4 lead which extends from Fig. 29 through Figs. 14, 17, 20, 19 and 16 to the break contacts **1606** of relay **19–COMP**, the break contacts **1605** of relay **15–OC4** and then through Fig. 19 and the operated contacts **1817** of relay **44–SO** to ground through the operated contacts **1801** of relay **15–5UP**. Relay **14–01** in operating closes contacts **1402** which contacts complete an obvious circuit for the operation of relay **14–01A**. Relay **14–01A** completes an obvious circuit for maintaining itself operated from battery through its winding and its operated contacts **1403**, the break contacts **1404** of relay **14–00** to ground through the operated contacts **1405** of relay **8–ST3**. The operation of relay **14–01A** closes contacts **1701** which contacts complete obvious circuits for the operation of relays **17–STR** and **17–STR1** through the break contacts **1703** of relays **14–02** and **14–03**, respectively. The operation of relays **17–STR** and **17–STR1** completes a circuit for the operation of relay **19–DCR** from battery through the winding of relay **19–DCR**, the operated contacts **1814** of relay **46–2F**, the operated contacts **1816** of relay **46–4B**, the operated contacts **1817** of relay **17–STR1** and the operated contacts **1818** of relay **17–STR**, the break contacts **1819** of relay **14–00**, the break contacts **1820** and **1821** of the respective relays **7–PFA** and **7–PFB**, contacts **1850** of relay **46–3A** to ground through the break contacts **1811** of relay **15–OC3** and the operated contacts **1811** of relay **19–DC3**.

The operation of relay **19–DCR** completes a circuit through its locking contacts **1922** and the operated contacts **1923** of relay **15–5UP**. Relay **19–DCR** also closes contacts **1557**, **1558**, **1559** and **1560** which contacts complete obvious circuits for the operation of the respective relays **15–OC2**, **15–OC3**, **15–OC4** and **15–OC5**. The operation of relay **15–OC3** interrupts the ground applied to the G3 lead through the contacts **1811**, thus interrupting the operated circuit of the above-described relays which are operated from a ground connected to the G3 lead including relay **14–01** and relay **29–SOT0**. The operation of relay **15–OC4** interrupts the ground connected to the G4 lead and thus interrupts the operating circuit of relay **14–01** which relay releases. However, relay **14–01A** remains operated as described above under control of contacts **1404** of relay **14–00** and contacts **1405** of relay **8–ST3**. Relay **14–01** in remaining operated maintains relays **17–STR** and **17–STR1** operated.

The operation of each of the relays **15–OC1**, **15–OC2**, **15–OC3**, **15–OC4** and **15–OC5** completes a series circuit through operated contacts of each of these relays and contacts **1819** of relay **15–5UP** for the operation of relay **18–CTR1**. Relay **18–CTR1** in operating interrupts the locking circuits extending through its contacts **1105**, **1116** and **4653**, thus permitting all of the order relays to release, relay **45–STP** to release which in turn permits relay **15–5UP** to release and restore the routine control circuit relays locked operated to it to normal. The release of the order relays and the control relays of Figs. 45 and 44 permits relay **18–CTR1** to release and the release of the relays in the routine control circuit to complete a down-check circuit through break contacts of these relays for the operation of relay **13–DCP** which relay then operates. Either the release of relay **18–CTR1** or the operation of relay **13–DCP** then advances the control circuits to cause another order to be entered upon the order relays as described herein. The operation of relay **14–01A** together with the operation of relays **17–STR** and **17–STR1**, **17–STR2** and **17–STR3** control switching circuits to condition the computer to respond to orders for perforating and storing material in both the A and B tapes and to respond to orders employed and information recorded in both of these tapes to control the computations necessary to solve the problem presented to the computer.

In a similar manner other orders similar to the above-described order may be entered upon the order relays of Fig. 46 and cause any one of the various order relays **14–00** through **14–14** to be operated which relays when operated condition the control circuits for the computer to accomplish the above-described functions and results.

Network problem

Assume now for purposes of illustration that it is desired to calculate the impedance of a network at a number of different frequencies. A simple network suitable for outlining the various steps in solving such a problem by means of the exemplary computer embodying the present invention described herein in detail is shown in Fig. 48. While the simple network shown in Fig. 48 has been chosen for purposes of description it is understood that any network of any degree of complexity may form the basis of a problem for solution by the computer described herein. The more complex the network the more steps are necessary to determine its impedance at each frequency and thus the more complex the operation of the mechanism. The network shown in Fig. 48 comprises three elementary networks all connected in series. The left-hand simple series circuit of a condenser C_1 and a resistor R_1 comprises this network. As assumed herein the resistor R_1 is assumed to have zero impedance. Consequently, it is shown only dotted. If a resistor R_1 of a predetermined value were inserted in this position the computation to determine its impedance would be substantially the same as described hereinafter. Below this elemental portion of a network the formula number D23 appears which is assumed to be the formula employed by the mechanism to compute the impedance of this portion of the network. The center portion comprises a resistor R_2 and a condenser C_2 in parallel which is designated by the formula D27. This formula is assumed to be the formula employed to calculate the impedance of such a parallel network. The final or right-hand portion

comprises a resistor R_3 and an inductance L_3. This elemental network is designated by D24 which is assumed to be the formula employed by the computer in determining the impedance of such a series circuit of an inductance and a resistor.

It is furthermore assumed that a formula numbered A37 is arranged to direct the computer to combine the impedances of three series networks to calculate the total or combined impedance of the three series elemental portions thereof.

It is further assumed that it is desired to employ both of the storage tapes in the solution of this problem. It is also assumed that it is desired to calculate the impedance of this network at a plurality of frequencies. The number of frequencies at which the impedance may be determined is determined by various parameters in the problem. For purposes of illustration it is assumed that it is desired to determine the impedance at two different frequencies f_1 and f_2. For purposes of description it is assumed that f_1 is 1,000 cycles and f_2 is 2,000 cycles. However, any suitable frequencies may be employed. Furthermore, there need be no relation whatever between the respective frequencies.

