Division 6 - Lincoln Laboratory
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SUBJECT: THE MTC SERVICE MANUAL

To: MTC Personnel and MTC Users

From: H. L. Ziegler

Date: 15 April 1957

Information about the Memory Test Computer and its use is being compiled in the form of a loose-leaf binder to be called the MTC Service Manual. When complete, this manual will contain all the information necessary to the operation and maintenance of the Memory Test Computer.

As stated in the Foreword of this manual a loose-leaf and highly-sectionalized format was chosen to simplify revisions and thus help ensure up-to-date information. An additional advantage gained by this format is that individual sections or subsections may be issued as soon as they are ready without waiting for the entire manual to be completed.

Copies of completed sub-sections will be distributed to all MTC personnel and to any other interested personnel. The effective date for the information on any page appears in the upper left corner of that page. If "private" files or manuals are kept the individual sub-sections should always be checked as being up-to-date before they are used. Such checks may be made by consulting the MTC Office, B-155 or by consulting one of the official copies as listed in the Foreword to the manual. In special cases one of the two MTC Office copies may be signed out for short periods to aid in such checks.

A supply of individual sub-section copies will be maintained in the MTC Office, B-155. These are available on request for study purposes or for use in submitting corrections, additions, and general comments concerning the MTC Service Manual. Under no circumstances may changes be made in official copies except when done by the MTC Office.

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MTC SERVICE MANUAL

INTRODUCTION

The MTC Service Manual is intended to satisfy the need for quick access to information about the Memory Test Computer and its use. Though written primarily as a reference text it should be quite helpful to those wishing to learn the computer system. To this end it has been organized into a logical progression from simple operating instructions in the first section, through detailed equipment description in the central section, to advanced design ideas in the final section. Information included in this manual is intended specifically for the Memory Test Computer; more general information may be found in publications listed in the individual section bibliographies.

It seems desirable at this point to reassure the casual reader about the task of learning the Memory Test Computer and its use. This isn't quite the formidable task that the size of this manual might imply. The detailed information presented here represents the combined efforts and knowledge of a number of persons no one of whom professes to know all areas in detail. In fact, one of the primary reasons for this manual is that of relieving the individual of the necessity to learn the entire computer in complete detail. The reader is advised to concentrate on acquiring basic principles while leaving details for future references to the manual. In this manner he will soon acquire sufficient knowledge of the computer for day-to-day needs while also acquiring the knowledge of where to find the details when required.

Present day digital computers represent a very real achievement in the electronic art. Anyone who has serviced radio, television, or radar can appreciate the operation and maintenance problems associated with a system containing thousands of vacuum tube circuits. To add further complications - beyond increased complexity - computer circuitry demands reliability far beyond that previously required of electronic circuits. For example, the basic 2MC Pulse Repetition Frequency (PRF) used in MTC is roughly equivalent to the carrier frequency of the standard broadcast band for commerical radio. Considerable noise and static can be tolerated in radio broadcasts; MTC requires every pulse to perform correctly. Only through very careful and well coordinated design, maintenance, and operating procedures has the necessary high degree of reliability been achieved.

Extreme attention to detail extends beyond the physical equipment to documentation, scheduling of time, preparing of tapes and IBM cards, and other incidentals of this nature. It is to assist in these areas that Section 3, Records and Procedures, has been included.

The Service Manual consists of three major parts, each having a specific aim. The first part is made up of the first three sections and portions of Sections 4 and 5. This part of the manual is intended for those persons who program and use the computer but do not need "troubleshooting" knowledge of the physical equipment.

Except for Sections 30 and 31, the remaining sections are devoted to detailed descriptions of the computer and its external devices plus certain programs of special interest to the MTC Section. This part is intended primarily as reference material for technicians and engineers directly concerned with the troubleshooting and maintenance of the existing equipment.

On the other hand, Sections 30 and 31 are devoted to developing better methods and techniques in the computer art. In some cases material presented here applies to new design work rather than to existing equipment.

Quarterly area assignments for MTC technicians are based on some sections of this manual. Lists of general type questions have been prepared to determine how well the section assigned has been learned. These lists have been included with the appropriate sections for other readers who may wish to check their own progress.

In a compilation of this magnitude there are bound to be numerous errors in spelling, grammar, and factual material. Also, in the ever-changing environment of MTC portions of material originally correct become obsolete and need to be replaced. Maximum value of the Service Manual will be realized only if such errors are corrected as quickly as possible. Readers are requested to assist in making these corrections by reporting immediately any errors they detect. All errors should be reported to the MTC office, B-155; under no circumstances should corrections be made directly in official copies of the MTC Service Manual.

No doubt there are also omissions - unintentional - of material that would be of considerable use to the MTC Section and to users of the computer. Increased use of this manual will help to point out these omissions. Suggestions for additions and improvements to the manual are always welcome. Please call them to the attention of the MTC office.

FOREWORD

The MTC Service Manual is the primary and official source of information about the Memory Test Computer and its use.

The following copies are designated as "Official Copy" and are not to be removed from the assigned areas. Only approved changes and corrections may be made to these copies and such changes will be made automatically by the MTC office.

Serial No.	Assigned to:	Location
#1	Section Leader	B-155
#2	Assistant Section Leader	B-155
#3	MTC Office	B-155
#4	MTC Office	B-155
#5	MTC Console	B-154
#6	Technicians	B-164

Official copies of the MTC Service Manual are intended to serve as reference texts ----- for other purposes individual sections of the manual are available from the MTC office. These individual sections should be used for study purposes and for submitting any proposed change or correction to the manual.

A loose-leaf and highly sectionalized format was chosen to facilitate corrections and additions to the manual. Normally such changes will affect only one or two pages and there should be no hesitation in making them. Each page is dated to permit checking that it is the latest version of that page. Suggestions for corrections, changes, and additions should be submitted to the MTC Office, B-155.

MTC Service Manual

Foreword

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MTC Service Manual, Section 1

OPERATING THE MEMORY TEST COMPUTER

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k. Audio Equipment

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m. Marginal Checking

POWER

Power for MTC is obtained from transformers at the end of Building B Basement and is distributed through the breakers in the wall just outside room B-044. The breakers are labelled "MTC: B-154" and "MTC: Alternator Power".

There are three broad classes of power used in MTC:

Computer Room A.C. is used to heat the vacuum tube filaments and operate blowers and the drum motor in the computer room, B-154. Although it is drawn through the breakers in the hall opposite B-051, it is usually controlled through the main breaker in the distribution box to the right of the duty technician's desk in the computer room (B-154).

Power Supply A.C. is used to heat filaments in the power supply room B-051; if the breakers in the hall and B-051 are on, this A.C. can be controlled by pushbuttons on the MTC console or in the frame to the left of the distribution box in the power supply room.

The above two classes of power are sometimes lumped under the term "Filament Power".

D.C., sometimes called "Plate Power", is used to keep the electrodes of the vacuum tubes at their proper potentials and to provide the power from which the MTC pulse signals are shaped. The various voltages are obtained by carefully rectifying, filtering, and voltage-regulating A.C. obtained through the breakers in the basement hall and those in the power supply room A.C. distribution panel. If both these sets of breakers are on, plate power may be controlled by pushbuttons on the MTC console and in the frame to the left of the distribution box in the power supply room B-051. Circuitry for the production and control of most D.C. is located in the power supply room; however, supplies delivering -7KV and +3KV to the display system are located upstairs, in the T-frame to the right of the camera oscilloscope.

Power On is the state of the computer in which all three classes of power are applied. It may be reached from Standby by pushing the "Power On" button on the MTC console; after a five-second warning signal from the buzzer, the various D.C. supplies come on in sequence.

The Standby state has two defining characteristics:

Both computer room A.C. and power supply A.C. are on, and all filaments warm; and D.C. is off but may be turned on at any time; that is, any fuse alarm or tripped sensitrol has been reset.

It is the state into which the machine is commonly put for servicing and may be reached from the Power On state by pushing either the "Standby" button on the console or the one in the power room. The significance of the term "Standby" is that the computer, while inoperative, is all warmed up and can be put into operation quickly by turning on D.C. with the "Power On" button on the console. There are pilot lights on the console to indicate the Power On and Standby states; each is located near the appropriate pushbutton.

Console Power Control Panel:

Near the "Standby" and "Power On" buttons on the power supply control panel of the MTC console is a "Power Off" button; this removes power supply A.C. but not computer room A.C. To regain power supply A.C. one must push "Standby". An automatic two-minute wait is allowed for the power supplies to warm up before the Standby state is reached, and the "Standby" light comes on. To the left of "Power Off" is "Reset", which must be pushed when power has been shut off by a Sensitrol (see below). There are five pilot lights labelled with various voltages from the power supply; their order, from left to right, is that in which the various D.C. supplies are turned on by the control circuitry. The "Fuse Out", "Alternator Power", and "Emergency A.C." pilots are inoperative. Of the two pilots labelled "Filaments: the upper one burns when computer room filaments are on, while the lower one indicates that filaments in the power supply room are on. The large red pushbutton labelled "Emergency Off" opens the main breakers in the basement hall opposite the power supply room, hence turns off all power. It should be used only in case of emergency such as fire or imminent electrocution of personnel. The small circuit breaker below the "Emergency Off" button interrupts power to the relay circuitry controlling the power supplies. The "Emergency Off", "Power Off", "Standby", and "Reset" buttons are duplicated on the panel to the left of the breaker panel in the power supply room.

Automatic Shutoff:

Two occurrences, both automatic, may turn D.C. off. The first of these is caused by the Sensitrols. These devices monitor output voltages of the D.C. supplies, and if one should deviate ±5 % from the specified value, all D.C. will be turned off automatically. A light on the panel will indicate which power supply voltage was at fault and whether it was high or low. After the cause of the failure has been removed, pushing the "Reset" button on the power supply control panel will restore the computer to the "Standby" state.

The second occurrence which may cause D.C. to be lost is the blowing of a fuse. Most MTC fuses are located on Power Distribution Panels (PDP'S) and are of the "grasshopper" type. When such a fuse blows, the melting wire releases a spring contact which touches a bus on the fuse mounting block. This action completes a circuit which turns off all D.C. supplies and sets off the Fuse Alarm; the fuse alarm light on the control console comes on, and the affected PDP is marked by a light to indicate where one should look for the blown fuse. After the fuse has been replaced, the "Reset" button on the PDP must be pushed to get the light out and return the computer to the Standby condition, from which it can be turned on again. Since a blown fuse which fails to set off the fuse alarm results in one of the most subtle of all ailments to troubleshoot, care should be exercised in replacing fuses to get them installed properly.

Failure of either power supply or computer room A.C. will dump D.C. (see Interlocks).

Interlocks:

To protect circuits, MTC is wired so that the voltages must be applied in a certain order. To begin with, the breakers in the basement hall outside B-051 must be on before anything will work. Then the main breaker in the power supply room B-051 should be closed. Thereafter the small breaker on the MTC console will turn on power for the indicator lights, and for the relays controlling the power supply. At this point the "Normal A.C." and "Power Off" lights should be on. Computer A.C. can now be turned on with the breaker to the right of the duty technician's desk, and Power Supply A.C. by pressing Standby. The logic of the circuitry is as follows:

1. The Standby light will not come on until all three of the following are satisfied:
   a. Power Supply A.C. has been on for at least two minutes.
   b. Computer Room A.C. is on.
   c. If a fuse has blown or a sensitrol tripped, it has been reset.

2. D.C. cannot be turned on unless both of the following are satisfied:
   a. The Standby light is on.
   b. Computer room filaments have been on for at least 15 seconds.

Although Computer Room A.C. and Power Supply A.C. are independent, failure of either will turn off D.C.

The kilovolt supplies for the oscilloscopes may be brought to Standby without bringing the whole computer to this state by means of the power switches on the supplies; however, they will not go on unless their switches are turned to on and the +90 volt supply is on to the rest of the computer. These supplies are connected to computer room A.C.

Normal Turn-Off:

1. Push "Standby". All D.C. power supplies should go off, and "Standby" light should be on.

2. Push "Power Off". All lights should be out except "Power Off" light, the "Normal A.C." light, and the upper "Filaments" light.

3. Turn off the main breaker to the right of the Technician's desk. The upper filament light should be out.

4. Turn off control power breaker on MTC console. All console lights should be off.

5. If work is to be done on the power supplies, turn off the main breaker in the power supply room.

It is not necessary to turn off the main breakers in the hall.

<u>Normal Turn-On:</u>

1. See that the following breakers are on:

   a.) Two in the basement hall outside the power supply room.

   b.) One in the power supply room in the A.C. distribution panel.

   c.) The small control power breaker on the console.

   d.) One main and 12 subsidiary breakers in the panels to the right of the Technician's desk in the computer room.

   The "Power Off" and "Normal A.C." lights on the console burn when breakers b.) and c.) are on.

   The upper "Filaments" pilot, and the computer room filaments come on when breakers d.) are on.

2. Push "Standby". The lower "Filaments" light should come on. The "Standby" light should come on after a two-minute wait.

3. Push "Power On". After a 5-second signal from the warning buzzer the five power supply indicators should come on in sequence during about a 3-second interval. The "Standby" light goes off.

AIR CONDITIONING

MTC makes use of components that are sensitive to heat and moisture in the air; in addition, cards and magnetic tape stored in the computer room may be damaged by moisture. Hence it is necessary that both the computer room and the power supplies be air conditioned to provide adequate cooling and ventilation, and to control relative humidity. To give an estimate of the magnitude of this task, it may be stated that during an air conditioning failure on a summer day the machine overheated within 15 minutes and had to be shut down.

MTC personnel should never make any adjustments of the air conditioning system. In the event of emergency, or to report need of routine service, call:

During working hours	Frank Mulholland	B-041	X460
At night and on weekends	Main guard desk in Building A		X397

The guards can locate Mulholland or the member of his crew on duty. See discussion below, under What to do About Alarms.

General Description:

In B-150 there is a large box called an "air handler" with cooling coils, heating coils, and a blower. The exhaust from the blower is carried through ducts to various parts of the computer where it can be directed by means of louvers to areas which need it most. The air then returns to B-150 through filters in the computer room wall, to be rechilled, mixed with fresh air from outside, and recirculated. The equipment in the power room (B-051) is similar to that in B-150 except that it has no heating coils since heating of the power room is never necessary. Cooling is provided by water chilled at the power house and supplied to MTC at a temperature of about 45 degrees. Heating coils handle steam from the same source; heat is normally required only in very cold weather or on humid days when air must be chilled below the dew point to dry it and then rewarmed to the proper duct temperature.

Controls:

The steam and chilled water are controlled pneumatically by temperature- and humidity-sensing elements on the computer room wall to the left of the T-frame. With these sensors are some pressure gauges, and, to the left, an alarm panel. There are two sensors in the power room to the right of the doors: a pneumatic thermostat for controlling the cold water supply, and a "Differential Pressuretrol" which sets off the Water Pressure alarm if the pumps forcing chilled water to circulate through the cooling coils should fail. Admission of outside air is controlled by a damper in the window of B-150 which is shut electrically when the room becomes so cold as to endanger the cooling coils from freezeup. On the wall by the window there is a switch controlling the damper motor. When it is in the "up" position the damper is normally open, but under automatic control as described; when it is "down" the damper should be closed. The damper is open when the rotating arm on the motor shaft points away from the window, and is closed when the arm points toward the window.

Although no one connected with MTC needs to tamper with the air conditioning system, the following description of switches, gauges, and alarms is given to aid in judging whether it is working properly.

I. Switches:

A. In B-150

1. Room lights: on the air handler just to the left of the door as you enter.
2. Water pump motor: on masonite wall to the right, just above the pump. There is an Allen-Bradley circuit breaker and an On-Off motor control switch, with a 3-phase fuse box and master switch directly above. The fuse box cannot be opened unless the master switch is off.
3. Blower motor: on the tile wall to the left, beyond the air handler. There is a Square-D circuit breaker and motor control switch, with a 3-phase box and a master switch directly above. The fuse box cannot be opened unless the master switch is off.
4. Outside air damper: toggle switch on the Masonite wall to the right of the window. When it is "up" the damper is normally open and under automatic control; when it is down the damper should be closed.

B. In B-051

1. Room lights: On cinder block wall to the left of the door.
2. Water pump motor: On wall behind air handler. There is an Allen-Bradley circuit breaker and motor control switch, with a fuse box directly above.
3. Blower motor: On back of air handler. There is a Cutler-Hammer circuit breaker and motor control switch, with a fuse box and master switch below.

