

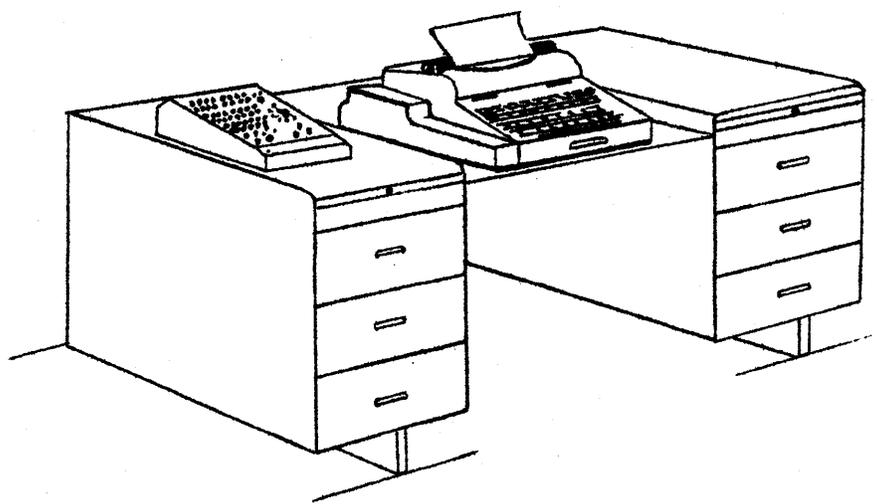
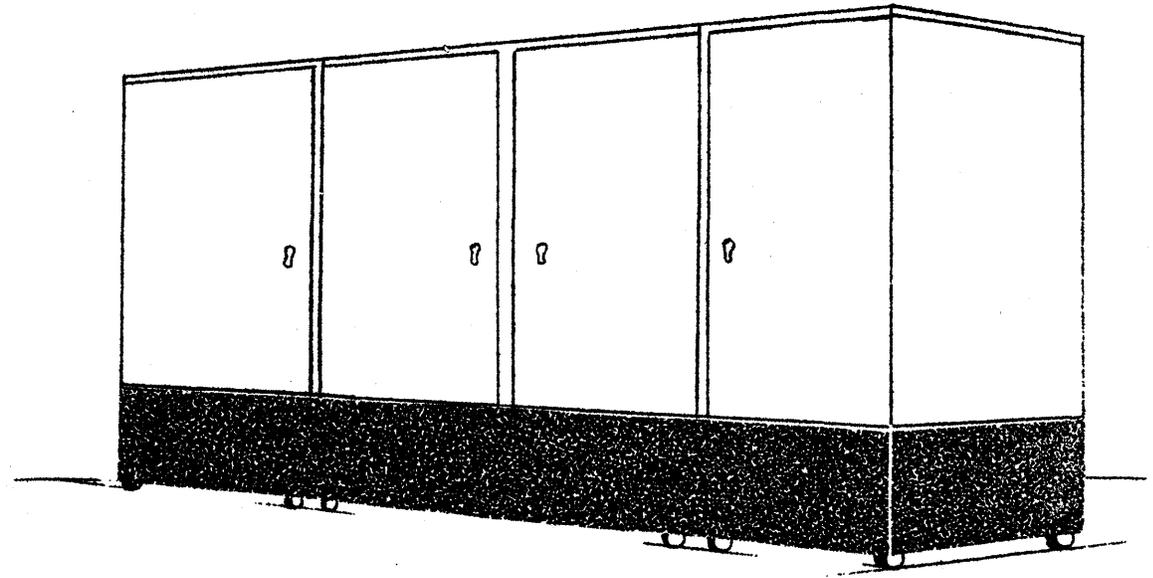
LOGISTICS RESEARCH INC.

ALWAC DIGITAL COMPUTERS
MAGNETIC LIBRARY SYSTEMS
ELECTRONIC BUSINESS MACHINES
DATA REDUCTION SYSTEMS
LOGRINC PLOTTER-FOLLOWERS

ALWAC III

ALWAC

GENERAL PURPOSE COMPUTER



LOGISTICS RESEARCH, INC.
REDONDO BEACH, CALIF.

GENERAL DESCRIPTION OF THE ALWAC III

The new model of the ALWAC, the ALWAC III, is a general purpose digital computer of the internally programmed magnetic drum type. Designed primarily for use by small commercial and technical organizations having large computation requirements, this machine is operable without specially trained computer staffs. The designers of the ALWAC present the most advanced version of a low-priced, fully automatic computer available to date.

This model incorporates all of the many advantages of our original prototype, the ALWAC I (which has operated continuously at our Redondo Beach plant since April 1953) and of our previous production model, the ALWAC II (an ALWAC II has been in operation at the David Taylor Model Basin in Washington, D. C. since February 1954). In addition, in the ALWAC III, the basic computing speed has been doubled, the number of words available in fast storage has been increased from 64 to 160, provision has been made for the convenient addition of supplementary input-output equipment, and 30 new commands have been added to facilitate operations such as floating point arithmetic, etc.

The ALWAC features a large capacity magnetic drum memory capable of permanently storing most of the standard routines that make up the major part of the computational work load of many engineering or accounting staffs. Electric typewriters with associated paper tape perforating and tape reading equipment are used as the basic input-output devices. Master programs containing numerical data to be operated on by these standard routines can be entered into the computer from the punched tape or manually via the keyboard. The final results can be printed out with form control, signs, decimal points, and alphabetical headings completely under the control of a permanently stored sequence of instructions. As many as ten electric typewriters can be attached to this machine at various remote locations and the computer will automatically scan these units for waiting problems whenever it has been cleared from a given problem.

Data reduction, trajectory studies, solutions of simultaneous equations, matrix algebra and matrix inversion, and partial differential equations are a few of the technical problems which this computer can readily handle. In commercial applications, payrolls can be automatically computed and pay checks printed; amortization schedules can be obtained in final printed form; statistical analyses, cost accounting, and production control problems can be solved; and any problems that can be expressed in numerical form can be handled in a single computer installation. A library of standard routines will be available to organizations using this computer.

The ALWAC is a serial, binary computer with automatic conversion from decimal-to-binary and binary-to-decimal during input and output accomplished by an internally programmed routine. Recirculating working channels and arithmetic registers permit high computational rates as a result of the low access time in these stores. The extensive repertoire of commands in conjunction with the simplified system of using subroutines makes it relatively simple to program new problems for the ALWAC.

MEMORY CAPACITY

The magnetic drum memory consists of a 4096 word main storage, a 128 word working storage, 4 arithmetical registers, and 32 words of fast access "special constant" storage. The words in the main storage are arranged into 128 channels containing 32 words each. Each word consists of a 32 binary bit number (equivalent to about 9.5 decimal digits) with a sign digit. A production model is also available with a 8192 word capacity. Using the principle of the "Air-Floating Head" supplementary storage systems of any size can be provided.

The ALWAC III uses standard one-address commands. Each word space in the memory is divided into two parts, and each part is capable of storing a command and its associated address. Since each command and its address occupies one half a word, there are usually two commands per word. Some commands which do not require an address can be doubled up and placed in the address portion. Thus, in some cases, it is possible to place as many as four commands in one word.

CONDENSED SUMMARY OF INSTRUCTIONS

COPY AND EXCHANGE

Twenty-one commands for various combinations of exchanging, copying, extracting between fast storage and the arithmetic registers.

TRANSFER CONTROL

Ten commands for transferring control unconditionally or dependent upon overflow, breakpoint switch settings, counting, comparison, A register negative, or A register not zero.

ARITHMETIC OPERATIONS

Fourteen commands for all combinations of addition and subtraction, double length addition and subtraction, multiplication and division both with and without addresses and with and without accumulation.

BLOCK TRANSFER

Eight commands for transferring blocks of 32 words between main memory and fast storage.

MODIFY ACCUMULATOR

Eleven commands for clearing, rounding, absolute value, change sign, complementing, regular shifts and floating point shifts.

INPUT-OUTPUT

Fourteen commands for typewriter decimal number input and output, alpha-numeric input and output, hexadecimal input and output, control of punching or typing of output, and punched card control.