In setting up the problem, the problem tape is first prepared and this problem tape will be as follows:

Problem Tape	Remarks
Blank Tape	The blank tape is provided so that the tape may be readily and properly inserted in the transmitter.
PS PS	Problem start codes.
$\overline{\text{SWR}}$	Switches problem control circuit to routine control.
T F 01 $\overline{\text{HH}}$	Special order 02 conditions computer for two-tape operation.
T F 04 $\overline{\text{HH}}$	This order indicates a return to higher level or in the present case directs the computer to read the next order in the problem tape and thus in effect clears out the control circuits of the computer and restores them to normal.
T F 07 $\overline{\text{HH}}$	This order causes the A tape to be set to fresh tape so that it will be in condition to record signals transferred to it as will be described hereinafter.
T F 08 $\overline{\text{HH}}$	This order causes the B tape to be set for fresh tape where it is in condition to record additional information.
$\overline{\text{RC}}$	This order returns the control to the problem control circuit.
$\overline{\text{PFA}}$	This order causes the problem control circuit to switch to the control circuit perforator A.
$\overline{\text{BI BI 100 TAC TAC}}$	This records the block 100 on tape A and would be in the form BI 101 TAC TAC.
C00	This selects the formula C00 and appears in the tape in the form of a number +200+00 $\overline{\text{NC}}$.
D23	This code selects the D23 formula and is in the form of a number +323+00 $\overline{\text{NC}}$.
C_1 NC	The value of the condenser C_1 is inserted here. (The sign of the number, each denominational order of the number, the sign of the exponent, each denominational order of the exponent, and $\overline{\text{NC}}$, i. e., number check each comprise a row across the tape.)
D27	This selects the formula D27 and appears in the tape as the number +327+000 $\overline{\text{NC}}$.
R_2 NC	The value of resistor R_2 is inserted here in the tape. (Numbers recorded as in C_1 above.)
C_2 NC	The value of the capacitor C_2 is inserted in the tape. (Numbers entered in tape as in C_1 above.)
D24	The code employed to select formula D27 is employed here and comprises the number in the form +324+00 $\overline{\text{NC}}$.
R_3 NC	The value of R_3 is inserted here. (Numbers entered in tape as in C_1 above.)
L_3 NC	The value of the inductance L_3 is inserted here. (Numbers entered in tape as in C_1 above.)
$\overline{\text{BI BI 101 TAC TAC}}$	This code is similar to the one above for block 100.
$\overline{\text{RC}}$	This code is employed to return the control to the problem tape.
$\overline{\text{PFB}}$	This code is employed to switch the problem control circuits of the following information as transferred to the B tape.
$\overline{\text{BI BI 100 TAC TAC}}$	Same as above.
f_1 NC	The magnitude of the first frequency, namely, 1,000 is inserted here. (Numbers entered in tape as in C_1 above.)
f_2 NC	The value of the second frequency, namely, 2,000 is inserted here. (Numbers entered in tape as in C_1 above.)
$\overline{\text{ENC}}$	This code indicates that no further computations with different frequencies are desired.
$\overline{\text{BI BI 101 TAC TAC}}$	Same as above.
$\overline{\text{RC}}$	This code returns the control agian to the problem control circuit.
$\overline{\text{SWR}}$	This code causes the circuits of the problem control circuit to switch to the routine control circuits.
P = T S $\overline{\text{TR}}$	This is an order which causes 100 to be inserted in the A block register.
P = T T $\overline{\text{TR}}$	This order causes 100 to be inserted in the block B register.
T H T T $\overline{\text{TR}}$	This code causes the tape control circuits to search the A and B tapes for the block which is registered in the block registers A and B, respectively, namely, the tape control circuits of the tapes to the first code in the 100 block which code is C00 in the A tape and the magnitude of frequency f_1 in the B tape.
T A 34 $\overline{\text{HH}}$	This code selects the formula A34.
$\overline{\text{RC}}$	This order returns the control to the problem control circuit.
PS PS	Start of next problem.

Thereafter, the operation of the computer proceeds as described hereinafter. In order to facilitate the description of the operation and clearly indicate the various steps in solving the above problem, Fig. 49 is prepared with a group of forty-six steps shown in the left-hand column of this figure. Following this a description of the operation of some of the steps appears. The next column indicates the formula of the tape controlling or selecting the various orders. The next columns are employed to indicate the formula and the step of the formula which calls for the particular order. The next five columns indicate the five portions of the order selected by each of the codes in the problem tape or from the formulas. The next three columns indicate the page, block and number in the A tape. The next three columns indicate the page, block and number in the B tape. The next twelve columns indicate the values stored in the various storage registers A to L. The next column indicates the information stored in the X register of the calculator section. The next three columns indicate the page, block and data to be perforated in the A tape. The next three columns indicate the page, block and data to be perforated in the B tape. The final column indicates the information to be printed under control of the computer. The first step shown in this figure is the final $\overline{\text{SWR}}$ code described above for switching the problem control tape to the routine control circuits. The next order in the problem control tape is P = T S $\overline{\text{TR}}$. As pointed out above this order causes 100 to be inserted in the A block register. Upon the next step the problem tape has the order

$$\text{P} = \text{T T } \overline{\text{TR}}$$

as shown in line 3 in Fig. 47 which causes 100 to be inserted in the B block register. In step 4 the order T H T T $\overline{\text{TR}}$ causes the B tape control circuits to hunt for the block 100 in the B tape with the result that the frequency f_1 is placed in position to be read by the tape and transferred to the B tape register. In line 5 the order T A 34 $\overline{\text{HH}}$ from the problem tape selects the formula A34 as shown in line 6. The first step of this formula A34 comprises the order N × R A $\overline{\text{HH}}$. Thus, the frequency f_1, i. e., 1,000 read from the B tape is multiplied by 2π with the result stored in the A register, as shown in the A storage register column for line 8. The second step of the A34 formula or the seventh line of Fig. 49 causes one to be divided by the quantity stored in the A register and the result stored

in the B register. Inasmuch as $2\pi f$ is frequency designated ω, it is shown as

$$\frac{1}{\omega_1}$$

in the B storage register. The next order circuits

$$\frac{1}{\omega_1}$$

from zero clears the B register and stores the result in the B register so that the B register now has stored in it

$$-\frac{1}{\omega_1}$$

The fourth step of the A34 formula shown in line 9 of Fig. 49 causes the A tape control circuit to search the A tape for block 100 as indicated in the A block register and as a result transfers the number representing the C00 formula to the A tape register as shown in the third column of the A tape in line 9 of Fig. 49.

The fifth step of the A34 formula shown in line 10 of Fig. 49 sets up the order M E A T $\overline{\text{CH}}$. This order causes the circuits to return the number in the A storage tape register as a formula number C00. As a result, the operation of the A34 formula is suspended after the fifth step of this formula and formula C00 set into operation. In addition, the A tape storage register is cleared of the number representing the C00 formula and the A tape automatically advanced to the next position where the number representing the formula D23 is transferred to the A tape register. The first step of the C00 formula is the same order as the step five of the A34 register with the result that the D23 formula is selected. In addition, the A tape storage register is cleared and the tape advanced where the magnitude of the value of condenser C which is the next set of perforations in the A tape is transferred to the A tape storage register.

The selection of formula D23 suspends the operation of the C00 formula after the first step. It should be noted, however, that neither the A34 formula nor the C00 formula is cancelled or released but merely operation and control from these circuits are suspended. Instead, the control is taken over by formula D23 now, step one of which causes a zero to be stored in the K register since the R_1 as pointed out above was assumed to be zero. The second step of the D23 formula causes the number in the A tape storage register which is the magnitude of condenser C_1 to be divided by

$$-\frac{1}{\omega_1}$$

and the result

$$-\frac{1}{\omega_1 C_1}$$

to be stored in the L register. This value is the value of the reactance of condenser C_1 at the frequency f_1. In addition, the A tape storage register is cleared with the result that the next stored information in the tape, namely, the number representing the formula D27 is transferred to the A storage register. Step three of the D formula shown in line 14 sets up the order returning the control to the next higher level, thus indicating that all of the steps of the D formula, namely, three, have been satisfactorily performed whereupon the control of the computing operations is returned to the C00 formula of step two as shown in line 15. Inasmuch as R_1 is zero, step two of the C00 formula causes the zero from the K storage register to be transferred to the C storage register and the K storage register cleared. Step four of formula C00 sets up the order to read the number in the A tape storage register as a formula which is formula D27 as described herein. The A tape register is also cleared with the result that the next information stored in the A tape register is transferred to the A tape storage register, namely, the magnitude of R_2.