All these switches should be left on at all times. If trouble in the air conditioning is suspected, these switches should be checked. If it is recommended by the air conditioning crew, operation of MTC may be attempted with one or more of these switches off while maintenance of the air conditioning is in progress. In this case a brief explanation should be entered on the "Live Messages" board.

II. Gauges:

A. In B-150 (similar gauges perform corresponding functions in B-051)

1. Chilled water temperature at input to cooling coils.

Should be about 45 degrees Fahrenheit.

2. Chilled water temperature at outlet of cooling coils.
   Should be about 53 degrees Fahrenheit.
3. Chilled water at pump input.
   Should read the same as 1, about 45 degrees Fahrenheit.

(Gauges 1, 2, and 3 are ordinary capillary thermometers set into the pipes.)

4. Chilled water pressure at circulating pump input.
   Variable, but should be around 60 pounds per square inch, gauge.
5. Chilled water pressure at circulating pump output.
   Should be about 4 pounds per square inch above input.
6. Air pressure in building supply.
   Should be about 30 pounds per square inch gauge.
7. Control air pressure at output of reducing valve.
   Should be 15 pounds per square inch gauge.

(Gauges 4 through 7 are ordinary Bourdon gauges.)

B. On Sensor panel in B-154

1. Branch Pressure. This is the output of the humidity sensor, and varies up to 15 pounds per square inch, gauge. The higher it reads, the greater the humidity.
2. Pilot Pressure to Cooling Valve. This reading should be equal to the greater of Branch Pressure and Pilot Pressure to Heating Valve. If it is less than 8 pounds per square inch gauge, the chilled water is completely shut off; water flow increases with increasing pressure between 8 and 15 pounds per square inch.
3. Temperature Controller Branch Pressure. This is the output of a sensor on core memory temperature. The lower it reads, the warmer is the memory stall, and the greater will be the output of Pilot Pressure to Heating Valve.
4. Pilot Pressure to Heating Valve. This is the output of the duct temperature sensor, and the pressure should increase with increasing temperature. Steam flow to the heating coils decreases with increasing pressure (hence with increasing temperature) between 0 and 8 pounds per square inch gauge; above 8 pounds per square inch the steam is shut off.

There is a mercury thermometer hanging in the core memory stall, which usually reads 80 degrees or less Fahrenheit. Another one hangs in C031, Control Switch and Power Cathode Follower Panel; the normal temperature is somewhat higher, perhaps 85 degrees.

The output of the humidistat (Branch Pressure) should be about 8 pounds per square inch gauge when the relative humidity is 50% and the temperature about 70 degrees Fahrenheit.

Although the outputs of the two thermostats (Temperature Controller Branch Pressure and Pilot Pressure to Heating Valve) vary oppositely with temperature, each should be about 8 pounds per square inch when its bulb is at the temperature to which it is set.

Note that when the duct air is cool but the computer room air is moist, both the steam and the chilled water may be on. This is normal, and means that the system is trying to dry the air by cooling it below the dew point and then rewarming it to the desired duct temperature.

III. Alarms:

Indicator lights for these are on a panel to the left of the T-Frame in B-154, together with a warning buzzer. The buzzer may be suppressed by throwing the toggle switch marked Buzzer to the Up position, but any alarm light will stay on, and the Buzzer Off light will come on. Buzzer suppression should always be recorded on the "Live Messages" board. Since the alarms are controlled by "fail safe" relay circuitry, an alarm may mean only a defect in the circuit.

A. Water Temperature

This alarm goes off when the temperature of the chilled water supply rises above 51 degrees Fahrenheit.

B. Room Temperature B-150

This alarm goes off when the temperature in the air handling room B-150 falls low enough to risk freezing of the cooling coils. Besides giving the alarm the circuitry closes the outside air damper in the window of B-150.

C. Airflow Basement and Air Flow 1st Floor. These alarms are controlled by thermally operated switches in the ducting of the power room and of B-150 respectively. The alarms are tripped when air flow decreases below a certain minimum level.

D. Control Air Basement and Control Air 1st Floor. These alarms go off if the output of the reducing value in either the power room or B-150, respectively, falls much below 15 pounds per square inch.

E. Water Pressure. This is actuated by the "Differential Pressuretrol" in the power room, and goes off when the difference between input and output pressures to the cooling coils becomes too small either in the power room or in B-150. If improperly adjusted it may go off on a hot day just because the water control values are wide open.

What to do About Alarms: Any alarm is an incident and should be logged. An alarm that does not necessitate shutting down the computer will usually not be reported to Frank Mulholland until the next day if it occurs outside of regular staff hours; however, any behavior of the system that is not understood should be reported early in the next regular workday and should be noted on the Live Messages Board in the computer room. Any condition that requires curtailment of operations, or any obvious malfunctioning of the air conditioning equipment, should be reported immediately to Frank Mulholland, via X460 during staff hours, or via the guard's desk in Building A (X397) at other times. If, at any time, it is suspected that shutdown may be necessary in the next 15 to 20 minutes, report it immediately.

The decision when to shut down MTC is simple: shut down when it overheats. If the magnetic cores in core memory get much above 90 degrees Fahrenheit Core Parity alarms will occur; before this happens, however, the computer room will become increasingly stuffy. Specifically, turn off D. C. and A. C. when the memory stall thermometer reaches 90 degrees Fahrenheit, or the one in C031 reaches 100 degrees. If one understands the air conditioning system one can usually make an intelligent guess about the seriousness of a disorder; for example, failure of the steam supply or of one of the circulating pumps might not cause overheat, whereas failure of chilled water or of control air almost certainly would. The duty technician should be able to anticipate need for shutdown in time to dump core memory (probably onto tape) and record the readings of the program counter and such other registers as the programmer may specify; preferably he should summon help in time to have a member of Mulholland's crew on hand before it is necessary to turn off the computer.

PANEL MEMORY

Panel Memory consists of a bank of toggle switches on the console, and a plugboard beneath the console. Taken together they make up field 0 of the MTC memory. The functions of the toggle switches and of the plugboard are discussed below.

Toggle Switches

There are 32 rows of toggle switches near the center of the MTC console. Each row has 16 switches, corresponding to the 16 characters of an MTC word; there is also a 17th switch, at the right-hand end, which may be used to substitute a 16 character flip-flop storage register (called LR-1) for the toggle-switch register*. The toggle switch registers are used for short special programs, for starting long programs, or for entering constants into a program after the program has been "read in" or stored in some other part of memory. For example, a user of MTC might instruct the computer to deliver the answers to a problem on cards if a certain switch in panel memory is up, but on magnetic tape if the switch is down.

Both the quantity stored in an MTC register and the name of that register are usually given in the octal number system; to use the machine one must be familiar with octal notation. The symbols 0 through 7 retain their usual meaning in octal, but 8 and 9 are never used; thus 8, 9, 18, 19, etc., cannot occur in a list of octal numbers. Techniques for converting from octal to decimal numbers and back again will be discussed later (Section 5). To operate MTC one must only know how to store octal numbers in the switches and read them from the lights. It is customary in every day speech to name the two states of a switch "on" and "off", but in computer parlance it is simpler to name these states "one" and "zero" ("1" and "0"). An MTC panel memory switch is in the "1" state if its toggle is up and is in the "0" state if its toggle is down. A bit is the fundamental unit of information. A storage device like a switch, which is in one of two positions, is said to store one bit. It takes three bits, (for example, three switches), to represent one octal character; the following correspondence, which will be explained later, should be memorized:

Switches	Octal Character
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

* A "register" is any device capable of storing a number (usually in binary form).

The MTC toggle-switch registers are numbered in octal from 0 to 37. The 16 switches of each register are arranged in 5 groups of three with an etched vertical line on the panel separating adjacent groups. The extra switch is at the left, and is called the "zero" column. The remaining columns are numbered from left to right, in decimal, from 1-15. The lone switch in the zero column obviously can store only "0" or "1"; it is called the "<u>sign</u> bit". If it is in the "0" state the number is positive. If it is "1", the number is negative. Programmers occasionally insert a "decimal" point in a number; it belongs between columns 0 and 1.

Now we can write octal constants in panel memory. A few examples are:

Octal Number	MTC Code
0.27546	0 010 111 101 100 110
1.34521	1 011 100 101 010 001
450	0 000 000 100 101 000

An MTC instruction is usually written as a two- or three-letter code followed by a four-character octal number, for example <u>cs 45</u>. The letters stand for a set of 5 binary characters and are written in panel memory with switches 0 through 4. Thus when the word to be written is an instruction, only the two low order (right-hand) switches in the second octal digit (that is, only columns 5 and 6) are available to represent part of the number. Hence the numerical part of an instruction must always be less than 4000 in octal notation.

There is no easy way to remember the instruction code. Users should be very familiar with the instruction list posted on the operating console. Referring to it, we can see that the following are examples of correctly coded instructions:

INSTRUCTION	Inst. Code	Octal Number
cs 45	0 101 0	00 000 100 101
to 3472	1 011 0	11 100 111 010

The rules used in constructing the table are: if fewer than four octal characters are given after an instruction, the characters given are to be placed in the low-order (extreme right- columns and preceded by zeros; for the purposes of reading the <u>numerical</u> part of an instruction, column 4 is always read as zero, and only columns 5-15 are read.

A word should be said about the most frequent use of panel memory. The "start over" button on the operating console causes the computer to take its first instruction from register 0 of panel memory, but programs usually begin in core memory. Hence the first few registers of panel memory usually must contain instructions which transfer control to the start of the actual program. The programmer will usually indicate the starting address with the number 1 or 2 followed by a dash, followed by an octal number between 0 and 3777. The 1 or 2 should be made the number part of an sof instruction in register 0 of panel memory; the following octal number should be the numerical part of a tro instruction. Thus, if the directions with a program are "Start at 1-47" the following should be set up in the panel memory switches:

Register	Instruction	MTC Code
0	sof 1	1 010 100 000 000 001
1	tro 47	1 000 100 000 100 111

Simple programs may be set up and run directly from panel memory without preparing any tapes. The writer of programs for this purpose must remember that the contents of a toggle-switch register cannot be changed by the computer. However, there are five "live registers" made of vacuum-tube flip-flops referred to as LR-1, LR-2, ... , LR-5, which may be made part of panel memory. LR-1 may be substituted for any toggle-switch register by putting the extreme right-hand (seventeenth) switch in the "up" position. Any of the live registers may be substituted for a plugboard register by a proper insertion of plugwires; hence the writer of programs for panel memory has at his disposal five registers capable of storing numbers computed during the running of a problem.

The Plugboard

The remainder of field 0 of memory, registers 40 - 77 (octal), is on a plugboard--essentially a large plastic matrix which supports contact points. When the plugboard is inserted in its receptacle these contacts protrude out the back of it and complete certain circuits inside the computer, much as the toggle switches do. The plugboard receptacle is under the operating table directly below the console oscilloscope. To remove a board, pull down and out on the receptacle door. The plugboard is now revealed, and may be lifted up and out by the handle. The only thing to remember about inserting boards is that the locating pins on the sides go at the bottom, so that the wires are out and the contacts in; the plugboard may be pushed nearly into place at the top, and, if the pins are properly located, closing the door will lock it in place. When you lay a plugboard down, do it only on a flat surface free of other objects; or, better yet, put it in the rack for spare plugboards beside the receptacle. Bolts, nuts, and books under a plugboard will push the plugwires part way out and make for uncertain contacts.

The purpose of a plugboard memory is semi-permanent storage of programs such as the paper tape read-in and test routines, which are 32 or fewer instructions long and are used very often. The button "Start-at-40" will cause MTC to take its first instruction from the first plugboard register. The most frequently used programs are left plugged up on spare boards; folders containing programs for all MTC plugboards have been filed in the computer room and in the MTC Office.

An MTC plugboard has 64 rows of holes, a pair of rows for each register. The octal number (name) of the register appears to the right and midway between the two rows of holes. As in the toggle switches these rows have vertical lines setting off the high-order (extreme left) pair of holes, then dividing up the others into five groups of three. To insert a "1" at a certain position, plug in a jumper wire between the pair of holes in the proper column. The numbers are coded in octal in the same way that toggle switches are, with three columns of holes for each octal character. The correspondence is, "1" is represented by a jumper; "0" by no jumper. The 17th and 18th holes in the top row of each register must be connected by a jumper, to connect that register to the computer. Any of the live registers can be substituted for a plugboard register by connecting a jumper from the 18th hole of the register to one of the holes at the bottom of the plugboard marked LR-1, ..., LR-5. There is a set of holes for LR-6, but LR-6 has not yet been built and its use should not be attempted. The four sets of holes at the extreme right of each plugboard register have no function in MTC and should not be used.

ALARM SUPPRESSION

Alarms are indications of conditions existing inside the computer; the machine stops, and a light on the Alarm Indicator Panel comes on to show why the step occurred. Directly below the Alarm indicator Panel is an Alarm Suppression Panel. Switches and switch-position indicator lights are arranged to line up with the corresponding alarm Indicator lights above. In general, to suppress an alarm is to prevent the circuitry from stopping the computer when the condition is detected. There are three types of alarms: those which occur normally and are programmed, those due to errors on the part of the programmer, and those designed to indicate machine malfunction. The classification is as follows:

Normal Operation	Programmer Error	Malfunction
Identity	Overflow	Drum Parity
Overflow	Card Copy	Tape Parity
Programmed	Tape Not Ready	Core Parity
		Drum Timing
		Card Copy

Except for the drum parity alarm, all alarm indicators to the left of the console, just under the "Automatic Memory Display" panel, are associated with the programmer, while those to the right (just to the left of the bookcase) are related to computer malfunction and normally are handled only during troubleshooting. A programmer should specify the desired settings of all alarm suppression switches on the left hand panel before his program is run.

Identity

The instruction id, occurring in a program, causes the machine to compare the number in the partial sum register with one stored in memory. If the numbers are equal, nothing happens; if they are unequal, the machine will stop and display the blue light labelled "Identity" provided the "Stop - Don't Stop" switch directly below is in the "Stop" position. If the switch is in the "Don't Stop" position, inequality will result only in a skipping of the next instruction in the program.

When the switch is in the "Don't Stop" position, the stop-on-inequality feature may be invoked by a pf 4 instruction in the program, and cancelled by a subsequent pf 5 instruction; when the switch is in the "Stop" position these pf instructions are overridden and have no effect.

Note that the program must call for a comparison.

Overflow

When a sum or difference computed by MTC is greater in magnitude than 0.77777 octal, information is lost because the machine cannot store such large numbers. Unless the following instruction is one which clears the resulting overflow condition (to, sr, mh, or et) the computer will normally stop, give a chime, and light the light labelled "Overflow".

The stop, chime, and light may be suppressed by throwing the associated suppression switch to the "up" position, but this has no effect on the internal state of the computer. If the instruction following the one on which the overflow occurred causes another overflow, the computer may stop in an alarm condition but with the overflow light off. The overflow check is unlike the identity check in that it occurs automatically.

Programmed

One version of the sof instruction will, besides its normal function, stop the computer in an alarm condition unless the Programmed alarm is suppressed by throwing the associated suppression switch "up".

Card Copy

This alarm may be caused by card machine malfunction, but is more likely to be caused by violation of one of the restrictions on use of card machine:

1. Exactly 48 words must be punched onto or read from each card.

2. Having read or punched one word on a card, the machine must receive an instruction to read or punch the next word within a few milli-seconds. The exact time lapses allowable are given in the discussion of the card equipment.

Tape Not Ready

This alarm is given when an instruction occurs to write on, or read from, an improperly loaded tape unit. The Tape Bypass switch is inoperative.

Parity

With each 16-bit MTC word is associated a 17th bit so chosen as to make the total number of "1's" odd. If a 17-bit word with an even number of "1's" is detected, the machine will stop with an indication of core, drum, or magnetic tape parity according to where the erroneous word was discovered. This is almost always a sign of malfunction, and calls for troubleshooting. These alarms may be suppressed by raising the switches; but to do so deprives the programmer of any check on the correctness of word storage.

Drum Timing

This alarm indicates that the circuitry used for locating positions (registers) on the surface of the drum is out of step. Provided no instructions referring to the drum are given in the program, this alarm may be suppressed until time is found to repair the drum circuitry.