SPEED OF OPERATION

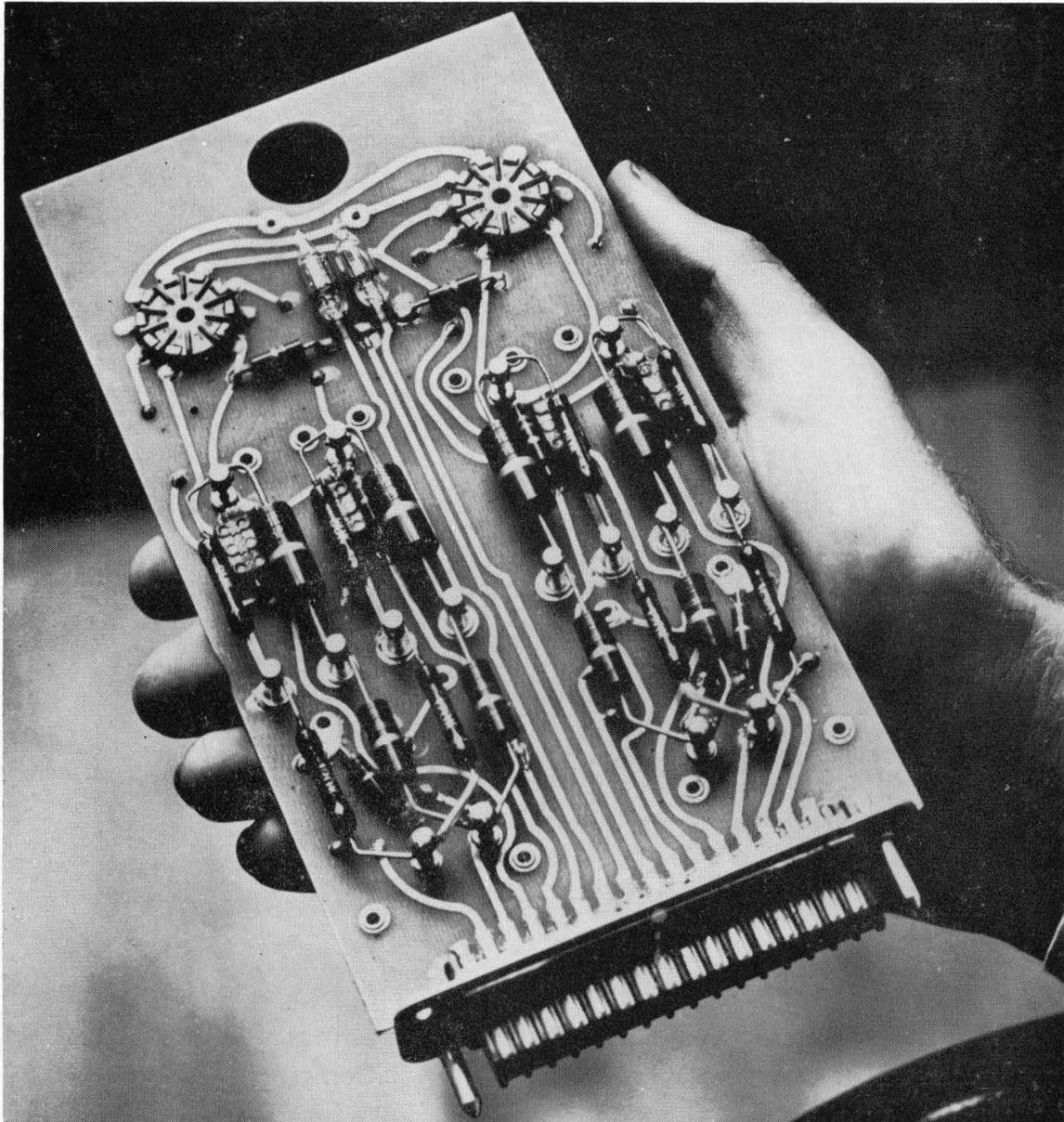
The basic time of operation for commands is one millisecond with an additional eight milliseconds if the order contains a non-optimum address. Of the 160 words of fast storage, there are always nine optimum address locations for any order position. In summarizing:

1. Multiplication or division without address or with an optimum address -- 17 milliseconds. If address is not optimum -- 25 milliseconds.
2. Input and output orders -- must wait for feedback or timing signals from input-output device.
3. Thirty-two word block transfers to and from main memory -- minimum 80 milliseconds, maximum 96 milliseconds.
4. Shift commands -- minimum 1 millisecond, maximum 17 milliseconds.
5. All other commands -- 1 millisecond or with non-optimum address -- 9 milliseconds.

RELIABILITY

The fundamental design philosophy followed in developing the ALWAC was to obtain a computer that would be entirely reliable in its operation at all times with no possibility of losing any information once it had been stored in the main memory. These aims have been accomplished by very conservative use of the operating ranges of all electrical

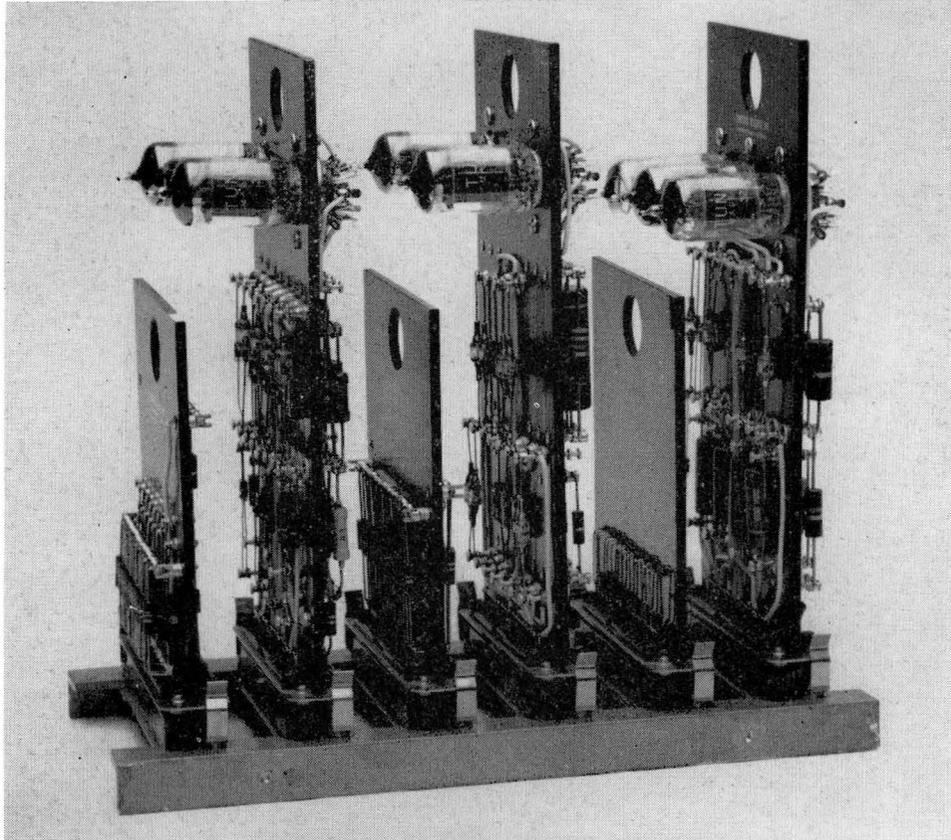
PRINTED CIRCUITS



The latest plug-in "flip-flop" showing the use of printed circuits. In keeping with the Logistics Research policy of up-to-date conservative techniques, all new developments are carefully followed and used when they have proven themselves sound and reliable.

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11542

LOGISTICS PLUG - IN COMPONENTS



The above six plug-in units represent the types most frequently used. In fact, over 90% of the components in an ALWAC Computer are of these six types. These units are, left to right, input circuit, flip-flop, resistor board, one-shot, diode board, and driver.

components, a simplified checking routine for detecting any electrical components which may become marginal, and automatic self-checking features in various critical computing sequences.

Operating with a clock pulse rate of only 67 KC and trigger voltage levels of 0 and 15, this computer uses only a small part of the rated capability of its crystal diodes and electronic tubes. As a further result of the low pulse rate, the dynamic response characteristics of the electronic circuitry is relatively non-critical; therefore, the normal drift in component characteristics will rarely affect the computing operations.

All electronic components are arranged into standardized plug-in units of limited variety to facilitate routine preventive maintenance checks and the replacement of marginal units. A test box for these plug-in units is supplied with the computer, making it entirely practical to check all electrical components in the computing circuitry in less than one hour. This test box automatically gives each plug-in a static and dynamic check of all grid and bias voltages in excess of the normal operating range.

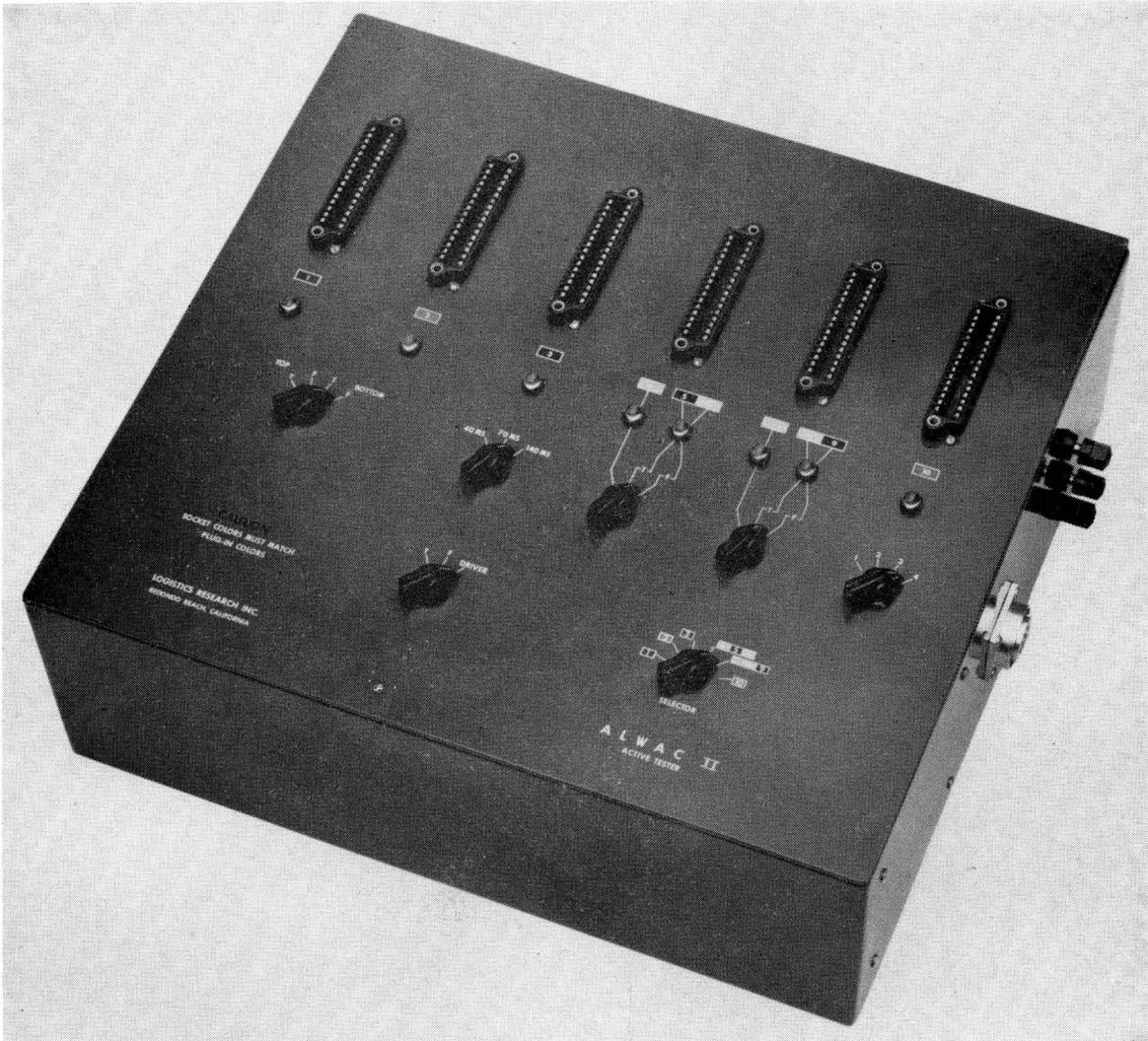
Self-checking features in the computer will detect many of the coding or machine errors that might occur, such as the unforeseen overflow of the arithmetic registers, the receipt of a non-existent order, or the attempt to copy a working channel into the wrong channel of the main memory. Any of these errors will stop the computer and an alarm will be given. Indicator lights on the display panel will then show which type of error has occurred.