In other words, the formula D23 was employed to calculate the resistance and the reactance of the first elemental portion of the network, namely, the condenser C_1 in series with resistance R_1 which resistance is zero. The results of these computations are stored in the C storage registers and the B storage registers, respectively, under control of steps two and three of the C00 formula. On step four of the C00 formula the D27 formula is selected which is employed to compute the resistance and reactance components of the impedance of the center section of the network comprising resistor R_2 in parallel with condenser C_2. Inasmuch as this network is a parallel network it is necessary to combine the conductance of both branches and the susceptance of both branches rather than the resistance and the reactance. Consequently, it is necessary to calculate first the conductance and then the susceptance of this network. In order to accomplish this formula D27 together with the complex number formula D21 are employed as will now be described. The first step of the D27 formula shown in line 18 of Fig. 49 sets up an order which causes one to be divided by the number in the A tape storage register, namely, the magnitude of resistor R_2 and the result stored in register G which result comprises the conductance of the resistor branch of the network. In addition, the A tape storage register is cleared with the result that the magnitude of condenser C_2 is then transferred to the A tape storage register as indicated in the third column of the A tape for line 18. The second step of the D27 formula computes the susceptance of the condenser branch C_2 of the center network by multiplying ω_1 obtained from the A storage register by the magnitude of C_2 obtained from the A tape storage register and the result is stored in the H storage register. In addition, the A tape register is cleared with the result that the tape advances and the number representing the formula D24 is transferred to the A tape storage register. The third step of formula D27 sets up an order for selecting formula D21. As a result, the selection of formula D27 is cancelled so that the remaining steps of this formula are not performed. Instead, formula D21 is employed to control the further steps of the computation and this formula is a complex number formula which is employed to obtain the equivalent resistance and reactance of the parallel network in accordance with the well-known formulas of conversion from conductance and susceptance to resistance and reactance. In other words, the equivalent resistance

$$R'_2=\frac{G}{G^2+H^2}$$

wherein the designation of the registers in which the various quantities are stored is employed to represent these quantities. Thus, G represents the conductance and H the susceptance. Likewise, the equivalent reactance of the center network

$$X'_2=\frac{-H}{G^2+H^2}$$

In calculating these values the first step of formula D21 of line 21 of Fig. 29 multiplies $G\times G$ and stores the result G^2 in the L register. The second step of the D22 formula sets up the order for multiplying $H\times H$ and stores the result H^2 in the X register of the com-

puter. The third step of the D21 formula adds G^2 to H^2, clears the L register and stores the results of G^2+H^2 in the L register. The fourth step of this register causes the computer to divide G by G^2+H^2, thus obtaining R'_2. In addition, the G register is squared. The fifth step of the D21 formula shown in line 25 causes the computer to divide H by G^2+H^2 and the sixth step causes the computer to subtract the result from zero thus obtaining

$$\frac{-H}{G^2+H^2}=X'_2$$

In addition, the H register is cleared at this time. The seventh step of the D21 formula shown in line 27 sets up the formula for returning the control to a higher level since all of the steps of the D21 formula have been prepared and the equivalent resistance and reactance of the center section of the network thus obtained. Consequently, the D21 formula is released and the control of the computer returned to step five of formula C00. Step five causes the resistance of the first section, namely, zero to be added to the equivalent resistance R'_2 of the second section and the result stored in the C register after the previously stored value of zero for R_1 is cleared from this register. The sixth step of the D21 formula causes the reactance X_1 of the first section of the network to be added to the equivalent reactance computed for the second section of the network and the result stored in the D register after the reactance of the first section has been cleared from the D register. Upon the seventh step of the C000 formula an order is set up which causes the computer to read the number in the A register as a formula which is formula D24.

Formula D21 is employed to compute the resistance and reactance components of the impedance of the third section of the network and comprises resistance R_3 and inductance L_3. The first step of this formula sets up the order for transferring the magnitude of the resistance from the A tape storage register to the K register and clears the A tape storage register with the result that the A tape storage control circuits advance the A tape and cause the next information to be set up in the A tape storage register which is the magnitude of the inductance L_3. The second step of formula D24 computes the impedance of the inductance coil by multiplying the magnitude of this inductance obtained from the A tape register by ω_1 obtained from the A storage register and stores the resulting impedance X_3 in the L storage register. The third step of formula D24 sets up the order for restoring the control to the next higher level of the formula which will be the eighth step of formula C00. Consequently, the control is now returned to the eighth step of formula C00 which sets up the order for adding together the resistance component of the first two sections of the network obtained from the C storage register to the resistance R_3 of the third section, thus retaining the resistance component at the frequency f_1 of the combined network. The value of this component is stored in the K register after the value R_3 has been cleared therefrom.

The ninth step of formula C00 shown in line 35 causes the reactance component of the inductance L_3 to be added to the reactance component of the other two sections of the network which were previously computed and stored in register D. The result is stored in register L after the magnitude of X_3 previously stored in this register has been cleared therefrom.

The tenth step of the C00 formula causes the control of the computer to be returned to the next higher lever which is the sixth step of the formula A34. The sixth step of the A34 formula causes the computer to print the frequency f_1 obtained from the B tape storage register and clear the B tape storage register with the result that the B storage tape control circuits cause the B tape to advance the transfer of the next number to the B tape storage register which number is the second frequency f_2, i. e., 2,000. The seventh step of the A formula causes the computer to print the resistance component of the impedance of the network at frequency f_1 and to clear the K register of this value. The eighth step of the formula causes the printer to print the reactive component of the impedance of the network at frequency f_1 and clears the storage register L_2 when this information was previously stored. The ninth step of the A formula causes the printer control circuits to transmit a calculation read and line feed code to the printer so that it will be in position to record the next values of the network obtained for another frequency in the manner similar to that described above.

The tenth and last step of the A34 formula again selects the A34 formula and the operation of the computer repeated as described above beginning with line 6 of Fig. 49. At this time the computations will be for frequency f_2 instead of frequency f_1.

Any number of repetitions of the above steps will be repeated by the computer, one for each additional frequency stored in the B block of the B tape in a manner substantially the same as described above with respect to frequency f_1. When the computer has computed the impedance of the network for the last frequency, the $\overline{\text{ENC}}$ code will be transferred to the B tape storage register which code returns the control of the computer to the storage tape which tape then has the special order T F 0 6 $\overline{\text{HH}}$ perforated in it which code will either advance the computer to the next problem or shut the computer down until another problem is inserted in the computer.