Drum Motor

This alarm, and the associated switch labelled Drum Bypass, are inoperative.

Fuse

Most MTC fuses are of the "grasshopper" type; that is, the fusible material is under tension. When the fusible material melts (when the fuse blows) a spring contact is released which touches a busbar behind the fuse panel. This completes a circuit which turns off all D.C. and sets off the Fuse alarm. The Fuse alarm, obviously, cannot be supressed.

Suppress Chime

This switch, in the "up" position, prevents the alarm chime from ringing, but affects the alarm circuitry in no other way.

Inactivity

This is not really an alarm; that is, no circuitry is set up by it which must be cleared before proceeding. However, the Inactivity light and alarm chime will be given whenever the circuit detects no pulses during an interval of time longer than that required by the slowest instruction.

PUSHBUTTON CONTROLS

Beneath the toggle switch panel of Panel Memory is a panel containing nine pushbuttons which are used to operate the Memory Test Computer. Next to them are toggle switches used to turn the computer room lights on and off. There follows a brief description of the actions of the various pushbuttons.

The buttons and their functions, reading from left to right, are: Start Over, Restart, Stop, Start at 40, Stop Reader, Clear CPC, Clear Alarms, Deselect Magnetic Tape and Camera Index.

Start Over

This button clears the arithmetic and control circuitry of MTC of all numbers left over from a previous problem, sets certain controls to starting positions, and starts the computer at the instruction in register zero of Panel Memory. If the program to be performed has been stored elsewhere than in Panel Memory, the first registers of Panel Memory should contain sof and tro instructions to transfer control to the register where the program actually begins. Start Over also clears all alarms which may be set.

Restart

This button clears the alarm circuitry but causes the computer to continue from the point where it was last stopped. The arithmetic circuitry is left undisturbed, and, if the computer is stopped in the middle of an instruction, the computer finishes it and then continues.

Stop

This stops the computer. Most circuits of MTC are so designed that it is always safe to stop; that is, any operation than cannot be interrupted will be completed before the "stop" signal takes effect. Thus one can usually take up where he left off by pushing "Restart".

The exceptions to this rule are the in-out equipment: photoelectric tape reader, Flexowriter, Soroban punch, card reader, Drum Memory, and Magnetic tape units. Pushing Stop during an instruction affecting one of these units may or may not generate an alarm; in any case it is probable that the instruction has not been correctly performed, and that one must Start Over or consult with the programmer for a suitable starting point.

Start at 40

Like Start Over, this button clears control, alarms, and arithmetic circuitry, sets certain controls to starting positions, but then starts the computer at register 40, the first register of the plugboard. Programs like the paper tape read-in, which are available on plugboards, can be started directly, without a "tr 40" instruction in register zero.

Stop Reader

This pushbutton is used only in emergencies. Its function is to stop the photoelectric tape reader, and its use should be necessary only if the reader has failed to stop at the proper place, or has read off the end of a tape. If it is pushed while the reader is actually reading tape, it is probable that the line of holes over the photocells when the button was pushed will not be read; hence, after pushing Stop Reader one cannot usually push Restart without inserting garbled information into the computer.

Clear CPC

"CPC" stands for "Clock Pulse Control", part of the central control circuitry. There are four pairs of indicator lights over the loudspeaker to the left of the console, labelled "Clock Control: D, C, B, A"; these indicate the states of flip-flops A, B, C, D in Clock Control. In certain malfunctions of the computer it may be impossible to Restart, Start Over, or Start at 40 because flip-flop A or B is in the "one" state, indicated by the fact that the upper (red) light of pair A or B is lit rather than the lower (white) light. Pushing Clear CPC will remedy this situation.

Clear Alarms

This pushbutton clears any alarm condition that may exist when the computer is stopped. Since Restart, Start Over and Start at 40 are connected so as to clear the alarm circuitry automatically, this button has very little use.

Deselect Magnetic Tape

The magnetic tape unit to which subsequent instructions are to refer is specified by a program in MTC; the Deselect Magnetic Tape button destroys the selection made in the program. It is seldom used in normal operation, but should be used to stop a runaway tape or one which has run past its "end of record" symbol.

Camera Index

This pushbutton will advance the film in the oscilloscope camera by one frame each time it is pushed. After a new film magazine is mounted on the camera, or just before an old one is removed for development, this button should be pushed manually 10 or 15 times; it is also advisable to advance the film a few frames between two programs both of which use the camera. Most users of MTC will program the "Index Camera" operation except at the beginning and end of a run.

In summary, we list the pushbuttons in two groups:

Those used during normal operation:

Start Over
Restart
Start at 40
Index Camera

Those used only on discovery of a programming error or on computer malfunction:

Stop
Stop Reader
Clear CPC
Clear Alarms
Deselect Magnetic Tape

Duplicates of these pushbuttons may be found under the Marginal Checking Panel at the right of the console; also, all but Index Camera and Clear Alarms are duplicated on the In-Out equipment portion of the S Frame.

PHOTOELECTRIC TAPE READER

The Photoelectric Tape Reader, sometimes called PETR for short, is located in the S-frame in front of the console, and is used to read information from seven-channel paper tape into the computer. The PETR is under program control via the ri instruction. It is operated as follows:

1. Turn on Motor-light switch

   This switch is located above the reader in the angle iron of the mounting frame. It should be off whenever the PETR is not used in order to prolong the life of the motor and gearing. The filaments of the internal amplifiers are on at all times. The external blower runs whenever the PETR is installed in its socket.

2. Insert the tape

   Raise the lever extending from the right side of the lamp housing (as the user faces the front - nameplate side - of the PETR.) This raises the tape hold-down plate of the machine. Now tape can be inserted under the plate and between the guide pins, and the hold-down plate lowered by lowering its lever. The 7th hole row on the tape should be inserted so that it is toward the user; this row can be identified by the fact that it is the one of the two edge rows of holes which is most nearly continuous. The 7th hole is used to tell the machine whether a line of information is to be read. On 4-6-6 tapes prepared by MTC the tape will be inserted correctly if the punched title on the tape - MTC xxx - can be read in a normal manner.

   Tape passes through the reader from right to left as viewed from the front, or nameplate, side of the machine. Unmarked flexo tape can be identified for beginning and end by realizing that the Flexowriter punches up through the tape and consequently leaves burrs, which can be felt with the fingers, on the side of the tape which was up as it went through the Flexo. This side should be down as the tape passes through the PETR. Again the 7th hole row will be nearly continuous.

3. Start read-in operation

   A read-in plugboard is available (and is normally plugged in) which will read in 4-6-6 tape produced by MTC's conversion program. The first address of the plugboard is 0-40 so the START AT 40 push button will initiate the program and thus read in a 4-6-6 tape.

   Other tapes and programs must be handled with a special plugboard made up by the programmer or by means of a stored program which would normally be initiated by START OVER.

THE FLEXOWRITER

The Flexowriter is the only output device on MTC that will produce printed copy directly. By means of facilities in other parts of the laboratory, results on cards or on magnetic tape may be printed, but some programmers prefer to have a printing monitor on progress of their programs, and use the Flexowriter for this purpose. The Flexowriter can also deliver results on punched paper tape and is used in this manner by the basic conversion program. Since the acquisition of the high speed photoelectric tape reader (PETR), the relatively slow mechanical tape reader on the Flexowriter is not used.

Printing and Punching occur under direction of the computer, one character at a time, by means of variations of the pr (print/punch) instruction.

OPERATION OF THE FLEXOWRITER

1. Printing

   a. Paper - If paper with sprocket holes is used the pressure release lever on the far left of the carriage remains in the forward (released) position. Bring the paper over the guide bar and under the roller. Guide the paper in and turn the roller until the holes line up with the sprockets. If paper without sprocket holes is used, pull the pressure release forward (released). Insert the paper just as before, but bring it up and position it. Then push the pressure release back, gripping the paper in place.

   b. Running - Turn the switch in the lower right hand corner to "on". Make sure the knob on the right rear of the Flexo is in the "normal print" position. The computer can now control all print operations including carriage returns, tabs, color change, upper case, etc. Note that the user can also use the keyboard. The only precaution is that the user should not type with the keyboard while an actual typing operation is being performed by the computer. Be careful, also, with the color change, upper case, and lower case. Some programmers assume the Flexo is left in the black color and lower case; therefore, care should be made to see that the case and color are proper when any printing is done. Caution! All other buttons (start read, stop read, etc.) should not be touched.

2. Punching

   a. New tape - To insert a new spool of tape, remove the bar on the rear of the Flexo. Remove the spool cover by loosening the knurled screw. Remove the old spool and place the new one on with tape coming off the bottom towards the right, (looking at the machine from the back). Thread the tape as given below.

   b. Threading - Bring the tape below the tape guide and over the tape tension arm roller (under the finger on the roller if there is one). Open the tape hold down arm (just in front of the plastic chip catcher) which also lifts the tape run out arm. (This is just to the rear.) The tape can now be placed into position by edgewise insertion. Close the tape hold down arm. Press the tape run out button and pull the tape out at the same time in order to run the tape into proper operating position.

c. Running - Turn the switch in the lower right hand corner to "on". Make sure the knob on the right rear of the Flexo is in the "normal print" position. The computer can now control punching. No punching can be accomplished by pushing keys. When the tape runs out, punching becomes disabled on the Flexo until new tape is installed.

THE MTC CARD MACHINE

The MTC card machine is an IBM Type 513 Automatic Reproducing Punch converted to operate primarily as a punched card input and output for the MTC computer. Cards punched on other card machines can be read with the MTC card machine and cards punched on the MTC card machine can be read with the other card machines, provided the compatible card layout and coding are used.

In order to use the MTC card machine for punching out results from MTC, op 3000 and op 3400 instructions are used; and for reading, op 1000 and op 1400 instructions are used. See the Programming Reference Manual.

The card machine can be used in different modes of operation. The two most common are computer control mode and test mode. The desired mode of card machine operation is determined by the wiring of a control panel (plugboard) placed in the card machine. A covered control panel is usually in position; this is the computer control plugboard. It is wired so that the computer controls the punching or reading of cards via the operate instructions. A separate test plugboard is wired so that the card machine will reproduce cards placed in the read feed onto blank cards placed in the punch feed, but since the card machine is usually tested under control of MTC, the test mode will not be discussed below.

COMPUTER USE OF CARD MACHINE

With the computer control plugboard in place, punching or reading using the computer can take place, providing the card machine is set up as follows:

READY FOR PUNCHING

a. Place an adequate number of blank cards in the punch feed hopper, 9 edge first, face down, with the plastic card weight on top. The phrase "9 edge first" is IBM jargon meaning "9 edge to the right as you face the side of the machine with the switches."
b. Place at least two cards in the read feed hopper, with the plastic card weight on top.
c. Hold down the start key until both feeds have operated or the red ready light is "on".

READY FOR READING

a. Run out any cards in the read feed.
b. Place the cards to be read in the read feed hopper, 9 edge first face down, with the plastic card weight on top. The phrase "9 edge first" is IBM jargon for "9 edge to the right as you

face the side of the machine with the switches."

c. Place at least two cards in the punch feed hopper, with the plastic card weight on top.

d. Hold down the start key until both feeds have operated or the red ready light is "on".

Note that without the card weights, jams are likely to take place.

In placing cards in the hoppers be careful that the cards are in place without binding against the sides of the hopper.

If cards run out of one of the feed hoppers during reading or punching (and the ready light is out) the computer will stop and wait when it tries to do another operate instruction. If, at this time, cards are placed in the empty feed hopper and the start key is depressed, the cards will feed in properly and the computer will resume operation of the card machine. Without restarting the computer, the program will continue.

However, if cards run out of one of the feed hoppers and the operator depresses the start key before inserting new cards, then the remaining cards in the feed will run out and cancel the automatic start operation. That is, when new cards are read in, the card machine will not start automatically, and the computer program must be started again.

GANG PUNCHING AND MTC IDENTIFICATION SWITCHES

Only two of the switches on the card machine are normally used. The one on the left marked "Rep" (for reproduce) is the gang switch. When this switch is "on" or up, then any punching in columns 2-16 of a card going through the punch feed will be punched into the following card; the punching in that card will be punched into the next following card, etc. In other words, any punching in columns 2-16 can be put into a deck of cards if the first card being punched has this punching, and the gang punch switch is up. Note, however, that this is true only when the card machine is under computer control, because of the wiring of the computer control plugboard. This switch has no effect on the read feed.

The switch on the right, marked "MTC", causes each card punched to be marked with an identification symbol characteristic of MTC. This symbol is the Hollerith code for the letter M punched into the first column and consists of punches in row 11 and row 4.

MAGNETIC TAPES

MTC has three IBM tape drives controlled through the Tape Adapter Frame; to each tape drive a number 1, 2, or 3 may be assigned by a rotary switch at the bottom of the tape drive door. Programs refer to tape drives by these assigned numbers, not according to the positions of the drives on the floor.

Near the selector switch on each door are four pushbuttons and four indicator lights. Use of the buttons is explained below under Operation; the significance of the lights is as follows:

1. Select: This light comes on when the computer executes a programmed instruction to prepare the tape drive for use.

II. Not Ready: This light indicates that the Load operation described below has not been completed. If a program attempts to use a "not ready" tape, the machine will give a "Tape Not Ready" alarm and stop.

III. File Protect On: If this light burns when a tape is mounted on the left hub, it indicates that the file protection ring has been removed, so that writing on the tape is impossible. This light always burns when there is no tape mounted.

IV. Not in File Area: When this light burns the tape may be selected, but reading or recording will be impossible until the unit has been put In File Area by a programmed instruction.

Note on file protection: Every file reel has a red plastic ring, called the file protection ring, fitted into a concentric groove in its back surface. If this ring is removed from a reel, the "File Protect On" light will burn on the tape mechanism holding the reel, and it will be impossible to record on that tape. If recording is attempted, the computer will stop with the following indications:

CS	cb.
AR	(1st word to be copied)
AC	(Word Count)-2
ECS	3300
SS	5
PC	(Address of cb) + 1

OPERATION OF THE MAGNETIC TAPE DRIVES

1. PRECAUTIONS

   1. Before attempting any manual operation, press the "RESET" button.
   2. If machine is "running away" or fails to stop on a tape break press "RESET" to stop it and restore

it to manual control.