INPUT-OUTPUT

Information to be stored in the main memory is normally stored first on punched paper tape by typing the numbers and code letters in the proper sequence on an electric typewriter. A visual copy may be typed at the same time, which may be immediately compared with the coding sheet for typing errors. The information is then automatically transferred to magnetic drum storage by the tape reader. Information can also be entered manually directly from the typewriter keyboard.

Numbers to be entered in the computer are normally typed on the electric typewriter in decimal form with decimal point and sign. Conversion from decimal-to-binary and binary-to-decimal during read-in and read-out is automatically performed by a subroutine at approximately the maximum rate of the electric typewriter reading and writing speed of nine characters per second.

ACTIVE TESTER FOR PLUG - IN COMPONENTS



All active plug-in components can be given very thorough static and dynamic tests by means of this component tester. This tester is used in conjunction with an oscilloscope. The patterns displayed permit the easy visual rejection of defective components. The model shown is designed for use with the ALWAC Computer and is connected by cable to the ALWAC power supply.

When a switch at the computer power supply is placed in the "test" position, power is made available to the tester and only the filament voltage is left "on" for the computer. Hence as components are checked, there is no "warm-up" period required.

11541
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DIODE TESTER



This tester is used for both input circuits and diode boards. Not only does it give a complete test of the diodes, but by means of one of the sixteen lights, an indication of the exact diode which is defective is indicated.

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Automatic graph following and graph plotting equipment can also be provided as input and output equipment for this computer. One version of the automatic graph follower will handle a function of two variables. Families of curves on a single sheet may be used and the follower will automatically switch from one curve to another in response to commands from the computer and automatically transmit the ordinate reading to the computer storage.

Punched card conversion equipment is available for direct tie-in to the ALWAC. This equipment will not only permit the use of punched cards for input-output, but will also automatically perform the decimal-to-binary and binary-to-decimal conversions, thus permitting a great increase in overall computing speed.

PHYSICAL SPECIFICATIONS

The entire computer is installed in three cabinets finished in gray and black wrinkle and mounted on ball-bearing swivel casters. The cabinet containing the magnetic drum memory is 28" deep x 34" wide x 64" high and weighs approximately 600 pounds. The cabinet containing the power supply is the same size and weighs approximately 900 pounds. The cabinet containing the logical elements of the computer is 28" deep x 53" wide x 64" high, and weighs approximately 600 pounds. The machine will operate from either a standard 110 or 220 volt, 60 cycle, single phase outlet and requires approximately 5 KW of power. The operation of internal fans provide adequate cooling of the computer at normal room temperature. An air conditioned room is not necessary, but it is recommended that the computer room have an outside exhaust fan.

WARRANTY

A one-year guarantee is given on all parts and components against failures which occur as the result of normal usage of the computer. Scheduled maintenance service is included for a period of one year and special maintenance service will be provided during this period in the event a breakdown occurs due to normal usage which cannot be corrected by a routine check of the plug-in units by the customer.

ALWAC III CONTROL PANEL



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11547

DESCRIPTION OF COMPUTER CONTROL PANEL FOR ALWAC III

In the normal operation of the computer, this panel is used for turning the computer on or off, for checking out new routines, and for preventive maintenance checks. In order to place the computer into operation, the NORMAL-TEST-CLEAR switch is placed in the CLEAR position, all other switches placed in the NORMAL position, and the ON button on the control panel is depressed. After a brief warm-up (about five minutes) the power switch on the typewriter is turned ON, the NORMAL-TEST-CLEAR switch is placed in the NORMAL position, the proper settings made on the typewriter switches, and the computer is ready for operation. The following is a brief description of the functions of each component on the control panel.

NORMAL-TEST-CLEAR SWITCH

When this switch is in the NORMAL position, the computer is under control of the typewriter and will not operate unless the typewriter is turned ON and the typewriter switches thrown to proper positions. In the TEST position, the computer will go through order sequences even though the typewriter is not ON. In the CLEAR position, this switch duplicates the function of the CLEAR switch on the typewriter and automatically transfers control to the first order of the start routine.

NORMAL-HOLD-SELECT SWITCH

In the NORMAL position, the computer will step through orders in its proper sequence. Throwing this switch to HOLD prevents the computer from changing orders and, for checking purposes, makes the computer follow the same command over and over. Moving this switch to the SELECT position causes the channel selection relays to select the channel which has been set up in the ADDRESS REGISTER.

NORMAL-STOP-ONE STEP SWITCH

This switch in the NORMAL position permits computation to be followed in the previously coded fashion. Placing this switch in STOP position stops computation. Alternately moving this switch from the ONE STEP to the STOP position permits the computer to follow a given routine of orders, one command at a time. This switch is very useful when verifying newly coded routines.

NEXT ORDER ADDRESS REGISTER

The configuration displayed by the eight lights of the NEXT ORDER ADDRESS REGISTER indicate the address of the command position from which the next order will be taken. For checking purposes, any given light may be turned on or off by pressing the button immediately below the light.

ADDRESS REGISTER

Whenever an order is followed which requires an address, then the address of the channel, word, or command positions will appear in the ADDRESS REGISTER.

ORDER REGISTER

The eight lights of the ORDER REGISTER indicate the next order to be followed by the computer. Thus throwing the NORMAL-STOP-ONE STEP switch to STOP position will stop computation immediately. At that time the configuration of lights on the panel will show the order that is about to be followed, the address that is associated with the order, and the address from which the next order will be taken after following the order set up in the ORDER REGISTER.

ALARMS

The NUMBER ONE ALARM is associated with reading and recording in the main memory. Whenever a channel from the main memory is copied into one of the four working channels, on the next revolution of the drum, the copy is compared with the original in the memory. If they do not agree, computation will stop and ALARM NUMBER ONE will be turned on. Associated with every word is a check digit which is normally zero. Whenever a word in one of the four working channels is modified or changed in any manner, this check digit is changed to one. Whenever one of the working channels is to be recorded into a channel in the main memory, the channel to be copied is first compared with the channel in the main memory. Every word with a zero check digit should agree exactly. If it does not, computation will stop, and ALARM NUMBER ONE will turn on. If all words with zero check digits compare satisfactorily, then on the next revolution of the drum, recording into the main memory will take place. After the recording is made, then another comparison is made between the new information recorded into the memory and the original working channel. These two channels should now agree exactly. If they do not, computation will stop and ALARM NUMBER ONE will be turned on indicating that information has not been properly recorded into the main memory. Since we still have a correct copy in the working channel, it is possible to preserve this information by setting up the proper configuration of orders on the control panel and recording the working channel into another location.

Thus in general, we could not copy the contents of channel 16 into channel 17 either deliberately or accidentally unless every word in 16 has been modified. This checking feature is eliminated in channels zero through three so that these channels may be used for the temporary storage of numbers or routines.

The ALARM NUMBER TWO will be activated whenever there is an improper overflow. If the OVERFLOW or DECISION light has been turned on, the computer will not follow any of a list of orders which might turn on the overflow. This situation is easy to recognize because in addition to ALARM TWO

being on, the DECISION light will be on and the ORDER register will show the particular order which the computer is attempting to follow. Whenever an alarm is activated, in addition to turning on the appropriate light, an alarm buzzer will sound if the alarm switches are in the NORMAL position. If they are in SILENCE position, the appropriate alarm light will turn on but the buzzer will not sound. After an alarm has been activated, the computer may be restored to normal operation by throwing the corresponding alarm switch to the RESTORE position and then returning it to either the NORMAL or SILENCE position.

DECISION REGISTER

The decision light is associated with the overflow register. By means of the associated push buttons, this can be turned ON or OFF.

A B D E W M REGISTERS

This rotary switch is associated with the oscilloscope output terminals located on the rear of the control panel. This permits the visual inspection of the four recirculating words A B D and E as well as the visual inspection of words located in the four working channels or in the main memory. To inspect a word in one of the working channels, throw the NORMAL-STOP-ONE STEP switch to the STOP position, set the ADDRESS REGISTER for the address of the word desired and that word will appear on the oscilloscope. Setting the register at M, throwing the NORMAL-HOLD-SELECT switch to the SELECT position, and setting the address of the channel in the ADDRESS REGISTER, permits inspection of information recorded in the main memory. This last is primarily an inspection technique which permits determining the condition of the read-record heads, amplifiers, etc.