It is thus apparent that even in the case of an extremely simple network such as shown in Fig. 48, it is only necessary to perforate in the problem tape some thirty-four different orders and values of constants and arguments in order for the computer to progress through more than seventh steps. Without the formula and the progressive control between them provided by this computer it would be necessary for the problem program tape to include all of this material. Furthermore, for each additional frequency, it is only necessary to supply one additional perforation in the problem tape or in the B tape whereupon some thirty-five steps are automatically repeated. Thus, for each additional parameter or frequency at which the impedance of the network is desired, it is only necessary to supply one additional number in the problem tape or in the B storage tape and the computer will execute some additional thirty-five steps. Without such list of formula to employ, each one of these additional steps would have to be individually stored in the problem or arguments tape of the computer.

Considered from another standpoint the saving in programming effort is even greater if, instead of supplying all of the order and programming information together with all of the numerical information in the problem tape in the manner described above, only the programming material is supplied in the problem tape and the other material manually inserted in the A tape transmitter and the B tape transmitter instead of being transferred from the problem tape to these tapes.

High degree polynomial equation problems

A typical method of programming of an exemplary computer in accordance with this invention for the solution of problems involving high degree polynomial equations will next be illustrated. The solution of the network problem described above and the solution of a high degree polynomial equation in the following description are for the purpose of illustration. These solutions are included to illustrate the great saving in programming time and effort in a computer in accordance with the present invention. It is to be understood, of course, that many other complex

and complicated problems may likewise be readily programmed by employing the various formula incorporated in the computer and readily selected by means of the various orders such as described herein.

One method of solution of polynomial equations of a high degree which has been suitable for use with a computer in accordance with this invention has been attributed to Bairstow. (See T. C. Fry, Quarterly of Applied Mathematics, vol. 3, No. 2, page 89, July 1945.) In this method a trial factor is assumed and then modified repeatedly until it satisfies the given equation to the desired degree of accuracy. Assume, for example, the polynomial of degree n as follows:

$$f(x)=x^n+a_1x^{n-1}+a_2x^{n-2}+ \ . \ . \ . \qquad (1)$$

In solving this equation a trial factor is assumed which trial factor is in the form of a quadratic which is divided into Equation 1 and at least two coefficients are examined. If the assumed factor is a true factor the last two coefficients r_1 and r_0 which are indicated as R and T on the following sheets are prepared for and by the computer. The assumed trial factor is in the form:

$$x^2+C_1x+D_1 \qquad (2)$$

When the original equation is divided the quotient is obtained as follows:

$$\frac{f(x)}{x^2+C_1x+D_1}=Q_1(x)+r_1x+r_0 \qquad (3)$$

If r_1 and r_0 are not zero or sufficiently close to zero, then the quotient Q_1 is again divided by the trial factor as follows:

$$\frac{Q_1(x)}{x^2+C_1x+D_1}=Q_2(x)+r_3x+r_2 \qquad (4)$$

The two quotients $Q_1(x)$ and $Q_2(x)$ are, of course, polynomials of degree $n-2$ and $n-4$, respectively. A new trial factor is now determined from the following expressions:

$$C_2=C_1+\frac{r_0r_3-r_1r_2}{D} \qquad (5)$$

$$D_2=D_1+\frac{r_0(C_1r_3-r_2)-D_1r_1r_3}{D} \qquad (6)$$

$$D=r_2(C_1r_3-r_2)-D_1r_32 \qquad (7)$$

The new trial factor in the form of

$$x^2+C_2x+D_2 \qquad (8)$$

is now employed as above and the above process repeated until the r_1 and r_0 are made sufficiently small for the accuracy required. The computer may be arranged to automatically determine when and if the coefficients r_1 and r_0 are sufficiently small and when they have been reduced to a sufficiently small value the computer may then be arranged to compute and then type the coefficients of the quotient or reduced equation which will then be a polynomial of degree $n-2$. As pointed out above the quotient is in the form:

$$Q_1(x)=x^{n-2}+q_1x^{n-3}+ \ . \ . \ . \ q_{n-2} \qquad (9)$$

The coefficients of the various terms may be found from the recursion formula:

$$q_r=(a_r-q_{r-2}D)-q_{r-1}C \qquad (10)$$

Thereafter, the computer will assume any desired trial factor and proceed as above and reduce the order by two degrees again. This process may be repeated until each quadratic factor is obtained. In each case the various steps may be printed and the coefficients of the reduced equation printed by the machine. Furthermore, if, as sometimes happens, the assumed trial factor is too far away from a real factor the coefficients r_1 and r_2 may not be reduced to zero after a reasonable number of operations of the machine. The computer is arranged so that it may count the number of trials and if the number exceeds a predetermined number without reducing the coefficients r_1 and r_0 to below the necessary value, then the computer may be arranged to interrupt the operations as described above and try a second trial factor. If desired, any number of possible trial numbers may be supplied to the machine and the computer will try one after another in the order supplied or directed in an effort to arrive at a satisfactory solution. If it is impossible to obtain a satisfactory solution with the number of trial factors entered in the machine it will thereupon stop and pass on to the next problem. Nevertheless, the computer has printed a record of each of the trials so that this information may be readily available for use in attempting to discover a more satisfactory trial factor.

The programming information entered into the problem tape which is inserted in one of the stations in order to solve a typical polynomial of high degree in the above manner is as follows where $n=8$:

Problem Tape	Remarks
PS	Problem start code.
SWR	
TFAB HH	Starting orders.
TFAE HH	
TFAH HH	Reset orders for storage tapes A and B.
TFAI HH	
RC	Printing instructions.
L-3 Repeater:	
8th Degree equation Factor Remainder	
X^2+CX+D $RX+T$	
O D R T	
RC	
PFB	Perforate on storage tape B.
BI BI 000 TAC TAC	Block 000.
+9931193186+00 NC	Coefficients of equation. (Tape printer omits decimal points.) (Each character or denominational order requires a line or row across the tape.)
+5963252620+00 NC	
+2835304483+00 NC	
+1182208772+00 NC	
+4547758130−01 NC	
+1660869330−01 NC	
+5874589900−02 NC	
+2035376500−02 NC	
ENC	End of numbers check.
BI BI 100 TAC TAC	Block 100.
ENC	
RC	
PFA	Perforate on storage tape A.
BI BI 000 TAC TAC	
+100−15 NC	
+100−18 NC	E^2 (limit on square of remainder coefficients). Coefficients of 1st trial factor.
+100−18 NC	
BI BI 001 TAC TAC	
RC	
SWR	
PSTR TR	Coded orders identifying internal routine (A35) to be used.
TADF HH	
RC	
PS	Problem start code to indicate start of new problem section.
PS	
PS	
PS	
PS	

In solving the above equation and executing the orders

called for on a problem tape, the computer will print the following information. The portions in brackets have been inserted by way of explanation herein:

L-3 Repeater: 8th Degree equation
Factor X^2+CX+D — Remainder $RX+T$

C	D	R	T
+.1000000000−18	+.1000000000−18	+.5874589900−02	+.2035376500−02
+.1814495332−01	+.1225488642+00	+.2612383992−02	+.9498850060−03
−.1653298883−01	+.2573463902+00	−.3816090993−02	−.6018285770−03
−.1133757302−01	+.2177185823+00	−.7196284470−03	−.4038575800−04
−.1680174590−01	+.2073805208+00	−.3617572400−04	+.1150744300−04
−.1814774568−01	+.2070472999+00	+.1700206000−06	+.9581900000−07
−.1815173757−01	+.2070513326+00	−.2800000000−11	−.3000000000−11

[Coefficients of reduced 6th degree equation (A_6=1.0):]

+.1011271056+01	+.4076302562+00	+.8154462604−01	+.3530066610−01
+.2923442624−01	+.9830298976−02		
+.1000000000−18	+.1000000000−18	+.2923442624−01	+.9830298976−02
+.1848806834+00	+.2784734698+00	+.5672226616−01	−.9257019994−02
+.3234915153+00	+.1776808692+00	+.2138949270 01	+.1317731058−02
+.5306231050+00	+.1855513371+00	+.8203324660−02	+.3115214911−02
+.5956442099+00	+.2492575562+00	−.1755236970−02	+.1033292480−03
+.5728750950+00	+.2377806303+00	+.9591030000−04	+.9227024100−04
+.5717745373+00	+.2382005953+00	+.4383600000−06	−.3080690000−06
+.5717877248+00	+.2382036534+00	+.7000000000−10	+.2400000000−10

[Coefficients of reduced 4th degree equation:]

+.4394833312+00	−.8186457120−01	+.2366724785−01	+.4126846424−01
+.1000000000−18	+.1000000000−18	+.2366724785−01	+.4126846424−01
−.2995357549+01	−.5041065217+00	+.3383792401+02	+.5440661927+01
−.1921927888+01	−.3292382680+00	+.9999165427+01	+.1616948745+01
−.1211353744+01	−.2090309624+00	+.2945188622+01	+.4858593575+00
−.7478678411+00	−.1197471839+00	+.8582733948+00	+.1521381152+00
−.4684609266+00	−.3617007799−01	+.2343550658+00	+.5500014192+01
−.4100827575+00	+.8911203061−01	+.2071585006−01	+.2545858182−01
−.5653110388+00	+.1800960032+00	+.1572733220−01	−.1385185800−01
−.5237997869+00	+.1633156496+00	+.2215037000−02	−.1093536450−02
−.5196693042+00	−.1623747758+00	+.2646450000−04	−.7664210000−05
−.5196375969+00	+.1623742253+00	+.1800000000−08	−.1700000000−09

[Final quadratic factor]

+.9591209281+00 +.2541564977+00

SUMMARY

Original equation:

X^8+.99311 93186X^7+.59632 52620X^6+.28353 04483X^5+.11822 08772X^4+0.04547
75813X^3+.01660 86933X^2+.00587 45899X+.00203 53765 00=0

Final factors:

X^2−.01815 17375 7X+0.20705 13326
X^2+.57178 77248X+0.23820 36534
X^2−.51963 75969X+0.16237 42253
X^2+.95912 09281X+0.25415 64977

Sum of C's=.99311 93184 Product of d's=.00203 5376507
A_1=.99311 93186 A_8=.00203 5376500

The corresponding orders entered into the computer during typical sequences of the computer mechanism solving the above equation are shown in Figs. 50 and 51. As indicated in Fig. 50 in solving this problem use is made of a C tape to control a computer for a number of steps. As indicated in Fig. 51 twenty steps are employed in the C tape. This is the same number as the maximum possible number of steps for some of the A formula. Thus, this routine could be wired into the computer as one of the A formulas. However, the solution of this type of problem is required only infrequently. It is uneconomical to so wire it into the formula and order circuits. Instead, a tape in accordance with this particular program is prepared and then manually inserted in the C tape transmitter. Of course, when desired the computer circuits may be all controlled from the problem tape in which case this formula would be inserted in the problem tape together with the necessary control signals to cause it to be perforated in the C tape after which the additional control signals would be perforated in the tape to cause the control of the computer to be controlled from the C tape as shown herein. As shown in line 2 of Fig. 50 the computer is arranged to be set up for C tape operation by the formula A35. This formula comprises the following steps:

1. T F 10 $\overline{HH}$
2. T F 13 $\overline{HH}$
3. R H TT $\overline{TR}$
4. T F 12 $\overline{HH}$
5. T F 11 $\overline{HH}$
6. T G TT $\overline{HH}$

The computer executes six of these steps between lines 3 and 3.

In solving the problem the computer has been arranged to not compare r_1 and r_0 with zero but rather to compute the quantity $r_1^2+r_0^2$ and compare this quantity with the quantity designated E^2 in the tape and entered into the L storage register in line 7 of Fig. 50.

With the above equations together with reference to the code chart for the various components of the orders shown in Fig. 47 the operation of the computer in solving the above equations may be readily followed.

In following through the various steps in solving the assumed equation the computer will record on a printing mechanism the following information down as far as summary. However, the portions enclosed in brackets are not printed by the computer but have been inserted to identify certain of the information printed by the computer as an aid in understanding the operation of the mechanism.

Of course, if desired the information recorded in the C tape may have been initially recorded in the problem tape and then the problem tape employed to control the complete solution of the problem. However, if it had been desired to start over and assume any trial factor or start over for any other reason the use of this C tape would simplify the programming of the computer because the C tape can be switched to the problem tape control circuit and then restored to its initial position under control of the page and block registers associated with the B storage tape control circuits as shown herein. Thereafter, the routine called for by the C tape would be readily repeated to perform another computation. It is to be noted that it required seven trials before a satisfactory trial factor was obtained which was sufficiently accurate to set the accuracy required. It required eight trials to obtain the second trial factor and eleven trials

to obtain the third trial factor which left the final quadratic coefficients.

It should also be noted that the programming method for the solution of polynomials of high degree is limited to even odd polynomials. However, this limitation may be readily overcome by multiplying the equation by the variable when the equation is odd in which case one of the roots of the modified equation will be zero. However, the method may be employed to determine all of the other roots.

It should also be noted that the above-described method is available for determining pairs of so-called imaginary roots when the roots of each of the quadratic trial factors is imaginary.

Printer control circuit and printer register

A printer register and printer control circuits such as shown in Figs. 1 and 2 in Figs. 64 through 72 are provided for controlling the printer. This printer control circuit is provided first for controlling the transfer of information from a problem tape to a printer which information will include the problem heading, heading of columns to be filled in by the printer and other information desired to be recorded by the printer along with the results of the computations performed by the computer. The printer control circuit is also provided to control the entering of orders and arguments and other data required for computation in either or both of the storage tapes provided. The printer control circuit is also employed to enter information from a problem tape into the routine control or C tape when desired.