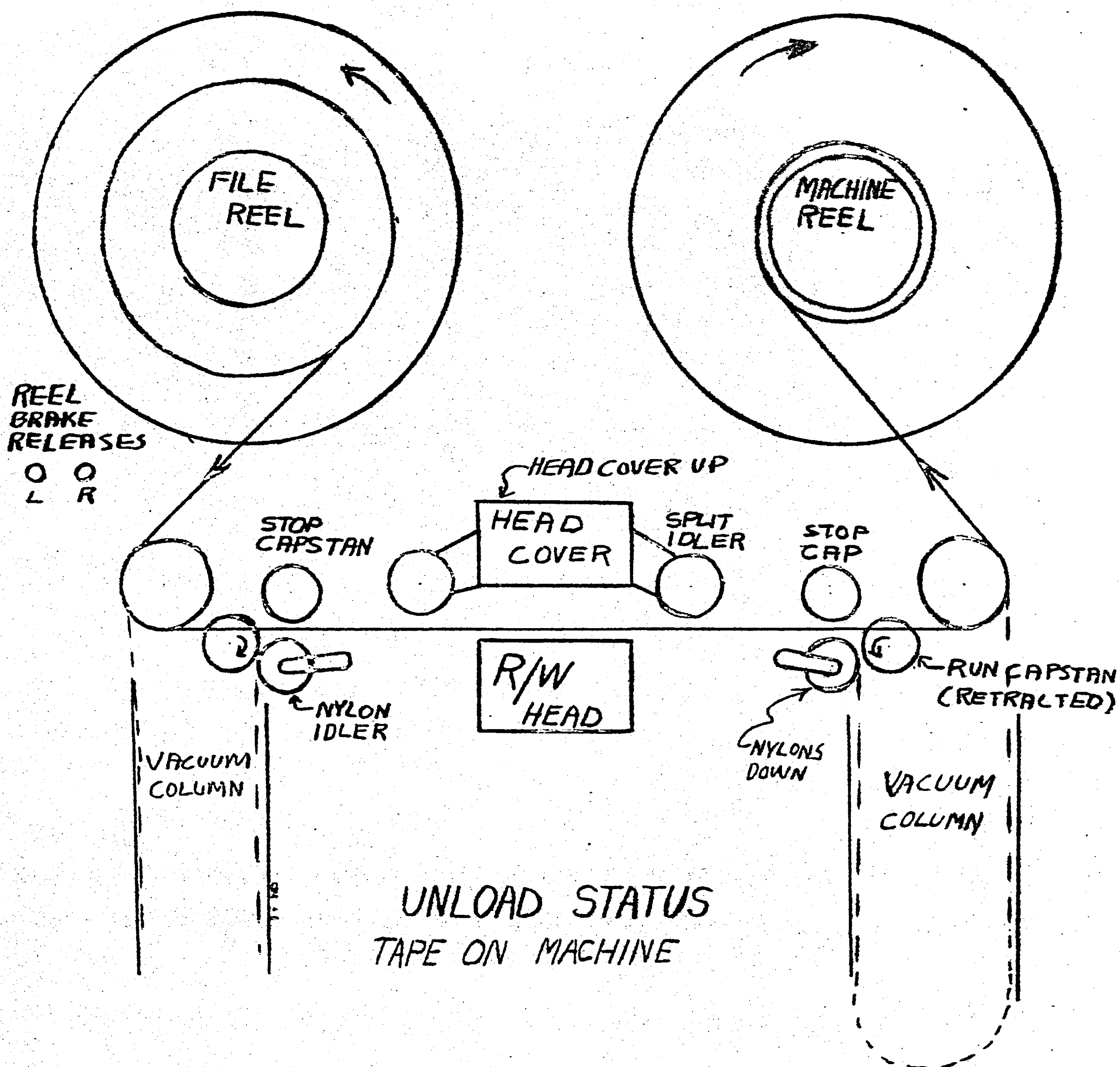
3. Never force the machine reel sensing arm into position after loading a tape; it will be set automatically when the door is closed.
4. Be sure that the tape is properly threaded through and that the load point is wound well onto the machine reel before attempting "LOAD/REWIND".
5. Do not open the door of the drive while it is in operation; opening the door drops power via a power interlock.
6. When handling a tape reel (for loading, manual winding, etc.) handle it as close to the hub as possible to avoid bending or warping the outer edges.
7. Whenever computer power is dumped be sure to follow up with "RESET" and "UNLOAD" on <u>each</u> tape drive. Repeat this procedure after power comes back on.
8. Do not attempt any manual operations on the tape drives while a program is being run on the computer.

II. <u>PREPARATIONS FOR LOADING THE TAPE DRIVES</u>

1. The machine must be in an UNLOAD status (see figure, next page).
   - A. The upper head section is raised.
   - B. The capstans are retracted.
2. If it is not in an UNLOAD status proceed as in Heading V. of this subsection.

III. <u>LOAD</u> Place the file reel (full reel of tape) on the left hub.

1. If file protection is desired, remove file protection ring from reel. See "Note on File Protection" above.
2. Loosen the knurled knob on the hub.
3. Press the reel firmly on the hub, then tighten the knob.
4. Thread the tape as shown in the figure.
5. Lift the sensing arm and allow it to catch in the UP position.
6. Lay the loose end of the tape in the machine reel (the right reel).
7. Depress the reel brake buttons under the left reel while winding 5 turns of tape on the right reel. Machine reel winding should be done in a clockwise direction while the tape is held firmly to the reel hub with one finger of the right hand.
8. After winding a few secure turns on the right reel remove your finger from the tape and continue turning the reel clockwise until the load point has been would well onto it. This should take several feet of tape.
   - A. The load point is a reflective spot on the face of the tape. It is easily recognizable.
   - B. The manual winding should be done by controll-



UNLOAD STATUS

TAPE ON MACHINE

ing the reel from the solid area near its hub. The spoked (cutout) areas should not be used lest the reel become bent or warped and chew up the tape edges.

9. Close the door securely.
10. Press the "LOAD/REWIND" button.
    A. The head assembly will lower.
    B. The tape will feed into the columns.
    C. The machine will wind tape in reverse until the load point is sensed, then it will stop and the NOT READY light will come on.
    D. Press the "START" button. The machine is now ready to use.

IV. <u>REWIND AND HIGH SPEED REWIND</u> (Note that it is also possible to rewind under control of the program). For manual rewind press "RESET" then "LOAD/REWIND".

1. If the machine reel contains more that one-half inch thickness of tape the rewind will occur at high speed until only one-half inch remains. The rest of the tape will be rewound at normal speed.
2. If less than one-half inch thickness of tape is on the machine reel the entire rewind will be accomplished at normal speed.
3. At the completion of a rewind the NOT READY light will come on. The tape can now be either <u>used</u> for reading or writing after pressing "START"; or it can be <u>unloaded</u> by pressing "RESET", then "UNLOAD".

V. <u>UNLOAD</u>

1. Rewind the tape to the load point by pressing "RESET" then "LOAD/REWIND".
2. When the tape is at the load point press "RESET" then "UNLOAD".
    A. The tape will be withdrawn from the columns.
    B. The head cover will raise.
3. After UNLOAD is complete open the door and unload the tapes as follows:
    A. Depress the reel brake buttons below the left reel and manually rotate the left reel in a counter-clockwise direction until all the tape is on it.
    B. To remove the reel loosen the knurled knob at the hub and pull the reel from the hub. Be careful not to bend the reel while removing it from the machine.
    C. After unloading the reel leave the machine in its present status. i.e. DO NOT push any buttons except "UNLOAD" once the tape has been unloaded from the machine reel.

BEFORE ATTEMPTING ANY OPERATIONS ON THE TAPE DRIVES RE-READ HEADING I OF THIS SUBDIVIDION CONCERNING <u>PRECAUTIONS</u>.

VIDEO SWITCH PANEL

There are twenty toggle switches at the top of T4 with connections of a semipermanent nature; they control certain functions which a programmer may wish to add or disable when using MTC in special applications. These so-called "Video Switches" are named for the fact that they control no gates but are connected directly in the coaxial video cables which transmit MTC pulses.

In each case the normal position of the switch is "Off" or down. When a special function is invoked by throwing the proper switch up, a green light just above the switch indicates the special status.

At present only the five switches named below have any function.

I. Charactron Operation switch disconnects the Charactron "end return pulse" from MTC. The Charactron is a cathode-ray tube output device in B034. Certain malfunctions of the equipment associated with it can send spurious pulses back to MTC; hence this switch should be left in the "Off" (down) position except when the Charactron is in use.

II. The Light Gun and Alarm switch is also part of the Charactron equipment. Computer operation is normal when it is "Off" (down); when it is "On" the Charactron light gun can set the alarm flip-flops, which are bits 7 and 8 of IR5.

This switch affects only the Charactron light gun, not the one to be used with the console display unit.

III. The Clear IR3 and 4 on Transfer switch, when "On" (up) causes IR3 and IR4 to be set to -0 on each tr, tro, tn, or tno instruction. If the switch is "Off" the transfer-type instructions do not affect IR3 and IR4; but in this case the pf7 instruction will clear them to -0.

IV. The Audio Zero Crossing Detector In switches are explained more fully in Section 1k. Both should be kept "Off" for normal operation; if both are "On," normal readout of IR4 is possible only when the output of the microphone connected to the zero crossing detector is positive. If the microphone output is negative, reading out of IR4 produces +0.

DISPLAY AND CAMERA

The display system is MTC's fastest output device, and is used in a variety of ways by programmers. It consists of two cathode-ray tube display units: a direct-viewing one in T5, and one in T12 equipped with a Fairchild camera under program control. The instruction ds x will cause a spot to be intensified whose vertical deflection from the center of the screen is proportional to the number in the accumulator, and whose horizontal deflection is proportioned to the number in the A-Register.

In an emergency, the Polaroid camera may be used to photograph the console display.

Power Supplies

The display system is normally on and ready whenever D.C. is on; heater power and amplifier plate power are drawn from the MTC supplies. Accelerating voltages are provided by two Northeast Scientific Company power supplies in T13. The input to these supplies is taken from Computer Room A.C., but they remain on Standby unless the +90 volt D.C. is supplied to the computer. Each supply has a three-position power switch on its panel; because of the interlocks these switches should be left On except when one wishes to work on the oscilloscopes without turning off D.C. In this case turning the power switches to Standby will leave the supply heaters on but will remove the high voltage from their outputs. The settings of the voltage control switches should never be changed except by an MTC engineer. The 10KV potential difference existing in the display system is lethal and should be treated carefully.

Controls

Associated with each display unit are three controls: Focus, Astigmatism, and Intensity. They are behind locked doors in the oscilloscope cabinets because they should never be changed except by an MTC engineer or duty technician. Keys to these doors are kept on the key board in the Meters and Probes cabinet. The usual reason for changing any voltage or intensity setting is that the photographs of the camera oscilloscope are turning out poorly, probably because of a change in film or cathode-ray tube characteristics. These situations should be reported to an MTC engineer for adjustment. A temporary readjustment to suit a special program warrants a log entry, and the system should be restored to normal before the next programmer takes over the computer.

Camera

The Fairchild Camera is permanently mounted on the display unit in T12; this unit always displays the same pattern as the one in the console, but uses a different phosphor on its screen and has a different physical layout. Either the operate 0 instruction or the Index Camera pushbutton will move the film ahead one frame. The shutter is normally open, but is closed when the film is advanced. The lens aperture of the camera is adjustable in six steps between f/2.3 and f/16. It should be changed only by an MTC engineer or duty technician; readjustments require log entires, and the system should be restored to normal before the next

AUDIO SYSTEM

The audio equipment of MTC includes a loudspeaker that can be connected to various flip-flops in the central computer, and a device called an "Audio Zero-Crossing Detector."

I. Loudspeaker and Amplifier

A. Use

By listening to this device one can tell whether the computer is running at all; if the same sequence of tones is heard repeatedly, it may mean that the machine is performing the same group of instructions over and over because of a programming error. More generally, anyone familiar with the sound of a program can obtain a quick check on its progress by listening. Bu clever programming, MTC can be made to talk, play music, or emit other strange sounds; such tricks have been used effectively to demonstrate the computer's versatility to laymen.

B. Equipment

1. Panel

The loudspeaker and its amplifier are located in the operating console at the bottom of T3. The panel contains for controls two input selector switches and treble, bass, and volume controls. In addition, there is a phone jack which may serve either as a high-impedance input to the amplifier or as a connection for an auxiliary amplifier from whatever computer circuit is selected by the input switches.

2. Switches

a. The function switch is the lower of the two input switches. It is a three-position switch.

i) In the fully counter-clockwise position (labelled "SB" for "Standby") the amplifier input is open. Unfortunately, there is a tendency toward oscillation in this condition unless the treble control is set at minimum.

ii) In the center position (labelled "TC" for "Tone Control") the selected input is fed to the amplifier through the circuit containing the treble and bass controls.

iii) In the fully clockwise position (labelled "DA for "Direct Amplifier") the selected input bypasses the tone controls, which are hence ineffectual.

b. The selector switch is the seven-position switch at the top of the panel. Whatever line is selected remains connected to the phone jack and the volume control; how it connects to the amplifier is determined by the function switch. In each case, connection is made to the "1" indicator line of the flip-flop specified below. Positions are numbered from 1-7, starting with the fully counter-clockwise position.

i) Position 1 goes to a clip lead in T3 labelled "LH Audio Out Spare." It may be attached to any indicator light in T3.

ii) Position 2 goes to a clip lead in T10 labelled "RH Audio Out Spare." It may be attached to any indicator light in T10, but at the moment it is connected to bit 6 of IR-2.

iii) Position 3 goes to bit 3 of the Accumulator. This is the position in which most operators expect to find the switch.

iv) Position 4 goes to the sign bit (bit 0) of IR-4.

v) Position 5 is the output of a 4-channel resistance mixer network whose inputs are terminals 5-8 on the input Jones strip. At the present the sign bits of IR1, IR3, and IR5 connect to terminals 5-7; if a jumper from terminal 4 to terminal 8 is added, this position will mix the sign bits of IR1, IR3, IR4, and IR5. This position is useful for playing 4-part harmony with computer programs.

vi) Position 6 is not connected.

vii) Position 7 is not connected.

3. Controls

a. The treble and bass controls are effective only when the function switch (2a above) is in the center (TC) position.

b. The volume control is effective whenever an input is connected to the amplifier, but is out of the circuit when the function switch is in the counter-clockwise (SB) position. It has no effect on the voltage supplied by one of the flip-flops to the phone jack, but will vary the amplification of a signal fed into the amplifier through the phone jack.

II Audio Zero-Crossing Detector

A. Function

The Audio Zero-Crossing Detector in T3 is a crude analogue-to-digital converter for getting into MTC information presented as an audio-frequency voltage. In MTC this voltage is usually derived from a microphone plugged into the detector chassis; its effect is to open a gate when the output of the microphone is above a certain level, and to close the gate whenever the microphone output is below that level. The discrimination level is usually near zero, so that the gate is open when the audio voltage is positive, but closed when the voltage is negative.

B. Program

To make use of the detector one must write a program to interrogate it periodically and store the information obtained. This can be done as follows:

There are two switches on the Video Switch panel in T4 labelled "Audio Zero-Crossing Detector In", which should always be in the same position. When they are "Off" (both down) the detector has no effect on computer operation; when they are "On", the pulse initiating the read out of IR-4 is made to pass through the gate. IR-4 has the octal address 77 on the read-in plugboard; thus the instructions

sof 0

ca 77

will produce in the accumulator the true contents of IR-4 if given during a positive half-cycle of the audio voltage, but will produce +0 in the accumulator if given during a negative half-cycle. By throwing the proper video switches the transfer-type instructions other than <u>to</u> can be made to set IR-4 to -0; hence the programmer can arrange to have all "1's" in the accumulator if the microphone output was positive, all "0's" if it were negative. See section li, "Special Video Switches."

C. Controls

These controls are all located on the front panel at the top of T3, and are discussed in order, beginning at the left. Descriptions of their uses are sketched, and experimentation is necessary in every application.

1. "Back-front" Toggle Switch

   This is located just above the microphone connector and connects the detector either to it or to the one on the rear of the chassis. The detector has a high-impedance input suitable for a crystal microphone.

2. "Gain"

is a potentiometer just to the right of the front microphone connector; it is in the circuit only when the switch described in 3. below is in the "blank" position. Since the detector is basically an amplifier of the "Infinite gain" or "saturated" type, this setting should not be critical. A setting of 5.5 has been used satisfactorily for normal speech.

3. The Capacitor Switch

This switch is just to the right of the gain potentiometer, shunts capacitors of various sizes for .001µfd to .01µfd across the audio circuit, thus limiting high-frequency response. Experimentation in each application will determine the best setting. The fully counter-clockwise position connects the gain control into the circuit.

4. The "Gating Level" Potentiometer

This is to the right of the capacitor switch and is unlabelled. It adjusts the level above which the audio voltage must rise in order to open the gate. Too low a setting will cause the gate to be opened by noise and stray signals; too high a setting will lose information by preventing it from opening except on audio peaks.

5. Polarity Switch

To the right of the gating level potentiometer are the coaxial connectors for the input and output pulses to the gate. These jacks are in parallel with similar ones on the back of the chassis, and these latter jacks are the ones that are permanently connected to the computer. The associated toggle switch controls the output pulse polarity; it should be thrown to the left.

PREVENTIVE MAINTENANCE PROCEDURES

1. Marginal Checking: Lines 500-947

A. General

Marginal checking is a technique of preventive maintenance wherein computer failures are anticipated and located by measuring the tolerance of various circuits to variations in power supply voltage. In the usual procedure a test program is run on the computer, and one voltage to some small section of the computer is varied by means of the marginal checking circuitry. The difference between the normal voltage and that at which the program stops running is called the margin; any narrowing of margins is noted in the Preventive Maintenance Notebooks, and may be cause for troubleshooting.

B. Amplidyne Control

Variation is accomplished by adding to the supply voltage the output of a variable Amplidyne generator, the voltage of which is constantly monitored on a zero-centered voltmeter on the Amplidyne control panel in T10. The Amplidyne is turned on and off with a toggle switch at the right of the Amplidyne control panel, and there is a red pilot to indicate whether it is running. Its output may be connected in series with the Ground, +90V, +150V, +250V, -300V, or -150V supply lines by means of the proper white pushbutton on the meter panel.

The meter range may be changed by a switch below the meter to a full-scale value of 100, 50, or 10 volts.