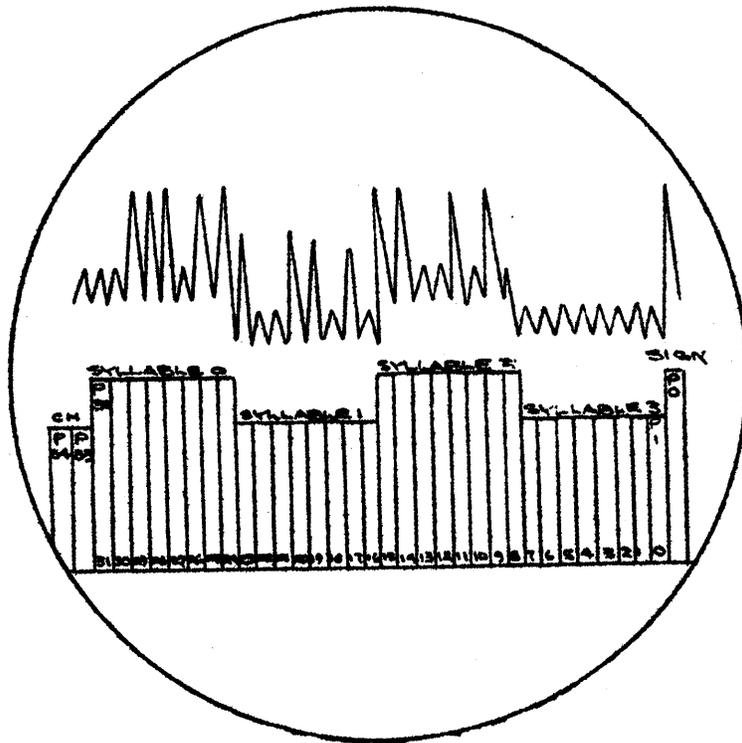
PROBE SWITCH

When the register selector switch is in the PROBE position, the oscilloscope will display the voltage appearing at any point in the machine to which the exploring probe is attached. This switch is used only for maintenance checks on the computer.

SKIP SWITCH

The two SKIP switches are associated with two conditional skip orders. For example, when the computer attempts to follow a "12" order, if the NUMBER 1 SKIP switch is down, the computer will take its next order from the address associated with the "12" order. However, if the NUMBER 1 SKIP switch is in the vertical position, then the "12" order will be ignored. The "14" order is associated in a like manner with the NUMBER 2 SKIP switch.

The sketch below shows the easily read manner in which words appear on the face of the oscilloscope. The staggering of the alternate syllables permits a ready inspection of recorded orders as well as the immediate determination of stored numbers in a hexadecimal form.



OSCILLOSCOPE DISPLAY

This shows the easily read hexadecimal configuration 3b9aca00 which is equal to the decimal number 1,000,000,000. In a like manner commands and addresses can be visually inspected.

DESCRIPTION OF TYPEWRITER AND TYPEWRITER CONTROLS FOR ALWAC III

The entire operation of the computer can be controlled from the typewriter. In addition to the four switches on the typewriter control panel, there are eight additional switches and one input light located just above the keyboard. The following is a description of these controls from left to right.

START READ

This is a momentary contact switch. Depressing this switch causes the punched tape to pass through the tape reader. If there is no tape in the reader, the reader will interpret this as an input of zeros and still continue to read.

STOP READ

Depressing the momentary contact STOP READ switch disengages the tape reader which will remain inoperative until the START READ switch is again depressed.

PUNCH ON

Depressing the fixed position PUNCH ON switch will cause tape to be punched by operation of either the typewriter keyboard or tape reader. The switch when restored to its normal position, disengages the tape punch.

CLEAR

Depressing the momentary contact CLEAR switch clears the first working channel of any orders which the computer is following and automatically brings the start routine into this channel. As soon as a four digit code number is typed indicating the address in the memory from which the next sequence of orders should be taken, computation will begin for the next routine. If the punch is on, then a special code is punched on the paper tape, and when the code is later read by the reader, this accomplishes the same result accomplished by the depression of the CLEAR switch.

INDICATING LIGHT

This light is "on" only when the computer is requesting a typed or taped input from the typewriter. In normal operation, the computer will accept inputs as rapidly as the average operator can type. However, when a considerable amount of computation is to be performed between sections of input data, and it is desired to enter these factors manually, then it will be necessary to wait for the indicating light before typing new factors.

COPY INPUTS

This fixed position switch is associated with the reading of tape. With this switch in its normal position, input tapes may be read directly into the computer without being typed. If a simultaneous copy of the tape input data is desired, this switch should be depressed. The typewriter will continue to type all tape inputs until the COPY INPUTS switch is restored to its normal position.

TAPE FEED

Depressing this momentary contact push switch will cause the punch to deliver tape leader, with merely the sprocket feed holes punched. As long as this switch is depressed, it will continue to produce tape leader.

CODE DELETE

Depressing this momentary contact switch causes the punch to cut all hole positions on one digit position in the tape. When the reader takes an input and scans a digit which has been punched in this fashion, the reader will ignore it and accept the next digit.

STOP CODE

Depressing this momentary contact switch causes the tape punch to punch the symbol "Stop Code". When the tape reader receives this punched tape position, the result is identical to that obtained by depressing the STOP READ SWITCH

There are four switches on the attached typewriter control panel to the right of the keyboard. They are as follows:

NORMAL-HOLD-COMPUTE SWITCH

This is a three position toggle switch. With this switch in the COMPUTE position, the typewriter has complete control of computations. With this switch in the HOLD position, all computation is stopped without affecting the computer. In this position column headings of descriptive material may be inserted into tables of computation. In both the HOLD and COMPUTE positions, the computer is in operation and under control of this particular typewriter.

Placing this switch in the NORMAL position completely disconnects the typewriter from the computer and permits operation of the electric typewriter in the standard manner.

ON-OFF SWITCH

This is the ON-OFF power switch for the typewriter only.

TYPE AND PUNCH SWITCHES

These two switches are used in conjunction with certain special commands, to edit the form of output from the computer. Associated with the typewriter are two relays, one of which causes computer outputs to be typed and the other which causes computer outputs to be punched. When the TYPE and PUNCH switches are depressed then the form of the output depends upon the setting of these two relays. For example, there are four computer orders:

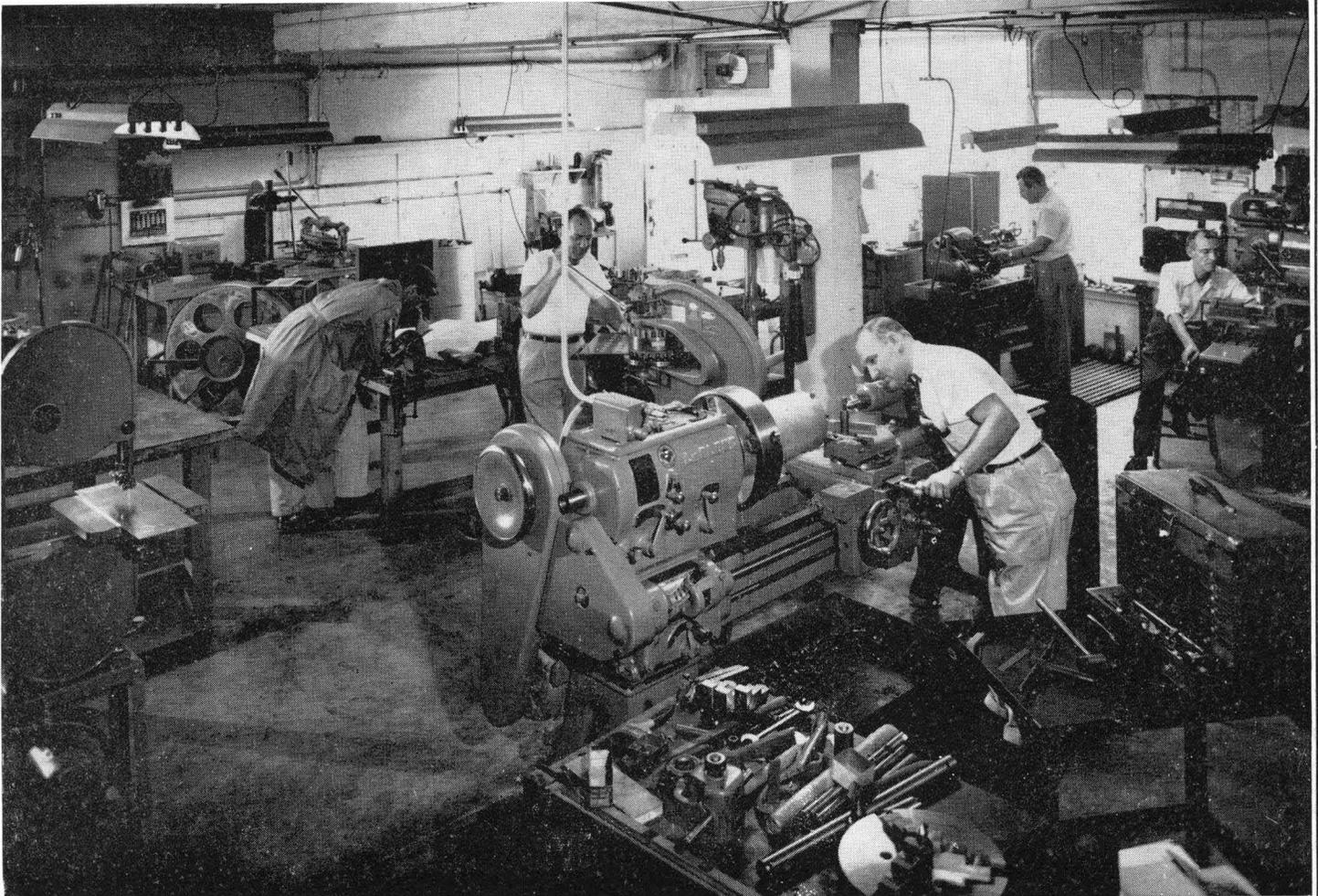
- 98 - For neither typing nor punching outputs
- 9a - For typing only
- 9c - For punching only
- 9e - For typing and punching

If the TYPE switch is in the vertical position, no outputs will be typed. If the PUNCH switch is in the vertical position, no outputs will be punched. Of course, if both of these switches are in the vertical position, all outputs from the computer will be lost. If the TYPE switch is up then all outputs will be typed regardless of computer orders. If the PUNCH switch is up, then all outputs will be punched regardless of computer orders. Thus, by means of these two three-position switches together with four typewriter editing commands, we have complete flexibility with regard to the form of our output.