In addition the printer control circuit is provided to receive information from a printer register and then convey this information either to the printer or to any of the specified storage tapes. As described herein, the results of the computations are transferred to the printer register which results are in the form of a biquinary code employed by the computer mechanism and conveyed over the X multiple to the printer register. Data stored in other registers may also be transferred to the printer register over the X multiple in the manner similar to that described above for conveying or transmitting numbers over either the X or the Y multiple. When a number is entered into the printer register over the X multiple the printer control circuit is set into operation and by means of translating and steering circuits translates the information stored in the printer register from the binquinary code into the code employed to operate the printing mechanism. This translation takes place for each denominational order of the number entered in the printer register and the translation for each of the orders is made in sequence. After the translation is made the information is transmitted to the printer which thereupon prints the result. The steering circuit receives the information from the register denominational order by denominational order and transmits it to the translating circuits for thus printing all of the information out of the printer register. As the information recorded in the printer register is printed the register is cleared. If it is attempated to employ the register by the computer mechanism prior to clearing out of the information stored therein by printing as described above, the computer circuit is required to wait until all of the information in the printer register has been utilized to control the printing and the printing of the information actually accomplished. After this time the next number may be entered in the printer register by the computing mechanism and the above cycle repeated.

Provisions are also made for conveying the translating information from the printer register to either or any of the storage tapes A, B or C for recording in these tapes under control of the orders which direct the numbers or information to the printer register.

The printer control circuit includes circuit and apparatus to recognize the various codes and switching symbols and to translate and print them in the printer as shown in the following table:

Symbol	Meaning	Printed Record*
PS	Problem Start	P.
SWP	Switch to Printer	Print all data recorded on tape following SWP symbol without further translation.
SWR	Switch to Routine	LTRS-CR-LF-S-R-CR-LF.
PFA	Perforate on A	LTRS-CR-LF-P-A-CR-LF.
PFB	Perforate on B	LTRS-CR-LF-P-B-CR-LF.
PI	Page Identification	LTRS-P-FIGS.
BI	Block Identification	LTRS-B-FIGS.
TAC	Tape Argument Check.	LTRS-T-CR-LF-FIGS.
NC	Number Check	CR-LF.
SLACK	Slack	CR-LF.
RC	Restore Control	LTRS-CR-LF-R-C-CR-LF.
CP	Compare	LTRS-SPA-C-R-CR-LF.
TR	Transfer	LTRS-SPA-T-R-CR-LF.
HH	Hold Hold	LTRS-SPA-H-H-CR-LF.
CH	Clear Hold	LTRS-SPA-C-H-CR-LF.
HC	Hold Clear	LTRS-SPA-H-C-CR-LF.
CC	Clear Clear	LTRS-SPA-C-C-CR-LF.
ENC	End of Numbers Check.	LTRS-E-N-C-CR-LF.
ERASE	Erase	None—By-Pass.
ET	End of Tape	T.
RST	Reset Storage Tape	R.

*Meaning of notation:
FIGS.—Figures shift.
LTRS—Letters shift.
CR—Carriage return.
LF—Line feed.
SPA—Space.
All other notation other than "-" notation is actually as shown.

Step by step operation

Provision has been made to operate the computer step by step under manual control so that the operation of the various steps may be controlled manually to observe the operation of the circuits and equipment in performing each of the steps. This arrangement is provided to facilitate the finding of troubles and maintenance of the computer circuits and apparatus. The lower portion of Fig. 13 discloses a number of keys and relays which are actuated in the routine control circuit to stop the operation of the computer after each of the steps and also for advancing it one more step by the actuation of an advance key. Similarly, keys **5B–10** and **5B–11** are provided for controlling the advance of the problem control circuit. In this case, the relay **5B–11** is operated and maintained operated and key **5B–10** is operated each time to advance the problem control circuit one step. These keys control relays and circuits through which the various relays of the computer are operated as described herein. Upon interrupting these circuits the various relays cannot operate so that it is necessary to operate the advance key each time it is desired to advance the control circuits of the computer one step.

Alarm lamp and miscellaneous circuits

In addition to the foregoing circuits described herein a group of alarm lamp and miscellaneous circuits is provided. The lamp circuits are arranged so that when desired the numerous lamps will be lighted to indicate the progress and condition of the various circuits and equipment. These lamps aid in the maintenance of the computer and in locating the operating troubles or other difficulties. A group of time-out circuits is provided the operation of which is initiated by various stages of the computer and if the computer function has not been completed within the time delay interval of the time-out circuit, then an alarm is actuated and the computer stopped. As shown in the drawing and described herein there are numerous contacts in the control circuits of the computer controlled by alarm circuit relays which relays are employed to stop the operation of the computer under trouble conditions. In addition the time-out and alarm circuits include other provisions for first timing out if the computer does not complete the execution of the problem at the desired time and then recycling the computer to attempt to perform the function or operation the second

time. If the computer is unsuccessful the second time, then the computer times out permanently and is either shut down or advanced to the next problem.

Typical alarm circuits of the type which will cause certain control circuits to be interrupted and then later reclosed are shown and described in United States Patent 1,623,777, granted to Carpenter April 5, 1927, and in British Patent 530,085, complete specification accepted December 4, 1940. While the alarm circuits employed herein are not identical with those shown in the above-identified patents the alarm circuits are similar in that a given trouble condition may cause them to time out twice with an attempt to perform the given condition a second time.

What is claimed is:

1. In a computer, multidigit registers, a source of multidigit values, a calculator, trunks accessible to said registers and to said source of values and to said calculator, a control circuit for selectively causing said calculator to perform the mathematical operation of addition, subtraction, multiplication and division with two values or to extract the square root of one value, directing means responsive to order signals representing orders to actuate said control circuit to order a calculation, said order comprising selected signals of a first group of directing signals to transmit values from specific registers or said source of values over said trunks, selected signals of a second group of directing signals to perform one of said mathematical operations thereon and selected signals of a group of a third group of directing signals to transfer the result over one of said trunks to a specific one of said registers, a plurality of signal responsive devices, each device being responsive to selected signals of said groups of directing signals, a transformer individual to each of said devices having primary circuits consisting of conductors interlinked with the magnetic circuit thereof which conductor interlinks the magnetic circuit of one device selected by the selected signals of each of said groups of signals, means for energizing said conductors for substantially simultaneously energizing the devices having transformers interlinked by said conductor and an electronic tube individual to each of said transformers actuated from said transformers.

2. In a computer, multidigit registers, a plurality of sources of multidigit values, a calculator, trunks accessible to said registers, and to said sources of values and to said calculator, a control circuit for selectively causing said calculator to perform the mathematical operations of addition, subtraction, multiplication and division with two values or to extract the square root of one value, control means responsive to order signals representing an order to control a calculation, said order comprising selected signals of a group of control signals to control transmission of values from specific registers or sources of values over said trunks, selected signals of a second group of control signals to selectively initiate one of said mathematical operations thereon and selected signals of a third group of control signals to control the transfer the result over one of said trunks to a specific one of said registers, means for selecting a given one of a plurality of predetermined orders, and means including a plurality of transformers, a single conductor selectively threaded through the magnetic structure of a plurality of said transformers and an electronic tube interconnected with each of said transformers and responsive to a pulse transmitted over said single conductor for simultaneously actuating one of said tubes in response to the selected signals of each of said groups of control signals.