To the right of the meter is a "Smooth-Step" toggle switch. When it is "up", Amplidyne voltage can be varied from -100 to +100 by means of the "Smooth Margins" knob beneath the meter; when it is down, deviation of the selected line from normal voltage is controlled from 0-90 in steps by means of a strip switch. There are two strip switches: one with red buttons for positive deviation, effective when the "Polarity Selector" switch is on "+"; and one with black buttons for negative deviation, effective when the polarity selector switch is on "-".

C. Line Selection

The marginal check panel consists primarily of 14 rows of line selection switches, with 16 switches in each row. Each switch is labelled with two line numbers; one above and one below; these numbers range from 500-947. When the switch is down, both lines controlled by it are on normal power. When it is up, marginal power is supplied either to the line named above the switch or the one below it, depending on whether the extra switch at the left of the row is up or down.

To the left of each row is marked the voltage normally supplied to the lines in that row. A line selection switch has no effect unless the Amplidyne is connected to the voltage normally supplied to that line, but one should always leave line selection switches down after checking.

Because of switching transients, the line selector switches should not be thrown while the computer is running.

D. Paperwork

There are in the Preventive Maintenance Notebooks pages headed "MTC Marginal Checking Record" for each of the lines numbered 500-947 that is connected. This page also gives the voltage of that line, and thus the information of where to find it on the marginal check panel; a list of units checked by it; the proper program to be used; and references to other pages for the same line. On the page are columns for the Last Set Margin (that is, the values most recently decided upon as acceptable minimum margins), the Failure Margin, and the date. If, on a given date, the margins for that line are wider than the set margins, the date is stamped in the proper column to indicate that the line has been checked, and no further entry is made. If, on the other hand, the margins have narrowed below the last set margin, the margins are noted in the column under "Failure Margins", and an entry is made on the separate sheet headed "MTC Marginal Checking Report" for that day, giving the line number, the failure margins, the program run, and any remarks. Thus the "MTC Marginal Checking Report" contains a list of all lines checked on a particular day that were below their last set margins, together with the margins actually obtained and any comments that the checker may wish to add.

It sometimes happens that, when one starts with the Amplidyne voltage at zero and gradually increases deviations, the program fails at voltage deviations somewhat wider than those at which it can be started over. This phenomenon is called hysteresis, and if it involves differences greater than five volts, is to be recorded under "Comments" or "Remarks", together with the widest margins at which the program can be started over.

E. Procedure

1. Turn on the Amplidyne by means of the "On - Off" toggle switch.
2. Find the "MTC Marginal Checking Record" page in the Preventative Maintenance Notebook for the line to be checked.
3. Connect the Amplidyne to the proper power supply voltage by means of the strip switch with the white pushbuttons.
4. Throw the switch at the end of the proper row up or down, depending upon whether the number of the line appears above or below the selector switch.
5. Put the Margin Selector toggle switch in the "Step" (down) position.
6. Start the test program running.
7. Select the desired polarity with the polarity switch and the Last Set Margin voltage on one of the strip switches - red for positive, black for negative.

8. If the program continues to run at the Last Set Margin, merely mark the date on the "MTC Marginal Checking Record" and check the other polarity. If the program fails, record under "Failure Margins" the narrowest margin at which the program won't run on both the record and report sheets; be sure to record the name of the program in the report sheets. Push the next voltage button to the right, thus decreasing the deviation. If the program cannot be started over at this margin, there is hysteresis, a fact that should be noted under "Comments" or "Remarks", together with the widest margins at which the program can be started over.

   Note: Because of switching transients, the program will stop every time a line selector switch is thrown.

II. Marginal Checking: Sense Amplifiers

In T9, just to the left of the amplidyne control panel, is the Sense Amplifier Marginal Check Panel, consisting of two voltmeters with associated voltage control knobs, and toggle switches, labelled from 0 through 16, corresponding to the 17 sense amplifiers in the core memory. When a given toggle switch is down, the corresponding sense amplifier is receiving for bias the voltage indicated on the left hand voltmeter (the one labelled "Sense Amplifier Bias"); if the toggle switch is up, the corresponding sense amplifier receives for bias the voltage indicated on the right hand meter. The adjusting knobs are potentiometers connected to the normal computer D.C.; therefore, it is not necessary to run the Amplidyne when checking the sense amplifier bias. It is customary to leave all 17 sense amplifiers connected to the left hand voltmeter; the procedure in checking is to note the voltage at which the program stops rather than the excursions from normal. The paperwork is the same as that for lines 500-947; except that, if acceptable margins are obtained when varying all 17 lines together, the meter is adjusted to the mean of the two voltage limits, and this adjustment noted under "Remarks". If unsatisfactory margins are obtained, one can try to locate the offending sense amplifier or memory plane, by varying one bias at a time with the right hand knob and meter.

If the sense amplifier bias switches are thrown while the computer is running, switching transients will cause Core Parity Alarms.

III. Checking Cathode Followers

In order to check a cathode follower, the flip-flop driving it must be put in the proper state for the cathode follower to be "up". One can then measure with a vacuum tube voltmeter the difference between the grid voltage and the output (cathode) voltage. If the cathode is 0.5 volt or more positive with respect to the grid, the cathode follower is acceptable; if not, the cathode follower should be replaced. In either case an entry should be made in the appropriate cathode follower sheet in the Preventive Maintenance Book.

In most cases the grids of cathode followers operate between levels of +10 volts and -30 volts; thus, when a cathode follower is checked, its grid should be at +10 volts and its cathode slightly more positive. There are two exceptions to the above. One is a group of cathode followers in the Memory Address Register, whose levels are -140 volts and -180 volts instead of +10 volts and -30 volts. The other exception is a group of "Mod II Cathode Followers" in Panel Memory, whose outputs are tapped down 10 volts on the cathode resistors and are thus about 0 volts and -40 volts.

The location of the flip-flop driving each cathode follower is given on the cathode follower sheet. In some cases it will be easiest to check all the cathode followers associated with a register by storing all "one's" in that register and checking cathode followers on the "One" side, then storing all "Zero's" and checking cathode followers on the "Zero" side. This can most easily be done from toggle switch storage. Some flip-flops must be set individually with the "tweeker", a portable device designed to provide the proper pulse to a clip lead; in some cases, such as in Memory Control, it is necessary to disconnect the input cables from the flip-flops in order that they remain in the desired state.

One should take care that he does not complement the flip-flop when connecting the voltmeter to the circuitry.

QUESTIONS

1. Describe the differences among "Start Over", "Start at 40", and "Restart".

2. In what way does the blowing of a circuit "grasshopper" fuse affect the rest of the computer? How does it do this? How do you recover from this type failure?

3. During air conditioning failure what are the maximum allowable temperatures and where are they measured?

4. Describe the steps necessary to use LR3 as register 0-44.

5. The computer stops on a Core parity alarm. How was this alarm detected and what are possible sources of the trouble?

6. What is the difference between "Flexo" tape and "4-6-6" tape?

7. What is the purpose of the card machine plugboard.

8. Can valuable information on magnetic tape be protected against destruction from accidental writing? Explain.

9. What is the purpose of the "Video Switches" on the console?

10. Computer power has dropped to Standby of its own accord; what is the status of the high voltages to the display scopes? Is it safe to work on display?

11. Describe audio monitoring of MTC programs.

12. Explain the steps necessary to select Marginal Checking Line #597 and determine its <u>exact</u> positive and negative margins.

13. Describe "loading" a magnetic tape drive.

14. How do you install a new roll of paper tape on the Flexowriter? What happens if the old roll is allowed to run out completely?

15. What happens if the card machine runs out of cards while reading or punching?

16. Describe the process of checking Marginal Checking Line #838 to predetermined excursions of +40 Volts and -30 Volts.

17. How does each of the following appear in a register of indicator lights? ca 20, +35742, tr 2765, 1.76543 (numbers are in <u>octal</u>)

18. In what way are "Stop Reader" and "Deselect Magnetic Tape" similar?

19. Are there circumstances under which certain alarms can be ignored? If so, how is the computer directed to ignore them?

20. Describe the process of "reading in" a program on paper tape.

21. What is a Sensitrol? What purpose does it serve?

22. The switch for bit 0 of register 0-0 is defective (open). How can you start a program stored in core memory?

23. Is it possible for the air conditioning control to call for cooling and heating at the same time? Explain.

24. What alarm is affected by instructions pf 4 and pf 5? Explain.

25. What special check is made on Mod 1 cathode followers? Why?

26. How is the Zero-Crossing Detector used?

27. How do you prepare the Fairchild Camera for use?

28. When is use of the "Clear CPC" required? Why?

29. What happens if the compressed air supply for the air conditioning control fails?

30. Describe how you would set up the card machine for reading. For punching.

31. Describe the "Standby" condition of MTC power.

32. Describe "unloading" a magnetic tape drive.

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MTC Service Manual, Section 2

PROGRAMMING FOR MTC

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c. Simple Arithmetic Operations

d. Comparisons

e. Word Manipulation

f. Loops

g. Programmed Switch

h. Indexing

i. Audio Output

j. CRT Display

k. The Automatic Camera

l. Memory Selection and Use

m. Auxiliary Storage; The Magnetic Drum

n. Paper Tape Equipment

o. IBM Card Equipment

p. Magnetic Tapes

q. Dispatchers

r. Use of Stored Tables

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t. Planning the Program

w. Flow Diagrams

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w. Fixed and Symbolic Addresses in coding

x. Conversions

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z. Modifying Existing Programs

A. Manual Intervention

B. MTC Instructions and Their Variations

PROGRAMMING FOR MTC

Y. Questions

Z. Bibliography

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MTC Service Manual, Section 3

RECORDS and PROCEDURES

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a. Computer Schedule

b. "Live Messages" Board

c. The Operation Log

d. Film Requests

MTC Personnel

Work Requests

e. Modifications

f. Construction Requisitions

g. Purchase Requisitions

h. Work Orders

i. Tape and Card Preparation

Computer Operation

j. Technician Work Schedule

k. Computer Watch

l. Checkoff Lists

m. Incident Reports

n. MTC Log Reports

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Documentation

p. Memorandums

q. Biweekly Reports

r. Reliability Reports

s. Standard Symbols for Logic

t. Prints and Print Files

u. Wiring and Cabling Schedules

v. Timing Charts

HOLLERITH LOG RECORD

The information contained in Incident Reports, the MTC Log, and Component Test Reports is valuable chiefly for trouble-shooting and other short-range maintenance; it is also useful, however, as a detailed history of the computer's operation, needed for evaluation of design safety factors and long-range component reliability. As run-of-the-mill faults are corrected, intermittent failures become responsible for most incidents, and these may require a detailed statistical analysis.

To make logged information available for quick statistical analysis, a system of Hollerith cards has been set up. A detailed table of the code is given below, but a general description may be helpful.

A new card is started each day at midnight, and runs until the first incident or until the first change in disposition of the computer. Subsequent cards cover succeeding periods of time, so that the entire day is accounted for. If the computer performed satisfactorily in an interval, the time is described on a "useful time card, type A." If an incident occurred, the useful time card is terminated, and the period of failure is accounted for on an "incident card, type "B (alternate)." The cards are distinguished by column 4, which is blank for a useful time card, but contains a dash (11 punch) for the incident card.

Cards are prepared by a member of the MTC office staff. The first step is to scan the log for the day under study, preferably after the MTC Component Test Reports have been returned from Component Test. The MTC office has standard 80-column sheets with headings corresponding to the type A and type B cards, and with one line for each card. The part of the task involving judgment is to fill out these sheets from the log, using the outline below as a guide. Several items have been deleted recently, and the corresponding columns should be left blank. In entering numbers, left zeros should in general be included.

The actual key punching is simple, once the 80-column sheets are completed.

USEFUL TIME CARD - TYPE A

ITEM	COLS.	INFORMATION	REMARKS
1.	1-3	IBM Room Identification, "008" for MTC	
2.	4	No punch	"11" punch (dash) here for incident card
3.	6	Day of Week "1." Monday "2." Tuesday "3." Wednesday "4." Thursday "5." Friday "6." Saturday "7." Sunday	
4.	8-12 8 9-10 11-12	Date Year (low-order digit) Month Day of Month	
5.	14-15	Card number for the day	Starts with "01". Card "01" must be a Useful Time Card; if computer is down at midnight, make card "01" a Useful Time Card with Time Start and Time Finish the same. Make card "02" an Incident Card starting at 0000.
6.	17-20	Time Start	In the case of routine component replacement involving no lost time, a single Useful Time Card will be punched for the whole maintenance period, followed by one incident card for each item replaced.
7.	22-25	Time Finish	
8.	26	Punch "A" if DC was Off	Item added 1 May 1957.

ITEM	COLS.	INFORMATION	REMARKS
9	27-28	System Assignment	
		"A." Program Operation	
		"a." Conversion "b." DDT-DDR "c." LRI "d." Display "e." GFI	These subcategories deleted 1 May 1957. If "A" punched is col. 27, leave col. 28 blank.
		"B." Program Checking and Analysis "a." Post Mortem	
		"C." Marginal Checking	If any marginal checking is done, punch "C" even though a program listed under "E" is run.
		"D." Preventive Maintenance	
		"E." Test Programs "a." MP 60 (Cores) "b." T15 (Drum) "c." T5 (Ziegler's scope test) "d." T12 (PETR) "e." Card Machine Test "f." Flexo Test (print or punch) "g." MC-100	Punch "E" only if only a few programs are run. For complete checkout, punch "H" after 1 May 1957.
		"h." Alarm System Test	"h" not yet written.
		"i." T6 (Magnetic Tape Test)	Added 1 May 1957.
		"j." Conversion Test	

ITEM	COLS.	INFORMATION	REMARKS
		"F." Engineering Changes "a" Modifications "b." Installation of New Equipment "c." Development of New Equipment "d." Improvement - MTC "e." Improvement - not MTC	
		"G." Unscheduled Time	
		"H." Computer Checkout	Added 1 May 1957. If computer checkout is in progress, punch this rather than making a separate card for each program listed under "E".
10.	30-31	Incident "A". Successful Operation "B". Successful Operation - interrupted "a." Punch error "b". Print error "c." Camera "d". Console Scope "e." Camera Scope "f". Card Machine "g". PETR "h". Drum "i." Charactron "j". Power Supply "k". Flexo mechanical failure "l" DDR-DDT "m." Accidental "n". Unknown	After 1 May, 1957, always make out a type B card for failure, even no lost time incident. Hence, punch "A" in column 30, leave cols. 30-37 blank.
11.	33-34	Items under Incident	
12.	36-37	Distributed Lost Time	

ITEM	COLS.	INFORMATION	REMARKS
13.	38-40	Unused Scheduled Time	If a programmer leaves early, or starts late not because of overtime of his predecessor, the unused time is punched in cols. 38-40 in hours, tenths, and hundredths.
14.	42-43	Alarms A. Core Parity B. Drum Timing C. Fuse D. Drum Parity E. Card Copy F. Illegal Overflow	Deleted 1 May 1957
15.	68-73	Filament Hours	Record full 6 digits. Readings should be taken once each day, as near midnight as possible, and recorded only on the first card each day. If taken early or late, readings can be extrapolated to midnight.
16.	75-80	Plate Hours	

INCIDENT CARD - TYPE B (ALTERNATE)

ITEM	COLS.	INFORMATION	REMARKS
1-9.	1-29	Same as for Type A Card	Denote type B card by "dash" ("11" punch) in col. 4.
2.	4	"Dash" ("11" punch) Here for Type B Card	Column four blank on type A card.
10.	30-31	Incident A. Failure-explainable a. Continuous B. Failure-unexplainable b. Intermittent C. Component replacement D. Emergency Maintenance (MTC time overrun)	
11.	33-34	Item under Incident	When more than one component is replaced at one time, each is described on a separate card. Number in cols. 33-34 starts at"01" for the first card of the series if replacement occurred during othen than scheduled MTC time; otherwise the series starts with "02". The condition for tallying cards in computing lost time is that "01" appear in col. 33-34 of the first type B card. Always number the first card "01" if a failure occurred.
12.	36-40	Physical Location	
	36	Frame letter (S,T,A,C)	
	37-38	Rack number	
	39-40	Panel number	

ITEM	COLS.	INFORMATION	REMARKS
13.	42-47	Panel Name	See standard list of abbreviations.
14.	49-53	Panel Serial Number	For test equipment panels, omit the 3-digit number preceding the hyphen.
15.	55-60	Component Identification "A." Rectifier (selenium) "B." Socket "C." Capacitors "D." Diode "E." Terminal-terminal strips "F." Lug "G." Pushbutton "H." Video cable "I." Pilot lamp "J." Jack "K." Relay "L." Induction "N." Bolt-nut "O." Other (specify) "P." Plug "R." Resister "S." Switch "T." Transformer "V." Tube (any type) "W." Wire "X." Circuit breaker	
16.	62-63	Nature of Defect (62) Mechanical "A." Broken "B." Loose "C." Worn "D." Bent "E." Dirty "F." Dug "G." Burnt Out "H." Bad Solder "I." Out of adj. "J." Timing "K." Corroded "L." Leaky "M." Jammed	This can often be determined from returned Component Test Reports if not from log itself.