AUTOMATIC CARRIAGE RETURN

The typewriter can be set to return the carriage at any pre-determined point. This is of great assistance in simplifying the editing of output information.

FABRICATION AND MACHINE SHOP



The Fabrication and Machine Shop where 70 per cent of all machine work needed for the ALWAC is performed. On the large lathe in the center, a memory drum for an ALWAC Computer is being turned.

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EXPERIMENTAL LABORATORY



One corner of an Experimental Lab showing development work in process for punched card adaptation for various items of equipment.

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THE IBM TIE-IN

The IBM Tie-in equipment for ALWAC III is available to **read and punch** standard 80 column IBM cards using an IBM Type 523 Gang Summary Punch. With this arrangement, inputs can be received, and output information punched at the rate of 8000 alphanumeric digits per minute.

In reading punched card inputs, the IBM Tie-In equipment is controlled by information in Working Storage Channel IV in ALWAC III. As many as ten 8 decimal digits, 80 alphabetic symbols, or a combination of alphanumeric information can be read from a single punched card, stored in the IBM Working Channel of the IBM Tie-In, and converted to binary notation. The information is transferred to Working Channel III of ALWAC III and operations performed on it in the 200 ms time elapsing before the Gang Summary Punch commences to read the following card.

In delivering outputs, the IBM Tie-In functions in a manner similar to reading punched cards. Binary coded, alphanumeric information, under the control of Working Channel IV in ALWAC III is delivered from Working Channel III to the IBM Working Channel of the IBM Tie-In, converted into decimal notation and punched on a standard 80 column IBM card. As many as ten 8 decimal digit numbers, 80 alphabetic symbols, or a combination of alphanumeric information can be punched on a card from information in a single Working Channel in ALWAC. Two hundred ms before the feeding of the next card is allowed for ALWAC III to perform its operations prior to delivering its next outputs.

There are five orders in the ALWAC III involving the IBM Tie-In.

- 06 - SET IBM PUNCH - sets the Gang Summary Punch to punch outputs on punched cards.
- 04 - SET IBM READ - sets the Gang Summary Punch to read inputs from punched cards.
- 0c - READ IBM - reads one 80 column punched card into IBM Working Channel under control of Working Channel IV.
- 0e - PUNCH IBM - punches one 80 column punched card from information in the IBM Working Channel under control of Working Channel IV.
- 94 - EXCHANGE IBM AND WORDS 80-be - Exchanges contents of IBM Working Channel with contents of Working Storage Channel III.

If the information to be punched or read consists of ten or less 8 decimal digit numbers, the operation will be self contained in the above orders. However, if the input or output involves some combination of alphabetic data and/or numbers of less than 8 decimal digits, it will be necessary to call up the IBM INPUT-OUTPUT SUBROUTINE. This routine is used solely for the purpose of indicating the desired configuration of punched card inputs or outputs.

For example, if it is desired to read or punch a card containing four numbers with eight, seven, one and four decimal digits respectively, in addition to thirty alphabetic columns, the operator would call up the IBM INPUT-OUTPUT routine and type the following:

48714

The cards would then be punched or read in their desired configuration by either the 0c or 0e orders.

ORDERS WHICH MODIFY THE ACCUMULATOR

| <u>CODE</u> | <u>COMMAND</u> | <u>DESCRIPTION OF COMMAND</u> |
|-------------|----------------|---|
| 22* | BINARY ROUND | This considers the double length word AB and rounds off the word to a single length word contained in A. Thus if B has a 1 in the most significant digit, then 1 is added to A . |
| 28* | CLEAR A | Change the number in A to zero and make sign digit positive. |
| 2c* | ABSOLUTE VALUE | Make the sign of the number in A positive. |
| 2e* | REVERSE SIGN | Reverse the sign of the number in A. |
| 3e* | COMPLEMENT A | Complement the number in A including the sign digit. |
| a0 | SHIFT AB RIGHT | Shift the double length number in AB right N binary digits. Each digit leaving A enters the B register. If the overflow is not on, then N zeros will be shifted into the N most significant digits of A and the N least significant digits of B will be lost. If the overflow is on then on the first shift right, a 1 is shifted into the most significant digit of A and the overflow is automatically turned off. For the remaining N-1 shifts, zeros are shifted into the most significant digits of A. |
| a2 | SHIFT AB LEFT | Shift the double length number in AB left N binary digits. The digits leaving the most significant part of B enter the least significant part of A. N zeros are shifted into the N least significant digits of B and the N most significant digits of A are lost. |
| a4 | SHIFT A RIGHT | Shift A right N binary digits. If the overflow is not on, then the N least significant digits of A are lost and N zeros are shifted into the N most significant digits. If the overflow is on, then on the first shift right a 1 is shifted into the most significant digit of A and the overflow is turned off automatically. For the next N-1 shift, zeros are shifted into the most significant digits of A. |

| <u>CODE</u> | <u>COMMAND</u> | <u>DESCRIPTION OF COMMAND</u> |
|-------------|-------------------------|--|
| a6 | SHIFT A LEFT | Shift A left N binary digits. Zeros are shifted into the N least significant digits and the N most significant digits of A are lost. |
| a8 | SCALE | This command is used for floating point operations. The double length number AB will be shifted right or left N places according to the number stored in the address portion of this command. Since there are only seven binary digits associated with each command and the command code is eight binary digits long, then for this particular command, the eighth binary digit serves as a plus or minus indication to designate the direction of the shift. Thus if this command contains a 1 in the eighth digit of the code, then AB will be shifted left N places; if zero, then it will be shifted right N places. The command 4c, which will be used for storing the number of places to be shifted, automatically puts this 1 or zero in the eighth position of the code depending upon the sign of A. |
| aa | FLOATING POINT SHIFT | This command automatically shifts the double length number AB so that A is zero and a 1 is contained in the most significant digit of B. A count is kept of the number of shifts right or left and is stored in the D register as a positive or negative number. This command together with others permits all forms of binary floating point arithmetic to be conveniently performed. |

ARITHMETIC COMMANDS

| | | |
|----|----------------|---|
| 60 | ADDITION | Add the number in the specified word to A, leave answer stored in A. If capacity of A is exceeded, turn on overflow. |
| 62 | ADD AND NEGATE | Add the number in the specified word to A and change the sign of the sum. Leave answer stored in A. If the capacity of A is exceeded, turn on the overflow. |

| <u>CODE</u> | <u>COMMAND</u> | <u>DESCRIPTION OF COMMAND</u> |
|-------------|------------------------|---|
| 64 | SUBTRACT AND NEGATE | Subtract the number in the specified word from A and change the sign of the answer. Leave the answer stored in A. If the capacity of A is exceeded, turn on the overflow. |
| 66 | SUBTRACT | Subtract the number in the specified word from A. Leave answer stored in A. If capacity of A is exceeded, turn on the overflow. |

The four add and subtract orders above give all possible combinations of sums and differences between a number in A and any number in working storage. The numbers in the specified words are not changed in carrying out these orders.

| | | |
|----|------------------------------|--|
| bc | DOUBLE LENGTH ADDITION | Add the number in the specified word to the double length number contained in A and B. The sign of the double length number is determined by the sign of B. |
| be | DOUBLE LENGTH SUBTRACTION | Subtract the number in the specified word from the double length number contained in A and B. The sign of the double length number is determined by the sign of B. |

These six addition and subtraction commands will not be followed if the overflow is on, instead the computation will stop and the alarm will turn on.

| | | |
|----|--|---|
| e0 | ACCUMULATIVE MULTIPLICATION | Multiply the number in B by the number in D, and store the double length product in AB. Any number previously in A is given the sign of the product and added to the product. |
| e2 | ACCUMULATIVE MULTIPLICATION WITH ADDRESS | Multiply the number in B by the number in the specified register and store double length product in AB. Any number previously in A is given the same sign as the product and is added to the product. The specified word is left stored in D. |
| e4 | MULTIPLICATION | This command is the same as e0 except that A is not added. |
| e6 | MULTIPLICATION WITH ADDRESS | This command is the same as e2 except that A is not added. |
| e8 | DIVISION | Divide the double length number in AB by the contents of D. Store the quotient in B and the remainder in A. |

| <u>CODE</u> | <u>COMMAND</u> | <u>DESCRIPTION OF COMMAND</u> |
|-------------|-------------------------------------|--|
| ea | DIVISION WITH ADDRESS | Divide the double length number in AB by the specified word. Store the quotient in B and the remainder in A. The specified word is left stored in D. |
| ec | SINGLE LENGTH DIVISION | Divide the number in B by the number in D. Store the quotient in B and the remainder in A. |
| ee | SINGLE LENGTH DIVISION WITH ADDRESS | Divide the number in B by the specified word. Store the quotient in B and the remainder in A. The specified word is left stored in D. |

In each of the four divide orders, if the overflow is on, this division will not be performed but will stop computation and sound the alarm. In the case of an improper division, that is, where the quotient would exceed one word in length, computation will stop and the alarm will sound.