3. In a digital computer, a source of multidigit values, a calculator section, a control section, sources of groups of orders to control said control section including a plurality of gaseous conduction tubes, an input coil individual to each of said tubes, a plurality of single conductors each electromagnetically interlinking groups of said input coils, apparatus responsive to orders of one of said groups of orders for obtaining values from said source of values, means responsive to each of a plurality of said orders for conveying said values to said calculator section including means for applying discharge initiating conditions to selected ones of said single conductors for simultaneously initiating a discharge through a group of said tubes, apparatus including said control section for selecting a group of said orders and other means responsive to one of the orders of said selected group of orders for reselecting said group of orders.

4. In a digital computer, a source of multidigit values, a calculator section, a control section, means for generating a plurality of groups of orders in sequence to control said control section including a plurality of gaseous conduction tubes, an input coil individual to each of said tubes and a single conductor electromagnetically interlinking groups of said input coils, means for selecting one group of said orders apparatus responsive to one or more orders of said group of orders for obtaining values from said source of values, interconnecting means connected to said control section conveying said values of said calculator section including means for applying discharge initiating conditions to selected ones of said single conductors for simultaneously initiating a discharge through a group of said tubes, other means responsive to one of the orders of said selected group of orders for reselecting said group of orders, and means for selecting a different value from said source upon each reselection of said group of orders.

5. In a digital computer, a source of values, a plurality of registers, a calculator section, a control section interconnected between said source and said calculator section, means connected to said control section for generating a plurality of sequences of orders to control said control section including a plurality of gaseous conductor tubes, an input coil individual to each of said tubes and a single conductor electromagnetically interlinking groups of said input coils, means for selecting one of said sequences of orders, apparatus responsive to orders from one of said sequences of orders for obtaining values from said source of values, apparatus included in said control section and controlled by a plurality of said orders for conveying said numbers to said calculator section including means for applying discharge initiating conditions to selected ones of said single conductors for simultaneously initiating a discharge htruogh a group of said tubes, other means responsive to one of said orders for reselecting said sequence of orders, means for selecting a different value from said source upon each reselection of said group of orders, and apparatus responsive to a signal indicating exhaustion of values from said source of values for preventing the utilization of said group of orders for further computations.

6. In a digital computer in combination, a plurality of registers for storing multidigit numbers, a calculator section constructed to perform mathematical operations of addition and subtraction and multiplication and division and square root, trunks interconnecting said registers and said calculator for conveying numbers between said registers and said calculator section, a plurality of order relays for controlling the interconnections between said trunks and said registers of said calculator section, means for simultaneously entering an order upon a group of said order relays including a gas discharge tube individual to each of said order relays, an input transformer individual to each of said tubes and a conductor interlinking the coils individual to the relays of an order, means for selecting said conductor and apparatus operative incident to the selection of said conductor for applying a pulse of current to said conductor to initiate a discharge through the tubes individual to the coils with which said conductor is interlinked.

7. In a digital computer in combination, a plurality of registers for storing multidigit numbers, a calculator section constructed to perform mathematical operations of

addition and subtraction and multiplication and division and square root, trunks interconnecting said registers and said calculator for conveying numbers between said registers and said calculator section, a plurality of order relays for controlling the interconnections between said trunks and said registers of said calculator section, sources of orders each order of which comprises a series of control signals means for simultaneously entering each order of a plurality of orders upon a group of said order relays including a gas discharge tube individual to each of said order relays, an input transformer individual to each of said tubes and a separate conductor for each order of said plurality of orders interlinking the coils individual to the relays upon which the respective order is entered, means for selecting said conductor and apparatus operative incident to the selection of said conductor for applying a pulse of current to said conductor to initiate a discharge through the tubes individual to the coils with which said conductor is interlinked, a plurality of stepping circuits each for selecting one of said conductors on each step thereof to form formulas of orders.

8. In a digital computer in combination, a plurality of registers for storing multidigit numbers, sources of orders each order of which comprises a series of control signals a calculator section constructed to perform mathematical operations of addition and subtraction and multiplication and division and square root, trunks interconnecting said registers and said calculator for conveying numbers between said registers and said calculator section, a plurality of order relays for controlling the interconnections between said trunks and said registers of said calculator section, means for simultaneously entering one order of a plurality of orders upon a group of said order relays including a gas discharge tube individual to each of said order relays, an input transformer individual to each of said tubes and a conductor individual to each order of a plurality of orders interlinking the coils individual to the relays of an order, means for selecting said conductor and apparatus operative incident to the selection of said conductor for applying a pulse of current to said conductor to initiate a discharge through the tubes individual to the coils with which said conductor is interlinked, a plurality of groups of stepping circuits, each circuit which comprises means for selecting one of said conductors for entering an order upon said order relays in each position of said circuit, a control circuit extending sequentially between said groups of order circuits, apparatus responsive to an order from one of said circuits for selecting one of said formulas for controlling said order relays and apparatus responsive to the selection of said formula for releasing all previously selected formula from control of said order relays when the selected formula is in the group of formulas causing the selection or in the group of said formula circuits located subsequently in said control sequence.

9. In a digital computer in combination, a plurality of registers for storing multidigit numbers, sources of orders in which each order comprises a group of control signals a calculator section constructed to perform mathematical operations of addition and subtraction and multiplication and division and square root, trunks interconnecting said registers and said calculator for conveying numbers between said registers and said calculator section, a plurality of order relays for controlling the interconnections between said trunks and said registers of said calculator section, means for simultaneously entering each order of a plurality of orders upon a group of said order relays including a gas discharge tube individual to each of said order relays, an input transformer individual to each of said tubes and a separate conductor for each of a plurality of orders interlinking the coils individual to the relays of an order, means for selecting said conductor and apparatus operative incident to the selection of said conductor for applying a pulse of current to said conductor to initiate a discharge through the tubes individual to the coils with which said conductor is interlinked, a plurality of groups of stepping circuits, each circuit which comprises means for selecting one of said conductors for entering an order upon said order relays in each position of said circuit, a control circuit extending sequentially between said groups of order circuits, apparatus responsive to an order from one of said circuits for selecting one of said formulas and apparatus responsive to the selection of a formula in a group of said stepping circuits subsequently in said control sequence for arresting the operation of the formula circuit entering the order for selecting said other formulas.