ITEM	COLS.	INFORMATION	REMARKS
		Nature of Defect (63) Electrical "A." Shorted "B." Open "C." Low back res. "D." High forward res. "E." Intermittent "F." Gone to air "G." Low margins "H." Microphonic "I." Unknown "Z." No defect	
17.	65	Cause of Defect "A." Manufacture "B." Accidental "C." Incorrect application "D." Improper installation "E." Marginal excursion "F." Incorrect wiring "G." Other component failure "I." Age "J." Faulty workmanship "K." Out of adjustment "L." Unknown	Leave blank if no defect.
18.	67	Corrected By "A." Replacement "B." Repair "C." Modification "D." Adjustment "E." Cleaning "F." Removed "G." Restored to operation but not corrected "H." Disappeared spontaneously	
19.	69-70	Why Suspected--Symptoms "A." Alarm "a." Core Parity "b." Drum Timing "c." Drum Parity "d." Card Copy	

ITEM	COLS.	INFORMATION	REMARKS
		"B." Fuse Blown "a." Memory "b." Power "c." Marginal Checking	
		"C." No Read-in	
		"D." No Print Out or Punch Out "a." Incorrect print "b." Incorrect punch	
		"E." Program Does Not Run	
		"F." Bad Spot on Display "a." No spot "b." Low intensity "c." Out of focus "d." Excessive fly-back intensity "e." Deflection non-linearity	
		"G." Operation Observation "a." Sight "b." Sound	

ITEM	COLS.	INFORMATION	REMARKS
		"c." Smell "d." Touch	
		"H." Marginal Checking	
20.	72	How Isolated "A." Reliability Program "B." Special Program "C." Cyclic Program "D." Signal trace "E." Neon indication "F." Pulse-by-pulse "G." Marginal excursion "H." Knowledge "L." Logical deduction "M." Component tapping "N." Visual observation	
21.	74-78	Component Test Report or Mod Notice Number Col. (74) - "M" if mod. notice number - first digit if log report number	

STANDARD ABBREVIATIONS FOR PANEL NAMES

AC Add High Speed Carry Complement Mixer	ACACCM
AC Add High Speed Carry Gates	ACAHCG
AC Carry In and Out Gates Mod I	ACIOG
AC Carry Mixer	ACCM
AC Complement SR, CR Mixer	ACCSCR
AC and PM Outgates and MD Inverter, Mod II	ACPMOG
AC Partial Sum Cathode Follower	ACPSCF
AC Shift Gates Mod II	ACSG2
Alarm Indicator Panel Mod II	ALIP2
Alarm Relay Panel	ALRP
Alarm Suppression Gate Panel	ALSGP
Alarm Suppression Switch Panel	ALSSP
Alarm Position Counter and BR Ingates	APCBRI
Angular Position Counter Crystal Mixer and Jack Panel	APCCMJ
AR "0" Cathode Follower	AROCF
AR "1" Cathode Follower	ARICF
AR Input Mixer Mod II	ARIM2
AR Mixer and Jack Panel	ARMJP
AR "1" Out To CS, ECS, SC PAR MAR Gates	ARIOG
AR "0" PAR and MAR PC "0" To PAR and MAR	AROPCO
AR To TAF Gates	ARTAFG
Audio Amplifier	AA
Audio Zero Crossing Detector	AZCD
Automatic Camera Control	AUCC
Automatic M.D. Digit Selector	AMDDS
AMD Mixer and Jack Panel	AMDMJP
B.R. Cathode Follower	BRCF
B.R. Mixer and Jack Panel	BRMJP
BR Shift Gates Mod II	BRSG2
Buffer Amplifier Panel Mod I	BAP I
Buffer Amplifier Panel Mod II	BAP 2
Camera Control Rectifier	CCR
Card Machine	CRDMX
Card Machine to BR Mixer and Jack Panel	CABRMJ
Card Machine Read Gate and Punch Thyratron	CARGPT
Cathode Follower Panel Mod II	CFP2
Cathode Follower Panel Mod IV	CFP4
Cathode Follower Panel Mod V	CFP5
Cathode Follower Panel Mod VI	CFP6
Charactron Control Mixer and Jack Panel	CHCMJP
Clock and Clock Control	CCC
Coincidence Detector Panel Mod II	CODP2
Command Buffers	CB
Command Mixers	CM
Completion Pulse Generator	COMPG
Control Switch Flip Flops and Power Cathode Followers	CSFFPC
Control Switch Matrix	CSM
Cyclic Control	CC

STANDARD ABBREVIATIONS FOR PANEL NAMES (Contd.)

D.C. Distribution Box	DCDB
Delay Line Amplifier	DLA
Delay Line Panel Test Equipment	TEDLP
Drum Address Register Mixer and Jack Panel	DARMJP
Drum Address Register Selection Matrix	DARSMA
Drum Field Switch	DFS
Drum Field Register Output Matrix	DFROMA
Drum Rotor Panel	DRP
Drum Read Outgates	DROG
Drum Read Switch	DRS
Drum Timing Panel	DTP
Drum Write Register Ingates	DWRIG
Extended Control FF	ECFF
Extended Control CF	ECCF
Ferranti PETR Clutch and Brake Control	PTRCBC
Ferranti PETR Control	PTRCP
Filament Power Panel Mod III Test Equipment	TEFPP3
Filament Transformer Mounting Panel Mod I, III	FTMPI (-3)
Filter Panel Power Room	FP
Flexowriter Control	FLEXC
Fuse Panel-Core Memory Filaments	FPCMF
Gate and Delayed Pulse Generator Test Equipment	TEGDPG
Indicator Light Panel Mod I, II (Flip-Flop)	ILP1 (-2)
Indicator Light Panel Tape Adaptor Frame	ILPTAF
Inhibit Gate Generator	IGG
Intensification Gate Amp.	IGA
Interlock Power Supply Panel	IPSP
LR 1 Mixer and Jack Panel	LR1MJP
LR 1 and 2 Ingates	LR12I
LR 1 and 2 Outgates Mod 2	LR1202
LR 1 to 3 and LR 2 to 4 Gates	LR1324
LR 2 Mixer and Jack Panel	LR2MJP
LR 3 and 4 Cathode Follower Mod 1	LR34CF
LR 3 and 4 Ingates	LR34I
LR 3 and 4 Outgates	LR340
LR 3 Mixer and Jack Panel	LR3MJP
LR 4 Mixer and Jack Panel	LR4MJP
LR 5 In and Outgates	LR5IO
LR 5 Mixer and Jack Panel	LR5MJP
Magnetic Drum	DRUM
Magnetic Tape Control	MTC
Medium Mode and Unit Gates	MMUG
MC Blown Fuse Indication Panel	MCBFIP
MC Control Panel	MCCP
MC Fuse Panel	MCFP
MC Toggle Switch Panel	MCTSP
Memory Control	MC

STANDARD ABBREVIATIONS FOR PANEL NAMES (Contd.)

Memory MC Control Panel	MMCCP
MAR Cathode Follower	MARCFP
MAR Decoder Panel	MARDP
MAR Matrix Fuse Panel	MARMAF
Memory Plane Mod 3	MP3
Multivibrator Pulse Generator Test Equipment	TEMVPG
Parity Check Panel A (B)	PYCKPA (B)
PAR Crystal Matrix	PARCMA
PAR Crystal Mixer and Jack Panel	PARMJP
Panel Memory Cathode Follower	PMCF
Panel Memory Conversion Matrix	PMCMA
Panel Memory Address Line	PMAL
PFR and OFR	PFROFR
Plugboard Storage	PBS
P.U. Cathode Follower Mod I, II	PUCF1 (-2)
P.U. Digit Plane Driver Mod II	PUDPD2
P.U. Drum Field Driver	PUDFD
P.U. Drum Read Amplifier Mod I	PUDRA
P.U. Drum Read Driver Mod I	PUDRD
P.U. Drum Write Driver Mod I	PUDWD
P.U. Drum Writer, Left Hand, Mod I	PUDWLH
P.U. Drum Writer, Right Hand, Mod I	PUDWRH
P.U. Dual Buffer Mod I	PUDB
P.U. Flip Flop Mod II	PUFF2
P.U. Gate Amplifier	PUGA
P.U. Gate Tube Mod II	PUGT2
P.U. Card Machine Read Gates	PUCARG
P.U. Register Driver Mod III	PURD3
P.U. Sense Amplifier Mod II, IV	PUSA2 (4)
PIUMP 19"	PP19
PIUMP 45"	PP45
PIUMP Digit Plane Driver Mod II	PPDPD2
PIUMP Drum Field Driver	PPDFD
PIUMP Drum Writer	PPDW
PIUMP M.A.R.	PPMAR
PIUMP Sense Amplifier Mod II	PPSA2
Power Distribution Panel Mod I, II, III	PDP1 (-2, -3)
Probe System Jack Panel	PSJP
Program Counter in-out Step Counter In-gates	PCSCG1
PC and SC Carry Gates, PC to LR 2 Ingates	PCSCG2
PC and SC Mixer and Jack Panel	PSCMJP
Push Button Panel	PBP
Regulator Amplifier	RG
Selection Matrix, Core Memory	CMSMA
Sequence Gates	SG
Sequence Switch	SS
Soroban Punch	SP

STANDARD ABBREVIATIONS FOR PANEL NAMES (Contd.)

Start Stop Panel	SSTP
Tape Adaptor Frame	TAF
Ten Bit Decoder and Line Driver	BDLD10
Toggle Switch Storage	TSS
Video Switch Panel	VSP

MODIFICATIONS, Permanent

Proposals for permanent changes to MTC must be submitted on the Standard "MTC Modifications" form (DL-603) and must be properly authorized before any of the work is started. No modification is considered complete until it has passed through all the stages described below and has been officially tested and approved.

An authorized modification notice is required for any permanent change to the computer system as made available to MTC users. This includes all system auxiliaries that can in any way affect the availability of the computer in its entirety to its users.

A modification may be requested by anyone proposing a change in logic, circuitry, or physical arrangement. Direct replacement of a damaged or suspect component does not constitute a modification and should be handled by the "MTC Log Report" according to the procedure described under that title.

Each modification notice must contain all the information necessary for its completion. This information usually includes additional attachments such as corrected prints, lists of Serial Nos., the print change notice, informal sketches, and may also include references to related modification notices. All blanks at the top of the form are to be filled in even if only by words such as "none" or "does not apply". Be sure to state clearly and concisely the reason for the modification. The originator of a modification notice retains the yellow copy for his file and submits the white and the pink copies to the MTC Office (R. B. Pugliese) for checking and authorization.

When submitted to the MTC office for authorization, modification notices will be checked for conformity with Section standards of logic, circuitry, mechanical design, and installation practices. Although various members of the Section may investigate a given modification proposal no work on the modification may be done until the notice has been "Authorized By" H. L. Ziegler.

After authorization of a modification the white copy and the print change notice are held in the MTC office in the "Pending Modifications" file until the work of the modification has been completed. The pink copy and all attachments (except the print change notice) together with the necessary components are turned over to J. J. Lynch for assignment of the work to the proper technicians. Each technician who works on the modification initials the proper line on the notice form. Upon completion of the modification, the work is inspected for workmanship and then is checked by performance tests of the affected portions of the computer. Anyone may be designated to do part or all of this checkout but the modification is not considered complete until it has been signed by A. D. Hughes as "Tested and Approved".

The pink copy with attachments, completely initialed and signed, is returned to the MTC office. At this point the information on this copy is used to correct all pertinent prints - those in MTC files as well as the "marked-up" print submitted with the print change notice to Drafting.

The pink copy is now held in the "Pending Print Revisions" file until Drafting has completed the print corrections and corrected prints are in the MTC files. At this time the white copy of the modification notice is removed from the "Pending Modifications" file and is stapled to the pink copy. The two copies are then filed under Completed Modifications where they will be retained for reference pusposes. Although no specific length of time has been set it is expected that these completed forms will be kept on file for a year or more. Anyone referring to these completed forms should bear in mind that the only true copy of the modification as actually performed is the pink copy.

MODIFICATIONS, Temporary

Proposals for temporary changes to MTC should be submitted on "Inter-Office Correspondence" forms as "Temporary Modification to MTC". Such requests for modifications must be properly authorized before any work is done.

Temporary modifications are those done to evaluate proposed design changes, to aid in difficult troubleshooting situations, or as a "quick-fix" of intolerable conditions. Specific details should be given when known. If it is not possible to specify individual components or the exact nature of the change the request should localize the area affected and describe the changes to the extent known.

The originator of a temporary modification request should retain the yellow copy for his file and submit the white and the pink copies to the MTC Office (R. B. Pugliese). After proper authorization of the request by H. L. Ziegler or A. D. Hughes , the pink copy will be returned to the originator as his work sheet. The white copy will be held in the MTC Office as a record of an incomplete temporary modification.

When the modification work has been done the pink copy should be revised to provide an accurate description of the work as actually done. The pink copy should then be returned to the MTC Office (R. B. Pugliese).

Special tags are kept in the computer room and are to be attached to the affected area at the time of the temporary modification. On this tag should be written a brief description of the modification, the name of the person originating it, and the date on which the work was done.

Changes that may affect users of the computer should be recorded on the "Live Messages" board (located near the operation console). Such messages should include the date and the initials of the person writing it.

Evaluation of a temporary modification must be completed within two weeks after the actual modification work is done. By the end of this period everything affected must have been restored to its original condition, or the changes made must have been written up as a permanent modification. In either case, once permanent conditions have been re-established the tag and the "Live Message" are removed and the temporary modification is completed by inspection and checkout of the work. When satisfactory, the work sheet (pink copy) will be signed "Tested and Approved" by A. D. Hughes and will be returned to the MTC Office. At this point the white copy will be withdrawn from the file of "Incomplete Temporary Modifications" to close out that modification as complete.

CONSTRUCTION REQUISITIONS

Construction requisitions (form DL-73-3) are required when requesting work from one or more of the following:

1. Sheet Metal Shop
2. Machine Shop
3. Electrical Shop
4. Inspection Shop
5. Outside Vendor

Items not listed above are handled as Work Orders or Purchase Requisitions by procedures described under those headings.

All Construction Requisitions must be processed through the MTC Office (R. B. Pugliese) for necessary signatures and for use in expediting, stock records, etc. The original copy is then submitted to the Production Control Office (PCO, M. J. Bright, D-139). Here the remaining information such as estimated times and completion dates are added by PCO. New copies are then typed and sent to those concerned. For MTC one copy is sent to the MTC Office for its files and another copy goes to the originator. The MTC copy is kept on file for reference purposes even after all work requested has been completed.

Individuals may either write their own Construction Requisitions to be submitted to the MTC Office or they may supply that office with the necessary information as described below and let the office do the required paper work. Only one job per requisition form is allowed.

Preparation of Construction Requisitions:

A. Box in upper right corner of form

1. Originator signs indicated line
2. PCO supplies proper CR number (when request reaches PCO)
3. MTC Office fills in Date, Project No., and Account No.

B. Table to left of box (see A above)

1. Purpose - - - - - - - - Check proper item
2. Type of Construction - " " "
3. Shop - - - - - - - - - - Check one or more items, as required
4. Est. Time - - - - - - - To be added by PCO
5. Approved by - - - - - MTC Office supplies necessary signatures

C. Name of Assembly - name of device being constructed. This must be the same as used on drawings if such exist.

D. Table covering rest of form

1. Drawing No. - - - - - Supply print number only; PCO will acquire prints as needed.
2. Description of part - Names of sub-assemblies or component parts illustrated by corresponding print. Name must be same as on print, if given there.