TRANSFERS OF CONTROL

| | | |
|----|--------------------------|---|
| 10 | UNCONDITIONAL SKIP | Take the next order from the specified address. |
| 12 | CONTROLLED SKIP I | If SKIP switch 1 on the CONTROL PANEL is "on" take the next order from specified address, otherwise continue in standard sequence of orders. |
| 14 | CONTROLLED SKIP II | If SKIP switch 2 on the CONTROL PANEL is "on" take the next order from the specified address, otherwise continue in standard sequence of orders. |
| 16 | COUNT DOWN AND ZERO TEST | Subtract one from the absolute value of the number in E, and if the resulting number is not zero, then take the next command from the specified address. If the result is zero, then continue taking orders in the normal sequence. |
| 18 | ZERO TEST | If the number in A is not zero, then take the next command from the specified address, otherwise continue in the normal sequence of orders. |
| 1c | NEGATIVE TEST | If the sign of the number in A is negative, take the next order from the specified address, otherwise continue following commands in the normal sequence. |

| <u>CODE</u> | <u>COMMAND</u> | <u>DESCRIPTION OF COMMAND</u> |
|-------------|----------------|--|
| 1e | OVERFLOW TEST | If the overflow is on, take the next order from the specified address, otherwise continue in the standard sequence of orders. This order turns the overflow off. |

In the orders which follow, "W" represents the word specified by the address associated with the order.

EXCHANGE ORDERS

| | |
|-----|------------------|
| 30* | EXCHANGE A AND B |
| 36* | EXCHANGE A AND E |
| 3a* | EXCHANGE A AND D |
| 68 | EXCHANGE A AND W |

COPY ORDERS

| | | |
|-----|--------------------|---|
| 08* | COPY E TO B | |
| 0a* | COPY E TO D | |
| 32* | COPY B TO A | |
| 34* | COPY E TO A | |
| 38* | COPY D TO A | |
| 40 | COPY W TO B | |
| 48 | COPY A TO W | |
| 56 | COPY W TO E | |
| 5a | COPY W TO D | |
| 78 | COPY W TO A | |
| b4 | COPY CONSTANT TO A | Copy the specified word located in the zero channel into the A register. This is not one of the four working channels, but is a special channel for the storage of frequently used constants. |

| <u>CODE</u> | <u>COMMAND</u> | <u>DESCRIPTION OF COMMAND</u> |
|------------------------|---------------------------------|---|
| BLOCK TRANSFERS ORDERS | | |
| 80 | TRANSFER TO WORKING STORAGE I | Transfer the 32 words contained in the specified channel to words 00 through 3e. |
| 82 | TRANSFER TO WORKING STORAGE II | Transfer the 32 words in the specified channel to words 40 through 7e. |
| 84 | TRANSFER TO WORKING STORAGE III | Transfer the 32 words in the specified channel to words 80 through be. |
| 86 | TRANSFER TO WORKING STORAGE IV | Transfer the 32 words in the specified channel to words c0 through fe. |
| 88 | STORE WORKING CHANNEL I | Transfer the 32 words contained in words 00 through 3e into the specified channel in the main memory. |
| 8a | STORE WORKING CHANNEL II | Transfer the 32 words contained in words 40 through 7e into the specified channel in the main memory. |
| 8c | STORE WORKING CHANNEL III | Transfer the 32 words contained in words 80 through be into the specified channel in the main memory. |
| 8e | STORE WORKING CHANNEL IV | Transfer the 32 words contained in words c0 through fe into the specified channel in the main memory. |
| 94 | IBM BUFFER | Exchange the 32 words contained in words 80 through be with the IBM Buffer register. |

INPUT-OUTPUT ORDERS

| | | |
|-----|-----------------|---|
| 04* | SET IBM READ | Set the Gang Summary Punch to read inputs from punched cards. |
| 06* | SET IBM PUNCH | Set the Gang Summary Punch to punch outputs on punched cards. |
| 0c* | READ IBM | Read one card into IBM Buffer register. |
| 0e* | PUNCH IBM | Punch the information contained in the IBM Buffer register. |
| 98 | SUPPRESS OUTPUT | This is one of four orders which enable the programmer to determine the manner in which the answers from the computer should be printed. This order may be used when it is desired to control the form of the output from the typewriter. The |

| <u>CODE</u> | <u>COMMAND</u> | <u>DESCRIPTION OF COMMAND</u> |
|-------------|-------------------------------|---|
| | | suppress output order may be overruled at the typewriter and the answers typed or punched on tape depending upon special TYPEWRITER switch settings. |
| 9a | TYPE OUTPUT | This order causes the answers to be typed and not punched unless overruled by TYPEWRITER switch settings. |
| 9c | PUNCH OUTPUT | This order causes the answers to be punched on tape and not typed unless overruled by TYPEWRITER switch settings. |
| 9e | TYPE AND PUNCH OUTPUT | This order causes answers to be both typed and punched on tape unless overruled by TYPEWRITER switch settings. |
| d8 | SIGN OUTPUT | Transmit to tape or keyboard the sign of the number in the A register. |
| dc | DECIMAL NUMBER OUTPUT | Transfer to tape or keyboard the last four binary digits to the right in A. This order is used to type numbers from the computer. |
| f0 | DECIMAL OR HEXA-DECIMAL INPUT | Shift A left four digits and copy from tape or keyboard into the four right-hand digits in A the binary form of the digit punched on tape. This order is used when entering numbers from the electric typewriter tape (or from the typewriter keyboard) to the computer. Repeat this order N times. |
| f2 | LETTER INPUT | Shift A left six digits and copy from tape or keyboard into the seventh through second right-hand digits in A the binary form of the typewriter letter or symbol punched on tape. Repeat this order N times. This order is used when storing alphabetical material, arithmetic symbols, or editing instructions such as tab control or carriage return. |
| f4 | HEXADECIMAL OUTPUT | Transfer to tape or keyboard the last four binary digits to the left in A and then shift A left four times. Repeat this order N times. This command is used when copying instructions or numbers in hexadecimal form from the computer. |

| <u>CODE</u> | <u>COMMAND</u> | <u>DESCRIPTION OF COMMAND</u> |
|-------------|----------------|--|
| f6 | LETTER OUTPUT | Transfer to tape or keyboard the six binary digits in positions 31 through 26 and then shift A left six digits. Perform this order N times. This order is used to transmit alphabetical information, arithmetic symbols or editing instructions such as tab control or carriage return to the electric typewriter. |

There are several other special orders which are incorporated only for special input-output tie-ins such as punched cards, magnetic tape or supplementary memory drums.

MISCELLANEOUS COMMANDS

| | | |
|-----|----------------------------|--|
| 02* | REVERSE OVERFLOW | If the overflow is on, turn it off. If it is off, turn it on. |
| 4c | COPY ADDRESS TO W | Copy the address stored in the A register into the specified word. |
| 4e | COPY ONE HALF WORD TO W | Copy the complete command including address from A to the specified word. |
| 50 | COMPARISON TEST | Turn the overflow on if the number in A is less in absolute value than the number in the specified word. This order will not be followed if the overflow is on, instead the alarm will sound and the computation will stop. |
| 6c | COPY ADDRESS TO A | Copy the address portion of the specified word into the A register. |
| 6e | COPY ONE HALF WORD TO A | Copy the complete command including address from the specified word into the A register. |
| 70 | EXTRACT | Leave a digit in A only where there is also a digit in the corresponding position in the specified word (logical multiplication). This order is useful in dealing with only parts of a word and permits breaking a word up into several numbers and then extracting them individually. |
| 74 | DOUBLE EXTRACT | Copy the specified word into A only in those digits in which there is a corresponding digit in D. Leave the rest of A alone. This order has many convenient uses in modifying orders, and in dealing with parts of words. |

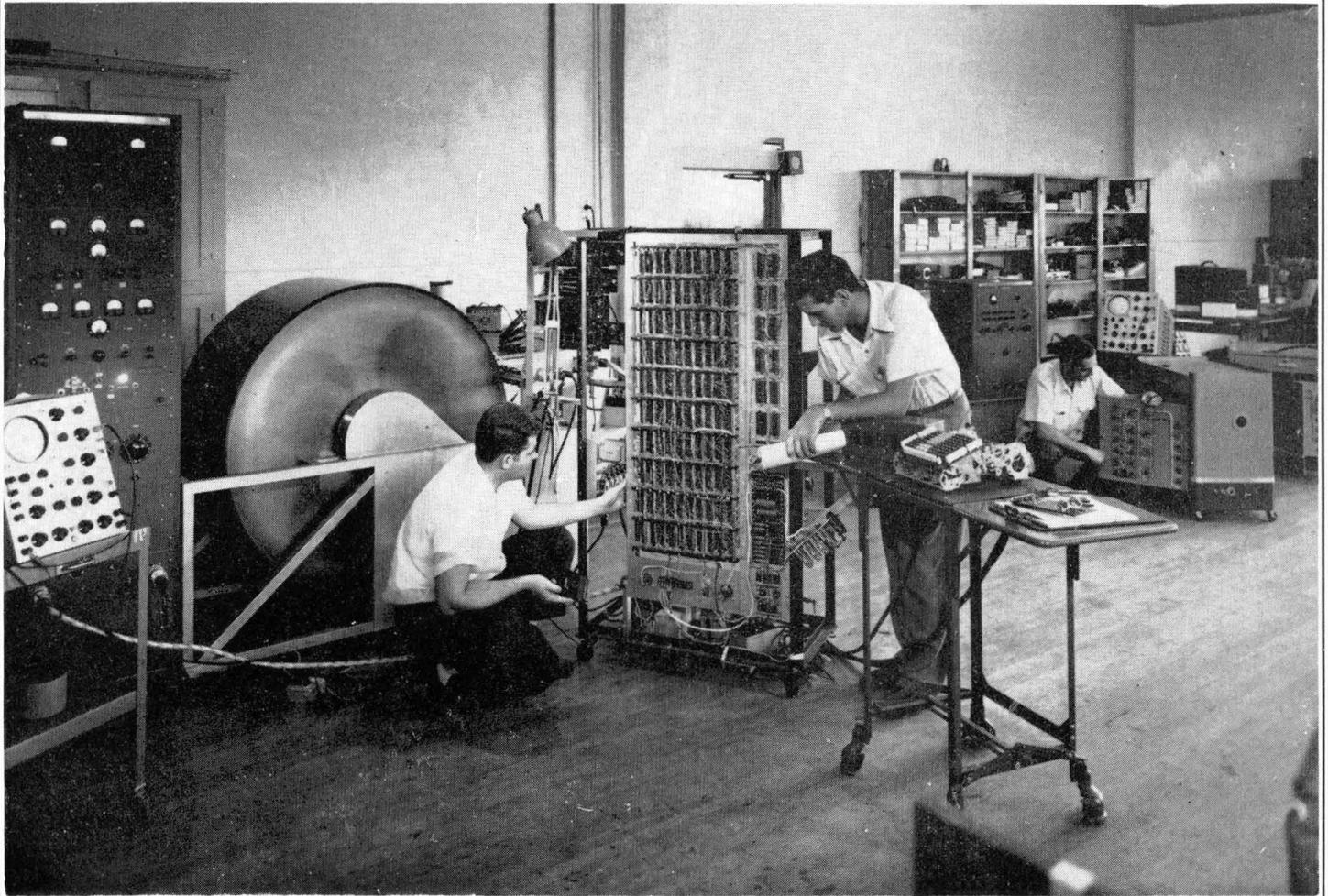
Orders marked with an * are special "no-address" orders which may be placed in the address portion of command when two of these orders appear in sequence. This is accomplished by increasing the first order by one and placing the next order in the address.