10. In a digital computer in combination, a plurality of registers for storing numbers, a calculator section constructed to perform the mathematical operations of addition and subtraction and multiplication and division and square root, means for conveying numbers between said calculator section and said registers, control means including a plurality of order relays, a problem storage tape control device, a problem storage tape operatively inserted in said problem storage tape control device having program control information recorded therein in the form of orders, means controlled by orders entered in said problem tape in said problem storage tape control device for interconnecting said problem storage tape control device with said order relays for thereafter controlling said interconnections in accordance with other orders from said problem tape in said problem storage tape control device, a plurality of groups of formula circuits, a sequential control circuit interlinking said groups of formula circuits in a sequential manner each of said formula circuits comprising means for successively entering a plurality of orders upon said order relays for controlling said transfer of numbers between said calculator section and said registers, interconnections for connecting said problem storage tape control device at the beginning of said sequential control circuit, an additional storage tape having recorded therein sequences of control signals comprising orders of a formula, additional storage tape controlled apparatus having said additional storage tape operatively inserted therein for sequentially entering orders upon said order relays and interconnecting means for interconnecting said additional storage tape controlled apparatus in said sequential control circuit between said problem tape control device and said groups of formula circuits.

11. In a digital computer in combination, a plurality of registers for storing numbers, a calculator section constructed to perform the mathematical operations of addition and subtraction and multiplication and division and square root, means for conveying numbers between said calculator section and said registers, control means including a plurality of order relays, a problem storage tape control device, a problem storage tape operatively inserted in said problem storage tape control device having program control information recorded therein the form of orders, means controlled by orders entered in said problem tape in said problem storage tape control device for interconnecting said problem storage tape control device with said order relays for thereafter controlling said interconnections in accordance with other orders from said problem tape in said problem storage tape control device, a plurality of groups of formula circuits, a sequence control circuit interlinking said groups of formula circuits in a sequential manner, each of said formula circuits comprising means for successively entering a plurality of orders upon said order relays for controlling said transfer of numbers between said calculator section and said registers, interconnections for connecting said problem storage tape control device at the beginning of said sequence control circuit, an additional storage tape having recorded therein sequences of control signals comprising orders of a formula, additional storage tape controlled apparatus having said additional storage tape operatively inserted therein for

sequentially entering orders upon said order relays and interconnecting means for interconnecting said additional storage tape controlled apparatus in said sequence control circuit between said problem storage tape control device and said groups of formula circuits, control means responsive to an order entered upon said order relays for selecting one of said formula circuits and means responsive to the selection of said formula circuit for releasing previously selected formula circuits in said group of formula circuits and in groups of formula circuits subsequent to the group of the selected formula circuit in said sequence control circuit.

12. In a digital computer in combination, a plurality of registers for storing numbers, a calculator section constructed to perform the mathematical operations of addition and subtraction and multiplication and division and square root, means for conveying numbers between said calculator section and said registers, control means including a plurality of order relays, a problem storage tape control device, a problem storage tape operatively inserted in said problem storage tape control device having information recorded therein in the form of orders, means controlled by orders entered in said problem storage tape in said problem storage tape control device for selectively interconnecting said problem storage tape control device with said order relays for thereafter controlling said interconnections in accordance with other orders from said problem tape in said problem storage tape control device, a plurality of groups of formula circuits, a sequence control circuit interlinking said groups of formula circuits in a sequential manner each of said formula circuits comprising means for successively entering a plurality of orders upon said order relays for controlling said transfer of numbers between said calculator section and said registers, interconnections for connecting said problem storage tape control device at the beginning of said sequence control circuit, an additional storage tape having recorded therein sequences of control signals comprising orders of a formula, additional storage tape controlled apparatus having said additional storage tape operatively inserted therein for sequentially entering orders upon said order relays and interconnecting means for interconnecting said other storage tape controlled apparatus between said problem storage tape control device and said groups of formula circuits in said sequence control circuit, control means responsive to an order entered upon said order relays for selecting one of said formula circuits, means responsive to the selection of said formula circuit for releasing previously selected formula circuits in said group of formula circuits and in groups of formula circuits subsequent to the group of said selected formula circuit in said sequence control circuit, and means operative responsive to the selection of a formula circuit in a group subsequent to the group of the previously selected formula circuit in said sequence control circuit to arrest the operation of a previously selected formula circuit in the groups prior to the group of the previously selected formula circuit in said sequence control circuit.

13. In a digital computer in combination, a plurality of registers for storing numbers, a calculator section constructed to perform the mathematical operations of addition and subtraction and multiplication and division and square root, means for conveying numbers between said calculator section and said registers, control means including a plurality of order relays, a problem storage tape control device, a problem storage tape operatively inserted in said problem storage tape device having program information recorded therein in the form of orders, means controlled by orders entered in said problem storage tape in said problem storage tape control device for controlling said interconnections in accordance with other orders from said problem tape in said problem storage tape control device, a plurality of groups of formula circuits, a sequence control circuit interlinking said groups of formula circuits in a sequential manner, each of said formula circuits comprising means for successively entering a plurality of orders upon said order relays for controlling said transfer of numbers between said calculator section and said registers, interconnections for connecting said problem storage tape control device at the beginning of said sequence control circuit, an additional storage tape having recorded therein sequences of control signals comprising orders of a formula, additional storage tape controlled apparatus having said additional storage tape operatively inserted therein for sequentially entering orders upon said order relays, interconnecting means for interconnecting said other storage tape controlled apparatus between said problem storage tape control device and said groups of formula circuits for sequentially entering orders upon said order relays, control means responsive to an order entered upon said order relays for selecting one of said formula circuits, means responsive to the selection of said formula circuit for releasing previously selected formula circuits in said group of formula circuits and in groups of formula circuits subsequent to the group of said selected formula circuit in said sequence control circuit, means operative responsive to the selection of a formula circuit in a group subsequent to the group of the previously selected formula circuit in said sequence control circuit to arrest the operation of a previously selected formula circuit in said groups prior to the group of said selected formula circuit in said sequence, apparatus responsive to the completion of operation of the operation of a selected formula circuit in a group subsequent to the group of a previously selected formula circuit in said sequence control circuit for resuming operation in the formula circuit previously arrested in a group of formula circuits.

14. In a digital computer, a plurality of registers, problem tape controlled apparatus, a calculator section constructed to perform the arithmetical operations of addition and subtraction and multiplication and division and square root, interconnecting means for conveying numbers between said registers and said calculator section, a group of order relays for controlling the information conveyed between said registers and said calculator section, a storage tape controlled apparatus, and means for conveying information from said problem tape controlled apparatus to said storage tape controlled apparatus concurrently with the operation of said calculator section in combination with said registers.

15. In a digital computer in combination, a plurality of multidigit registers, a source of multidigit values, a calculator section constructed to perform the mathematical operations of addition and subtraction and multiplication and division and square root, trunks accessible to said registers and to said sources of value and to said calculator section, a control circuit for controlling the interconnection of said trunks with said calculator and with said multidigit registers and with said source of multidigit values including a plurality of order relays, means to enter orders upon said order relays, and apparatus responsive to the incomplete execution within a predetermined time interval of an order entered upon said order relays for recycling said control circuit to re-execute said order entered upon said order relays.

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