If assembly is identified by serial numbers the starting serial number for the requested quantity must be given.

3. No. Reqd. Quantity of this item required. Originator usually specifies only number of complete assemblies desired; quantities of component parts are entered by PCO.

4. Date Needed Be realistic!

All remaining items are completed by PCO.

In certain special cases and at the discretion of PCO some construction requisitions have been accepted with sketches when formal prints did not exist. Usually this was done to avoid excessive delays in critical items. Such exceptions should be considered as "special privilege" and something not to be abused. Always use formal prints when they exist or there is sufficient time for them to be drafted.

PURCHASE REQUISITIONS

The Purchasing Department can obtain material not carried in the Division 6 Stock Room or unavailable from the Stock Room in sufficient quantity.

I General Procedure:

A Requisition Work Sheet, form DL-998-2, should be obtained from the MTC office, filled in according to the instructions below, and returned to the MTC office, B-155 (R. B. Pugliese). The office staff will complete the requisition, obtain necessary signatures, and forward it to the Purchasing Department, via H. B. Morley of Division 6 Material Requirements Office, D-109.

II Preparing a Purchasing Requisition Work Sheet:

A. Upper Left Hand Corner of Form

1. Supplier--will be filled in by Purchasing Department unless a request is being made for a special item which is handled by one vendor or distributor. This usually happens only when contact with the distributor has been made by the requisitioner.
2. Attn. of--applies only when direct contact with vendor representative is made.

B. Upper Right Hand Corner

1. Date--date form is prepared.
2. Date Delivery is Required--approximate date.
3. Bldg.--Bldg. E Receiving Room (filled in by MTC office).
4. Attention--filled in by MTC office.
5. Account No.--filled in by MTC office.

C. Center Section

1. Quantity
2. Description--clear, concise, and complete description.
3. Price--if available.

D. Material to be Used for--state reason

E. Bottom Section

1. Wanted by--to be filled in by MTC office.
2. Group--Group 64.
3. Bldg.--B.
4. Room--B-155.
5. Telephone--7231.

A sample Requisition Work Sheet, shown in the form in which it should be presented to the MTC office (R. B. Pugliese) for expediting, is shown on the next page.

III Book Purchase Requests:

The Lincoln Laboratory will not purchase books for individuals but will acquire and put in its library, A-229, most books on request. The Book Purchase Request, form plf-478, is self-explanatory; when completed, it should be turned in to the MTC office.

MASS. INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY
DIVISION 6

REQUISITION WORK SHEET

Suggested Supplier ____________________

Address ____________________

____

Attn. of ____________________

Date 7-26-57

Date Del. Required 8-7-57

SHIP TO:

Bldg. E Receiving Rm.

Attn: __________ Tel. __________

Account Number ____________________

QUANTITY	UNIT	DESCRIPTION	UNIT PR.	PRICE
100	ea.	G.E., NE-77 Neon lite Tube		
25	ea.	R.C.A., 5U4G Tube		
2	sets	V-221 Fan Belts (each set matched)		
1000	ea.	Allen Bradley, 220 ohm 1 Watt Carbon Resistor		
6	ea.	Sprague, 6TM-S22, Tubular Paper Capacitors		
2	ea.	Stancor, P-6135 Filament Transformer		

Material is to be used for: M.T.C.

Wanted by ____________________ Group 64 Bldg. B Room 155

Telephone 7231

DL-992-2

WORK ORDERS

When requesting any of the services listed below a standard Lincoln Laboratory Work Order form should be used. All such requests must be made through the MTC Office (R. B. Pugliese) where sheet number 2 of the form will be retained for the office files. From these files the MTC Office will do the necessary follow-up and expediting work.

Work Orders are required for:

1. Building Services (address to George Richardson, Bldg E4)
   a. Electrical (Lights, outlets, bldg. distribution, inter-com)
   b. Plumbing and Heating
   c. Air conditioning
   d. Transportation of Equipment
   e. Cleaning and Waxing
   f. Building Alterations

2. Office Equipment and Furniture (address to Joseph Bova, Bldg. A-270)
   a. Desks and Chairs
   b. File Cabinets
   c. Fans
   d. Typewriters, Dictation Equipment
   e. Desk Calculators

3. Telephones and IBM Equipment (address to Robert E. Carter, B-110)
   a. Telephone installation and maintenance
   b. IBM purchases
   c. IBM rentals

Individuals requesting the above services may either write up the desired work order as described below and then submit it to the MTC Office or they may supply that office with the necessary information and leave the paper work to the MTC Office.

Preparing a Work Order

1. Date - date that form is prepared
2. To; Address - person and address as indicated above
3. Work to be Performed For - R. B. Pugliese B-155
4. Dept. or Project - MTC (Gp. 64)
5. Tel. Ext. - Ext. 7231
6. Work Should be completed by - give date that represents a reasonable length of time
7. Quantity } supply if known or pertinent; usually
8. Drawing or Part No. } not required
9. Description - clean, concise, and complete description of work being requested

10. Estimated Cost - not filled in by MTC
11. Shop Work Instructions - please read and comply
12. Originator - Signature of person requesting work
13. Approval - Necessary signatures (Sect., Gp., Div.) acquired by MTC Office (R. B. Pugliese)

TAPE AND CARD PREPARATION

I. General

There are at present three conversion programs which convert the programmer's symbols into notation suitable for storage in MTC. All of them produce for outputs punched paper tape of the "4-6-6" format described in Section 23 of this manual and in Memorandum 6M-2527-2. A standard plugboard, labelled "Read-in", will cause a 4-6-6 tape to be stored in locations specified on the tape itself. In addition, the second of the three programs mentioned below can be made to deliver output on binary cards. The resulting deck can be read in using utility tape U3A, "Binary Card Load", or, in an emergency, with two bootstrap cards and a plugboard labelled "Van's Card Read".

The three conversion program are:

A. Bagley's Basic Conversion Program is available on 4-6-6 tape U1 in the drawer of the duty technician's desk. It requires for input Flexowriter tape prepared in the format described below.

B. SAP (Symbolic Assembly Program) is available as a deck of cards to be read in by tape U3A. It accepts as inputs Hollerith cards prepared on the 026 Key Punch, as described under Card Preparation.

C. SYAAP (Farley's Symbolic Address Assembly Program) is available on 4-6-6 punched paper tape, and accepts Flexowriter tape as an input medium.

In addition, there is a little-used tape U15, which uses for input Flexowriter tape prepared in the format of the Basic Conversion Program and delivers output on binary cards.

II. Format for Bagley's Basic Conversion Program

This program regards the letter "l" and the digit "One" as identical, and ignores space, color change, "comma", backspace, "stop code", upper and lower case, "delete", and blank tape.

A sample coding sheet, DL-1490, and the copy of the Flexowriter print of the resulting tape, are included on the next two pages for illustration.

A. Heading

The information in the heading will be found in the lower right hand corner of the octal program form (DL-481-3 or DL 1490).

1. Feed out approximately six inches of blank tape.
2. Type the word "tape", then the tape number specified on the program form. The title of the program and the author's name may be included on the same line, but no tabs may be used. The last character must be a carriage return.

	100		
	101	1.00000	initial x
	102	1.00000	x
	103	1.37777	
	104	ha 0	increment
	105	ha 0	not used
205	106	ca 101	
	107	st 102	reset x
	110	sof 0	
	111	tr 200	
	12		

111	200	ca 20	
	201	sof 1	
	202	st 104	get new increment
212	203	ca 102	
	204	ad 104	
	205	to 106	start over if x=+1
	206	st 102	augment x
	207	mh 102	
	210	su 103	
	211	ds 102	display
	212	tr 203	

7-20-51

	70		
	71		
	72		
	73		
	74		
	75		
	76		
	77		

	70		
	71		
	72		
	73		
	74		
	75		
	76		
	77		

Auto start at 1-106

increment in 0-20

LINCOLN LAB. M.I.T. DIV. 6
LEXINGTON 73, MASS.

OCTAL PROGRAMMING CHART

TITLE Parabola Display

AUTHOR Kellogg DATE 19 July

TAPE NO. 07d19 INDEX

3-1-2

DL-1667

```
tape 07d19 kellogg

octal

1-101|   1.00000   1.00000   1.37777   ha0     ha0     ca101   st102   sof0

111|     tr200

200|     ca20      sof1      st104     ca102   ad104   to106   st102   mh102

210|     su103     ds102     tr203

auto

start at 1-106
```

3. Type either the word "octal" or "decimal" on the second line. This word must be followed by a carriage return.

B. Body

1. The first item on the next line is the field designation of the first word in the program, which will either be a "One" or a "Two" and should be found to left of the first address. If the programmer forgets to specify this, type the digit "One". Follow the field number by a dash. Immediately after the dash type the first address, a bar, and a tab.

2. Type the words successively across the page, following each by a tab; do not type the comments. Follow the eighth word by a carriage return instead of a tab, if the word "Octal" was typed on the second line. If the word "Decimal" was typed on the second line, type ten words across the page before the carriage return if the carriage is long enough; otherwise type five words across the page and give a carriage return.

3. Each line should begin with the address of the first instruction in that line, followed by a bar and a tab. After the first line of the program it is not necessary to repeat the field designation unless it changes.

4. All words in a line must be stored in consecutive registers. A new line must be started after every gap in the program.

C. Ending

There are two endings for a tape: "Start at" and "Auto start at".

1. "Start at" is typed at the left margin, followed by the field designation, dash, address, and a carriage return.

2. "Auto start at" is typed:

"auto", carriage return, "start at", followed by the field designation, dash, address, and carriage return.

III. Format for Farley's Symbolic Address Assembly Program

Programs to be converted by SYAAP should be prepared on the coding sheet, form DL-1663. A sample coding sheet is shown on the next page, followed by a sample of the proper Flexowriter output.

This program does not regard the letter "l" and the digit "One" as identical, and ignores only stop code, backspace, and delete. The general format consists of a "location tag", tab, "word", tab, "Comments", and a carriage return. Any one or two of these elements

PROGRAM TITLE Quartic parabola
DESCRIPTION Displays picking increment from 0-20

PROG.NO. 07s20
PAGE NO. 3-1-5
AUTHOR Small
DATE 19 July

	TAG	INSTRUCTIONS OR DATA OP	ADDRESS	COMMENTS
	1-1000	ca	rc 1.00000	initial x to reset
		st	x	x deflection
		sof	0	
		ca	20	get increment
		sof	1	
		st	increment	
	display	ca	x	
		mh	x	calculate y coord
		mh	x	
		mh	x	
		ds	x	
		ca	x	increment x
		ad	increment	
		to	1000	start over when x=+1
		st	x	
		tr	display	
	end			

DL-1663

```
1-1000      ca rc 1.00000     initial x to reset
            st x              x deflection
            sof 0
            ca 20             get increment
            sof 1
            st increment
display     ca x
            mh x              calculate y coord
            mh x
            mh x
            ds x
            ca x              increment x
            ad increment
            to 1000           start over when x=+1
            st x
            tr display
end||||||||
```

may be omitted. Each MTC instruction and the letters rc (register containing) must be followed by a space.

The rules for typing programs in this format are few and simple.

1. Feed out approximately six inches of blank tape.

2. Carriage return.

3. Start typing with the first instruction or tag, omitting all material in the heading. The format will yield three distinct columns:

   a.) The first will contain all the tags,

   b.) the second will contain the MTC words (material contained in the "Instructions or Data" columns of the Coding Sheet), and

   c.) the third will contain all the comments.

4. After approximately one page of typing or when the programmer specifies, give a carriage return, type six or more bars, give another carriage return, and continue as though it were a new tape.

5. The end of the program is indicated by typing carriage return, the word "end", and six or more bars. The first bar must come immediately after the word "end", with no intervening spaces.

6. The symbol || (two bars) will cause SYAAP to ignore all material since the last carriage return. Hence this symbol may be used to correct typing errors. It is not necessary to correct minor errors in the comments, since they are ignored by the program.

IV. Flexowriter Operation

The Flexowriter has been designed to punch a tape while a typed copy is being prepared. Each character on the keyboard will punch a six-bit code on the tape.

A. Functional Switches

Except for the "On-Off" switch, which is located at the right of the keyboard, and the "Normal Print - Reproduce No Print" switch, these switches are located on the face of the machine directly above the keyboard.

1. Start Read - Depress and release this button to start the tape reader. Whenever it is depressed it stops the reader until it is released.

2. Stop Read - Depress and release this button to stop reader.

3. Punch On - When this button is depressed, typing will cause the codes to be punched into the tape. When it is lifted only the typewritten copy is produced.

4. Ignore Stop Code - When this button is depressed, the tape reader ignores both the stop code and other illegal combinations of holes. When it is lifted these codes will stop the reader.

5. Seventh Hole - When this button and the "Punch On" button are depressed, an accompanying seventh hole is punched for each character on the tape. This button must be down whenever tape is being prepared to be read into the computer.

6. Stop Code - When depressed this button punches a code into the tape which, when read, will cause the reader to stop.

7. Code Delete - When this button is depressed, all six holes will be punched, thereby changing the character into an ignored combination.

8. Tape Feed - When this button is held depressed with "Punch On" depressed, tape will be fed.

9. Normal Print - Reproduce No Print - Located either on the right or top of the machine. See D and E below.

B. Loading Paper

If paper with sprocket holes is used the pressure release lever of the far left of the carriage remains in the forward (released) position. Bring the paper over the guide bar and under the roller. Guide the paper in and turn the roller until the holes line up with the sprockets. If paper without sprocket holes is used, pull the pressure release forward (released). Insert the paper just as before, but bring it up and position it. Then push the pressure release back, gripping the paper in place.

C. Loading Tape

To insert a new spool of tape, remove the bar on the rear of the Flexo. Remove the spool cover by loosening the knurled screw. Remove the old spool and place the new one on with the tape coming off the bottom towards the right, looking at the machine from the back.

Bring the tape below the tape guide and over the tape tension arm roller, under the finger on the roller if there is one. Open the tape hold-down arm, just in front of the plastic chip catcher, which also lifts the tape run-out arm. The tape can now be placed into position by edgewise insertion. Close the tape hold-down arm. Depress the "Punch On" button, press the "Tape Feed" button, and pull the tape out at the same time in order to run the tape into proper operating position.

D. Normal Print

The switch is located on the right of some Flexowriters, but at the top left of others.

1. With the switch in this position and no other buttons depressed, the Flexo operates like an electric typewriter.

2. With the "Punch On" button depressed, the machine will also punch a paper tape.

3. If "Start Read" is depressed with a tape in the reader, the tape being read will be typed on paper. If in addition the "Punch On" button is depressed, a new tape will be made.

E. Reproduce No Print

This is the same switch as Normal Print.

Place a tape in reader. Press "Start Read" and a duplicate tape will be punched. All buttons should be up.

F. Correcting Errors

1. To correct an error detected immediately:

   a. Back up the tape 1 character with the knurled knob to the left of the punch.

   b. Push the "Code Delete" button.

   c. Type the desired character and proceed.

The "Backspace" key on the keyboard will cause a backspace character to be punched on the tape. Therefore, do not bother to correct the typewritten copy, but rather complete the tape and then print it again with the punch off. Use this second printed copy for final proofreading.

2. To correct an error discovered much later:

   a. Make note of the error, but complete the tape.

   b. In the "Normal Print" mode, copy the tape by running it through the reader with the punch on and with the "Seventh Hole" button depressed.

   c. Depress the "Stop Read" button as that character is typed which immediately precedes the error.

   d. Depress the key on the keyboard corresponding to the desired character.

   e. Advance the faulty tape one character by means of the knurled knob to the left of the reader.

   f. Push "Start Read" to continue copying.

The corrected tape so obtained should be printed with the punch off, and the copy so obtained should be used for final proofreading.

V. Card Preparation

At present MTC has only one card assembly program, called SAP (Symbolic Assembly Program). Cards are prepared for the programmer from FSQ-7 Coding Sheets (Form DL-1428). Therefore, the correct format is the programmer's responsibility. This format is described completely in Memorandum 6M-4403. Columns 8-42 of a sample coding sheet, and the Hollerith Card punched from the third row of the sheet, are shown on the next page.

Cards prepared at MTC may be taken to the card room in the basement of Building A for numbering or for listing by the 407 accounting machine.