The following is an actual sample of a stencil cut by the ALWAC computer. The code number 16b3 calls up the routine from the main memory and after typing the first value, the increment, and the number of lines for the computer, the ALWAC took over and computed and typed a complete table of square roots.

16b3 First value 1.000000 Increment 1.000000 Number of lines 50.

| | | | |
|-----------|----------|------------|-----------|
| 1.000000 | 1.000000 | 51.000000 | 7.141428 |
| 2.000000 | 1.414213 | 52.000000 | 7.211102 |
| 3.000000 | 1.732050 | 53.000000 | 7.280109 |
| 4.000000 | 2.000000 | 54.000000 | 7.348469 |
| 5.000000 | 2.236067 | 55.000000 | 7.416198 |
| 6.000000 | 2.449489 | 56.000000 | 7.483314 |
| 7.000000 | 2.645751 | 57.000000 | 7.549834 |
| 8.000000 | 2.828427 | 58.000000 | 7.615773 |
| 9.000000 | 3.000000 | 59.000000 | 7.681145 |
| 10.000000 | 3.162277 | 60.000000 | 7.745966 |
| 11.000000 | 3.316624 | 61.000000 | 7.810249 |
| 12.000000 | 3.464101 | 62.000000 | 7.874007 |
| 13.000000 | 3.605551 | 63.000000 | 7.937253 |
| 14.000000 | 3.741657 | 64.000000 | 8.000000 |
| 15.000000 | 3.872983 | 65.000000 | 8.062257 |
| 16.000000 | 4.000000 | 66.000000 | 8.124038 |
| 17.000000 | 4.123105 | 67.000000 | 8.185352 |
| 18.000000 | 4.242640 | 68.000000 | 8.246211 |
| 19.000000 | 4.358898 | 69.000000 | 8.306623 |
| 20.000000 | 4.472135 | 70.000000 | 8.366600 |
| 21.000000 | 4.582575 | 71.000000 | 8.426149 |
| 22.000000 | 4.690415 | 72.000000 | 8.485281 |
| 23.000000 | 4.795831 | 73.000000 | 8.544003 |
| 24.000000 | 4.898979 | 74.000000 | 8.602325 |
| 25.000000 | 5.000000 | 75.000000 | 8.660254 |
| 26.000000 | 5.099019 | 76.000000 | 8.717797 |
| 27.000000 | 5.196152 | 77.000000 | 8.774964 |
| 28.000000 | 5.291502 | 78.000000 | 8.831760 |
| 29.000000 | 5.385164 | 79.000000 | 8.888194 |
| 30.000000 | 5.477225 | 80.000000 | 8.944271 |
| 31.000000 | 5.567764 | 81.000000 | 9.000000 |
| 32.000000 | 5.656854 | 82.000000 | 9.055385 |
| 33.000000 | 5.744562 | 83.000000 | 9.110433 |
| 34.000000 | 5.830951 | 84.000000 | 9.165151 |
| 35.000000 | 5.916079 | 85.000000 | 9.219544 |
| 36.000000 | 6.000000 | 86.000000 | 9.273618 |
| 37.000000 | 6.082762 | 87.000000 | 9.327379 |
| 38.000000 | 6.164414 | 88.000000 | 9.380831 |
| 39.000000 | 6.244997 | 89.000000 | 9.433981 |
| 40.000000 | 6.324555 | 90.000000 | 9.486832 |
| 41.000000 | 6.403124 | 91.000000 | 9.539392 |
| 42.000000 | 6.480740 | 92.000000 | 9.591663 |
| 43.000000 | 6.557438 | 93.000000 | 9.643650 |
| 44.000000 | 6.633249 | 94.000000 | 9.695359 |
| 45.000000 | 6.708203 | 95.000000 | 9.746794 |
| 46.000000 | 6.782329 | 96.000000 | 9.797958 |
| 47.000000 | 6.855654 | 97.000000 | 9.848857 |
| 48.000000 | 6.928203 | 98.000000 | 9.899494 |
| 49.000000 | 7.000000 | 99.000000 | 9.949874 |
| 50.000000 | 7.071067 | 100.000000 | 10.000000 |

MAIN ASSEMBLY ROOM



One corner of the Main Assembly Room where an inventory control machine is being completed. This inventory control machine utilizes a four-foot magnetic drum incorporating our own specially designed "air-floating" head and is capable of remembering the balances on 275,000 items. In the background is shown the final assembly of a production run of Logrinc Plotter-Follower units.

LOGISTICS RESEARCH INC.
11544

SUB - ASSEMBLY AREA



This is the Sub-Assembly Area of the main assembly room where plug-in components are constructed, special coils wound, and various small electronic units are assembled. In the rear at the far right can be seen the frameworks for two ALWAC Logic sections.

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**INVENTORY CONTROL EQUIPMENT ANALYSIS
BY MEANS OF THE ALWAC**

In the past we have recognized the existence of what might be referred to as the inventory paradox, that is, the difficulty of specifying the precise equipment for solving inventory and production control problems until that same equipment is available for solving these problems. The logical course out of this dilemma is by means of the "pilot plant" technique, so frequently used by the chemical engineer. Here is a proposed process analyzed in all of its conceivable variations to determine the precise form of the specific equipment for the large scale process.

On many occasions in the past, we have used our existing General Purpose ALWAC equipment to analyze the proposed design specifications of special-purpose equipment. On one such instance, we simulated a small portion of the Air Force inventory problem. In this case, the ALWAC Computer was set to remember seven things with regard to each Air Force stock number. These seven things were the stock number, the stock level, the number of serviceable items, the number of reparable items, the number due in, the number due out, and the reorder level. In the following section will appear several actual samples of the types of decisions and operations which were programmed in the ALWAC for this example. In each case, the remarks, numbers, etc. which are underlined were typed under the control of the ALWAC; everything else was typed by the operator. In the first example below, typing 4100 4800 caused the ALWAC to type its own column headings. After typing 1916, and the corresponding stock numbers, the complete listing of the stored information with regard to each stock number is listed.

| <u>4100 4800</u> | <u>STOCK NUMBER</u> | <u>STOCK LEVEL</u> | <u>SERVICEABLE</u> | <u>REPARABLE</u> | <u>DUE IN</u> | <u>DUE OUT</u> | <u>REORDER</u> |
|------------------|---------------------|--------------------|--------------------|------------------|---------------|----------------|----------------|
| 1916 | | | | | | | |
| 1ALFZ008590249. | | <u>45</u> | <u>30</u> | <u>10</u> | <u>15</u> | <u>0</u> | <u>15</u> |
| 1ALF106308-3. | | <u>30</u> | <u>0</u> | <u>5</u> | <u>45</u> | <u>15</u> | <u>10</u> |
| 8700-582535. | | <u>20</u> | <u>15</u> | <u>7</u> | <u>5</u> | <u>0</u> | <u>7</u> |
| 8700-571500-698. | | <u>45</u> | <u>40</u> | <u>0</u> | <u>0</u> | <u>0</u> | <u>15</u> |

To issue a stock number, the code 1917 is typed and then the corresponding stock number and number of line items to be issued. The ALWAC was programmed to recognize four distinct situations.

1) The number of items to be issued is less than the number of serviceable items and the new number of serviceable on hand is greater than the reorder level, hence the issue is completed and no action is taken.

2) The number of items to be issued is less than the number of serviceable items on hand, but the result of the issue reduces the serviceable items below the reorder level in which case the ALWAC computes the number of items which should be ordered based on the stock level, the due-in and the due-out records. In this case, the ALWAC will either specify the precise number which should be ordered or will specify that the stock is low but no additional items should be ordered.

3) The number of items to be issued is greater than the number of serviceable items on hand but an adequate supply of reparable items are available.

4) The number of items to be issued is greater than the number of serviceable and the number of reparable items.

The following insert shows the manner in which the ALWAC was programmed to react to each of these situations.

1917

1ALFZ008590249. 5. (This is an issue of 5--number of serviceable is now 25.)
1ALFZ008590249. 26. INSUFFICIENT UNITS--BUT ADEQUATE SUPPLY OF REPARABLE

1917

1ALFZ008590249. 36. INSUFFICIENT UNITS--CHECK "DUE IN"

The code number 311e receives parts from REPARABLE

311e

1ALF106308-3. 2. We now have 2 serviceable, suppose we issue 1 using the code 1917

1917

1ALF106308-3. 1. STOCK LOW--BUT ADEQUATE SUPPLY ON ORDER

If we issue below the reorder level then--

1917

1ALFZ008590249. 11. 16 UNITS SHOULD BE ORDERED AT ONCE

Of course among the many other operations programmed in this same example was the ability to transfer parts to serviceable from reparable and to transfer parts to serviceable from due-in. Also the stock level, due-in, due-out, reorder level and reparable could be increased or decreased as necessary. The versatility of the electronic equipment also permits the programming of the ALWAC Computer to recognize any inconsistencies which might arise. Two of the programmed inconsistency checks are indicated below. The first is an attempt to issue from a non-existent stock number and the second is a situation where parts are received from reparable and transferred to serviceable. The code number 311e permits parts to be received from reparable, but if more

parts are received than are actually reparable, the ALWAC interprets this as an inconsistency and recommends a recheck of records.

The ALWAC tests for inconsistencies---

311e

1ALFZ008590249. 11. EXCESS UNITS RECEIVED-RECHECK RECORDS

1917

1ALFZ008950249. 5. UNIT NOT STOCKED

Condensed Order List For ALWAC III

MODIFY THE ACCUMULATOR

| | |
|-----|-------------------------------|
| 22* | Binary Round |
| 28* | Clear A |
| 2c* | Absolute Value |
| 2e* | Reverse Sign |
| 3e* | Complement A |
| a0 | Shift AB Right n places |
| a2 | Shift AB Left n places |
| a4 | Shift A Right n places |
| a6 | Shift A Left n places |
| a8 | Scale (Binary) |
| aa | Floating Point Shift (Binary) |

ARITHMETIC COMMANDS

| | |
|----|-----------|
| 60 | A + W |
| 62 | - A - W |
| 64 | - A + W |
| 66 | A - W |
| bc | AB + W |
| be | AB - W |
| e0 | B x D + A |
| e2 | B x W + A |
| e4 | B x D |
| e6 | B x W |
| e8 | AB/D |
| ea | AB/W |
| ec | B/D |
| ee | B/W |

EXCHANGE ORDERS

| | |
|-----|---------|
| 30* | A and B |
| 36* | A and E |
| 3a* | A and D |
| 68 | A and W |

COPY ORDERS

| | |
|-----|---------------|
| 08* | E to B |
| 0a* | E to D |
| 32* | B to A |
| 34* | E to A |
| 38* | D to A |
| 40 | W to B |
| 48 | A to W |
| 56 | W to E |
| 5a | W to D |
| 78 | W to A |
| b4 | Constant to A |

TRANSFER OF CONTROL

| | |
|----|------------------------|
| 10 | Unconditional Skip |
| 12 | Breakpoint Skip I |
| 14 | Breakpoint Skip II |
| 16 | Skip if E - I not zero |
| 18 | Skip if A not zero |
| 1c | Skip if A negative |
| 1e | Skip if overflow on |

BLOCK TRANSFERS

| | |
|----|------------------------------|
| 80 | Transfer to Words 00-3e |
| 82 | Transfer to Words 40-7e |
| 84 | Transfer to Words 80-be |
| 86 | Transfer to Words c0-fe |
| 88 | Store Words 00-3e |
| 8a | Store Words 40-7e |
| 8c | Store Words 80-be |
| 8e | Store Words c0-fe |
| 94 | Exchange IBM and Words 80-be |

INPUT-OUTPUT ORDERS

| | |
|-----|---------------------------------|
| 04* | Set IBM Read |
| 06* | Set IBM Punch |
| 0c* | Read IBM |
| 0e* | Punch IBM |
| 98 | Suppress Output |
| 9a | Type Output |
| 9c | Punch Output |
| 9e | Type and Punch Output |
| d8 | Sign Output |
| dc | Decimal Number Output |
| f0 | n Decimal or Hexadecimal Inputs |
| f2 | n Letter Inputs |
| f4 | n Hexadecimal Outputs |
| f6 | n Letter Outputs |

MISCELLANEOUS COMMANDS

| | |
|-----|---|
| 02* | Reverse Overflow |
| 4c | Copy Address to W |
| 4e | Copy One Half Word to W |
| 50 | Turn on Overflow if A less than W |
| 6c | Copy Address to A |
| 6e | Copy One Half Word to A |
| 70 | Logical Product of A and W |
| 74 | Logical Product of D and W Stored in A |

Orders marked with an * are special "no-address" orders which may be placed in the address portion of command when two of these orders appear in sequence.

| | |
|------------------------|--|
| Hexadecimal Conversion | 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 |
| Computer | 0 1 2 3 4 5 6 7 8 9 a b c d e f 10 |

Order List For ALWAC III

Arranged in Numerical Sequence

| <u>Code</u> | <u>Description</u> | <u>Code</u> | <u>Description</u> |
|-------------|--------------------------------------|-------------|---|
| 02* | Reverse Overflow | 70 | Logical Product of A and W |
| 04* | Set IBM Read | 74 | Logical Product of D and W Stored in A |
| 06* | Set IBM Punch | | |
| 08* | Copy E to B | 78 | Copy W to A |
| 0a* | Copy E to D | | |
| 0c* | Read IBM | 80 | Transfer to Words 00-3e |
| 0e* | Punch IBM | 82 | Transfer to Words 40-7e |
| | | 84 | Transfer to Words 80-be |
| 10 | Unconditional Skip | 86 | Transfer to Words c0-fe |
| 12 | Breakpoint Skip I | 88 | Store Words 00-3e |
| 14 | Breakpoint Skip II | 8a | Store Words 40-7e |
| 16 | Skip if E - 1 not zero | 8c | Store Words 80-be |
| 18 | Skip if A not zero | 8e | Store Words c0-fe |
| 1c | Skip if A negative | | |
| 1e | Skip if overflow on | 94 | Exchange IBM and Words 80-be |
| | | 98 | Suppress Output |
| 22* | Binary Round | 9a | Type Output |
| 28* | Clear A | 9c | Punch Output |
| 2c* | Absolute Value | 9e | Type and Punch Output |
| 2e* | Reverse Sign | | |
| | | a0 | Shift AB Right n places |
| 30* | Exchange A and B | a2 | Shift AB Left n places |
| 32* | Copy B to A | a4 | Shift A Right n places |
| 34* | Copy E to A | a6 | Shift A Left n places |
| 36* | Exchange A and E | a8 | Scale (Binary) |
| 38* | Copy D to A | aa | Floating Point Shift (Binary) |
| 3a* | Exchange A and D | | |
| 3e* | Complement A | b4 | Copy Constant to A |
| | | bc | AB + W |
| 40 | Copy W to B | be | AB - W |
| 48 | Copy A to W | | |
| 4c | Copy Address to W | e0 | B x D + A |
| 4e | Copy One Half Word to W | e2 | B x W + A |
| | | e4 | B x D |
| 50 | Turn on Overflow if A less Than W | e6 | B x W |
| | | e8 | AB/D |
| 56 | Copy W to E | ea | AB/W |
| 5a | Copy W to D | ec | B/D |
| | | ee | B/W |
| 60 | A + W | | |
| 62 | - A - W | d8 | Sign Output |
| 64 | - A + W | dc | Decimal Number Output |
| 66 | A - W | | |
| 68 | Exchange A and W | f0 | n Decimal or Hexadecimal Inputs |
| 6c | Copy Address to A | f2 | n Letter Inputs |
| 6e | Copy One Half Word to A | f4 | n Hexadecimal Outputs |
| | | f6 | n Letter Outputs |

Orders marked with an * are special "no-address" orders which may be placed in the address portion of command when two of these orders appear in sequence.

Hexadecimal Conversion 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
 Computer 0 1 2 3 4 5 6 7 8 9 a b c d e f 10

ALWAC III

PROGRAMMING FORM

LOGISTICS RESEARCH INC.

ROUTINE _____ CHANNEL _____ BY _____ DATE _____ CHK. _____ NO. _____

NOTES _____

00 0-4-8-c 01

| | | | |
|--|--|--|--|
| | | | |
| | | | |

02 0-4-8-c 03

| | | | |
|--|--|--|--|
| | | | |
| | | | |

04 0-4-8-c 05

| | | | |
|--|--|--|--|
| | | | |
| | | | |

06 0-4-8-c 07

| | | | |
|--|--|--|--|
| | | | |
| | | | |

08 0-4-8-c 09

| | | | |
|--|--|--|--|
| | | | |
| | | | |

0a 0-4-8-c 0b

| | | | |
|--|--|--|--|
| | | | |
| | | | |

0c 0-4-8-c 0d

| | | | |
|--|--|--|--|
| | | | |
| | | | |

0e 0-4-8-c 0f

| | | | |
|--|--|--|--|
| | | | |
| | | | |

10 1-5-9-d 11

| | | | |
|--|--|--|--|
| | | | |
| | | | |

12 1-5-9-d 13

| | | | |
|--|--|--|--|
| | | | |
| | | | |

14 1-5-9-d 15

| | | | |
|--|--|--|--|
| | | | |
| | | | |

16 1-5-9-d 17

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18 1-5-9-d 19

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1a 1-5-9-d 1b

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1c 1-5-9-d 1d

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1e 1-5-9-d 1f

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20 2-6-a-e 21

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22 2-6-a-e 23

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24 2-6-a-e 25

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26 2-6-a-e 27

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28 2-6-a-e 29

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2a 2-6-a-e 2b

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2c 2-6-a-e 2d

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2e 2-6-a-e 2f

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30 3-7-b-f 31

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32 3-7-b-f 33

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34 3-7-b-f 35

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36 3-7-b-f 37

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38 3-7-b-f 39

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3a 3-7-b-f 3b

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