Most programmers desire to have some sort of identification punched on each card. This is punched in the first four or six columns of the card, and then duplicated on succeeding cards. The MTC operator will not number entire decks of cards, but correction cards will be numbered, if the programmer so requests. This numbering is done in columns eight through sixteen.

Since the position of a character on the card is very important, care should be exercised during the punching to be sure that each character is punched into the card column corresponding to the column which it appears on the coding sheet.

To distinguish between the letter "O" and the digit "zero", many programmers draw a slash through the zero, e.g. DØØØ. These slashes should not be punched.

The card machine is not intended for duplication of binary cards, but a binary card can be punched on this machine, one row at a time.

However, the MTC operator <u>will not</u> punch binary cards.

VI. IBM 026 Key Punch

A. General

The key punch records information from its keyboard on 80-column cards in Hollerith Code.

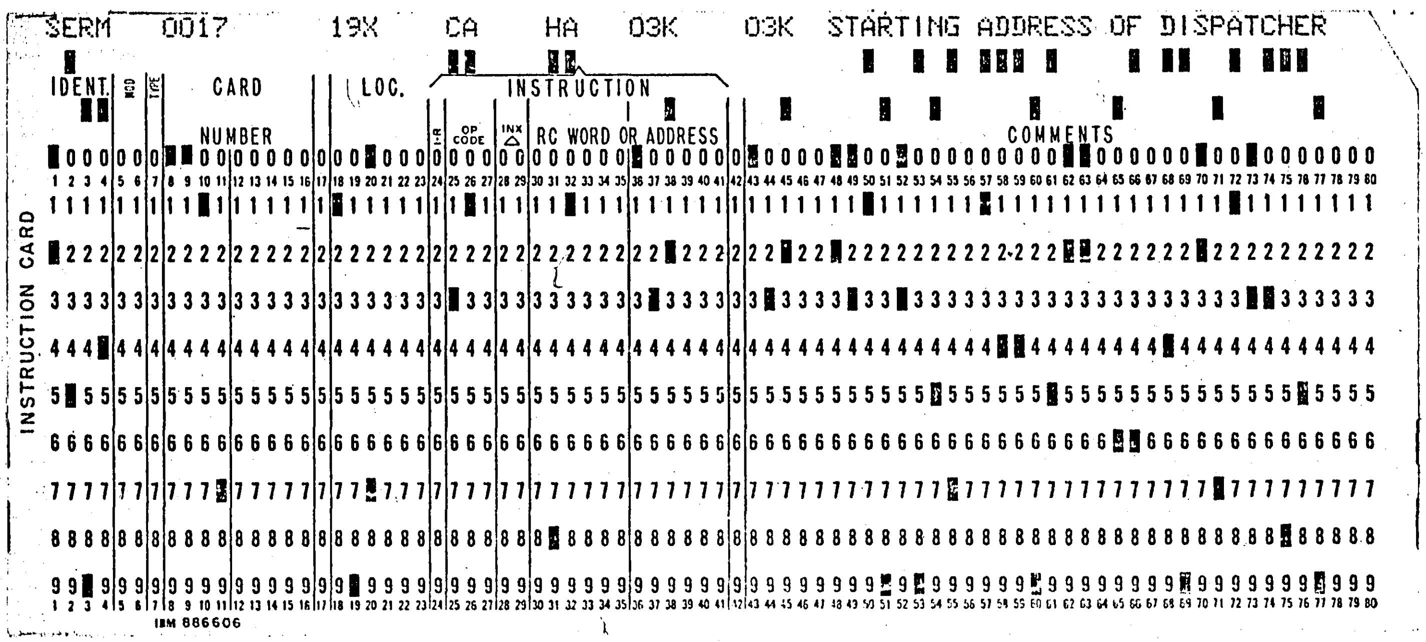
Cards move from the feed hopper at the upper right to the punch station just below. The punch is in the partition between the punch station and the read (middle) station, and punches one column at a time; thus the card moves one column to the left every time a character is punched into it. Unless printing is suppressed by Program Control, the character punched is simultaneously printed in the colored strip at the top of the card. Finished cards go to the stacker at the upper left, just below the power switch.

The partition between the read station ahd the stacker contains brushed for card reading. In normal operation the card just punched moves out of the read station as the card being punched moves into it; when the machine is in its "Auto-Dup" (automatic duplication) function, punching from the card just punched is duplicated in the corresponding column of the card being punched. "Auto-Dup" is explained more fully under Program Control, below.

Above the read station is a compartment containing a Program Control Drum, around which is wrapped a standard 80-column card. Punches in this card may be used to control automatic duplication,

FSQ-7 CODING SHEET | TAG. | IDENT. SERM | PROG. Small

CARD TYPE (7)	CARD NUMBER (8–16)	LOCATION (18–23)	IR (24)	OP CODE (25–27)	INX Δ (28–29)	RC WORD (30–35)	ADDRESS (36–41)	OVF (42)	(43–48)
	0015	01E		RF			02E		EXIT
	0016			ET		OCT	000077		MASK
	0017	19X		CA		HA	03K		03K
	0018			RA			04E		DISP
	0019	04E		TR			03K		
	0020								



automatic skipping of columns, keyboard shifts, and other functions if the Program Control Lever (the blue plastic lever under the drum housing) is "On" (left end pushed in). With the Program Control Lever "Off", these operations may be controlled manually from the keyboard; in this case the program card need not be in the machine at all. Around the base of the drum is a scale numbered from 1 to 80, by means of which one can tell what column is next to be punched.

B. Keyboard

Except that the digits are found as upper case characters at the right hand end, the keyboard is conventional. When the Program Control Lever is "Off" (right end pushed in) the normal shift is alphabetical, that is, lower case. To get a numeric (upper case) punch one must hold down the "Num" shift key while striking the proper character. After a series of upper case characters has been punched, it is wise to tap the "Alph" key to insure that the alphabetic shift is engaged; however, this key need not be held down.

The backspace button is not on the keyboard but on the body of the machine just under the read station. Pressing it will move the cards in both the read and punch stations to the right, so that additional punching may be done in a column previously punched. If the button is held down, backspacing is continuous at the rate of about four columns per second; to backspace one column, depress the key and release it quickly.

In normal operation of the key punch, card advance occurs automatically, just before the hole is actually made in the card. However, the "Mult Pch" (multiple punch) button on the keyboard prevents the card from advancing on any but the first character of the new column, so that several characters may be punched in the new column.

There are two "Skip" keys on the keyboard. The upper one, marked with a dash, gives a single punch in row 11; the other one, on which only the word "Skip" appears, produces no punch, but merely moves the card left one column. The space bar has the same function as the latter skip. Card format, and the correspondence between characters and punches, can best be understood by looking at the figures on the next page.

The Symbolic Assembly Program and the 407 Accounting Machine interpret the sign "#" (3 punch and 8 punch) as meaning "+" or plus, and the "@" sign (4 punch and 8 punch) as "-" or minus. In addition, the dash (11 punch only) is an acceptable minus sign for SAP.

C. Hollerith Code

As interpreted by IBM 026 Key Punch

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
12	12	12	12	12	12	12	12	12																	
									11	11	11	11	11	11	11	11	11								
																		0	0	0	0	0	0	0	0
1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	2	3	4	5	6	7	8	9

Row	&	-	0	1	2	3	4	5	6	7	8	9	/	.	$	,	#	⌑	*	%	@
12	12													12				12			
11		11													11				11		
0			0										0			0				0	
1				1									1								
2					2																
3						3								3	3	3	3				
4							4											4	4	4	4
5								5													
6									6												
7										7											
8											8			8	8	8	8	8	8	8	8
9												9									
407 Accounting Machine	+																+				-

Notes: The 407 Accounting Machine makes the substitutions shown above for "&", "#", and "@".

The MTC Symbolic Assembly Program (SAP) interprets "#" (3 punch and 8 punch) as "+", but not the "&" (12 punch only).

SAP interprets either 11 punch, or 4 punch and 8 punch, as "-" (minus).

D. Operating Instructions: Manual Control

1. Punching

Either the Program Control Lever or the "Auto-Dup" switch should be "Off" when punching the first card of a series, or when punching a single card.

When the Program Control Lever is "Off", the keyboard is normally in alphabetic shift. To punch any upper case character, the "Num" key must be depressed, and held. After a series of upper case characters has been punched, it is wise to tap the "Alph" key to insure that the alphabetic shift is engaged; however, this key need not be held down. When the Program Control Lever is "On", the normal shift is numerical unless alphabetic shift is programmed; but the program card may be overruled by means of the shift keys on the keyboard.

Before releasing the first card of a series or punching its 80th column:

a. If automatic feeding of successive cards is desired, turn on "Auto-Feed".

b. If program card control of succeeding cards is desired, turn on "Auto-Skip, Auto-Dup" and the Program Control Lever (it is on when pushed in at the left).

2. Card Removal

To remove a card from the punching station, turn the "Auto-feed" switch off. Then push:

a. "Rel" (release)

b. "Reg" (register)

c. "Rel" — Cards may be removed manually at this time.

d. "Reg" — Cards will be stacked.

Cards will automatically be removed from the card bed as other cards are fed into the punching station.

3. Single Card Feed

To get a single card under the punch, place a card in the feed hopper at the upper right, then:

a. Turn "Auto-feed" off.

b. Push "Feed".

c. Push "Reg" (register). The card will now be under the punch.

Pause after pushing a control button.

4. Automatic Feed

To punch a series of cards, place an adequate deck in the feed hopper. Then:

a. Turn "Auto-feed" on.

b. Push "Feed" twice. The first card will now be under the punch. Each subsequent card will be placed automatically under the punch as soon as the previous card is released or its 80th column punched.

5. Duplication of a Single Card

a. Turn "Auto-feed" and "Auto-skip, Auto-Dup" off.

b. Insert the card to be duplicated through the plastic guides between the reading station and the punching station.

c. Feed a single card.

d. Hold down the "Dup" (duplicate) button.

6. Lock-up

The machine may jam and lock its keyboard if two keys are accidently pushed simultaneously or if letters are encountered during an automatic duplication in numerical shift. Backspacing will relieve this condition, or, if the remaining columns may be skipped, the card may be released. If an "Auto-Dup" was stopped by a letter, one can depress "Alph Shift" and then backspace. "Auto-Dup" will reproduce numbers satisfactorily when in alphabetic shift.

E. Program Control

It is possible to place the operations of "Auto-Skip", "Auto-Dup", shifting, and printing under Automatic control; in a given column of card being punched, these operations are controlled by punches in the corresponding column of the card on the program control drum. When the Program Control Lever is "On" (pushed in to the left) these functions are normally controlled by punches in rows 12, 11, 0, 1, 2, and 3; the function in a given column of the card being punched is controlled by the punches in the corresponding column of the program card. However, when the "Alternate Program" button is pushed, control is transferred to the punches in rows 4-9 of the corresponding program card column.

The program control drum should be removed or replaced only when the program control lever is off, and when the drum is in the column 1 position; the best way to make sure is to press "Release". The drum cover is loose at the top and hinged at the bottom. The drum snaps into place and can be removed by pulling parallel to its axis.

The card locking lever is inside the drum at the top. When it points toward the center, the column 80 end of the card is released; when it points in a clockwise direction, the column 1 end is released; and when it points in a counter-clockwise direction, both ends are locked. The column 80 end of a new card should be inserted first, then the column 1 end; the card should then be pushed down so that its 9 edge rests firmly on the bottom flange of the drum, and locked in place.

F. Program Card Preparation

It is convenient to define a field as a group of consecutive columns on which a given operation is to be performed. Fields are denoted on the program card by a simple code: there is no 12 punch in the first column of a field, but there are 12 punches in all subsequent columns. For alternate program fields, the beginning of a field is defined by absence of a 4 punch, and subsequent columns by the presence of a 4 punch. Operations within a field are controlled as follows:

1. Auto-Skip: If the first column of a field of the program card has an 11 punch (or 5 punch for the alternate program) all columns of the field on the card being punched will be skipped, provided that the "Auto-Skip, Auto-Dup" switch is "On".

2. Auto-Dup: If the first column of a field of the program card has a 0 punch (or 6 punch for the alternate program), punching in all columns of the field on the card being punched will be duplicated into corresponding columns of the following card.

   Shifting, Printing of left zeros, and suppression of printing during automatic duplication will work as described below.

3. Alphabetic shift: Under program control, the normal shift is numerical, and the machine will stop duplicating automatically if a lower-case character is encountered. But a 1 punch in a column of a program card (or a 7 punch for the alternate program) will cause the shift to be alphabetic when the corresponding column is being punched, whether under keyboard or Auto-Dup control.

4. Left Zero Print: The machine normally suppresses left zeros in the printing, but will print left zeros in any column if the corresponding program card column has a 2 punch (8 punch for the alternate program).

5. Print Suppress: If the program card has a 3 punch (9 punch for the alternate program) no printing will occur in the corresponding column of the card being punched.

These rules are summarized inside the Program Control Drum cover, but may be more clearly presented by the following table:

D. Program Card Codes

Main Program

Operation	1st Column of Field	Subsequent Column of Field
Field definition	Space	&
Auto-Skip	Dash-Skip	&
Alph Shift	1	A
Left Zero Print	2	B
Print Suppress	3	C
Auto-Dup:		
Num Shift	0	&
Alph Shift	/	A
Left Zero Print	S	B
Print Suppress	T	C

Alternate Program

Operation	1st Column of Field	Subsequent Column of Field
Field definition	Space	4
Auto-Skip	5	4
Alph Shift	7	4 and 7
Left Zero Print	8	4 and 8
Print Suppress	9	4 and 9
Auto-Dup:		
Num Shift	6	4 and 6
Alph Shift	6 and 7	4, 6, and 7
Left Zero Print	6 and 8	4, 6, and 8
Print Suppress	6 and 9	4, 6, and 9

MTC COMPONENT TEST REPORT

Whenever a plug-in-unit, or tube, is removed from MTC, it is replaced with a pretested "interim unit"; a defective component is replaced with a new one. In either case the suspect item must be tested, and the cause and nature of any failures so discovered must be recorded on the Hollerith log record. The vehicle for the paperwork is the MTC Component Test Report. Blank forms for this report are kept in the Duty Technician's desk; since they are numbered consecutively, one should be sure to take sheets from the top of the pile, and to take only as many as will be used. Sections A through D and section F should be filled out at the time the plug-in-unit, tube, or component is removed. The Component Test Report should also contain the incident number under "Remarks"; and the Component Test Report number must appear in both the log and the incident report.

The offending device and the triplicate form should both be sent to the MTC office (R. B. Pugliese). What happens then depends on the type of device:

1. If it is a tube, the white copy of the report is filed in the MTC office; the yellow and pink copies accompany the tube to the tube test shop under Ted Clough in the Barta Building. An MTC engineer may elect to request a new tube; in this case, or if the old tube tested defective, the new new tube is returned to the MTC office, along with the completed pink and yellow copies. The pink copy is filed with the white copy indicating that the transaction is ready for IBM cards; and the yellow copy is returned to the tube shop when the tube is put back in service.

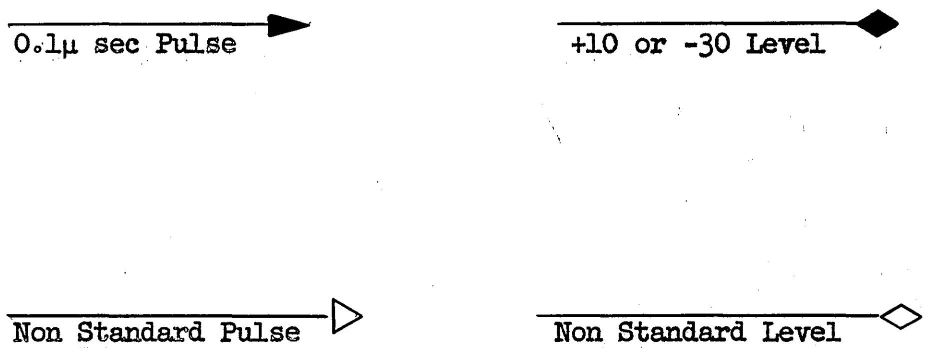
2. If the defective device is a circuit element, such as a resistor, capacitor, pulse transformer, or diode, it is sent to the component test shop under Howard Hodgdon in D-243. The procedure is the same as for a tube, except that the component is not returned, since it has since been replaced with a new one. If the yellow copy has been returned, it is discarded.

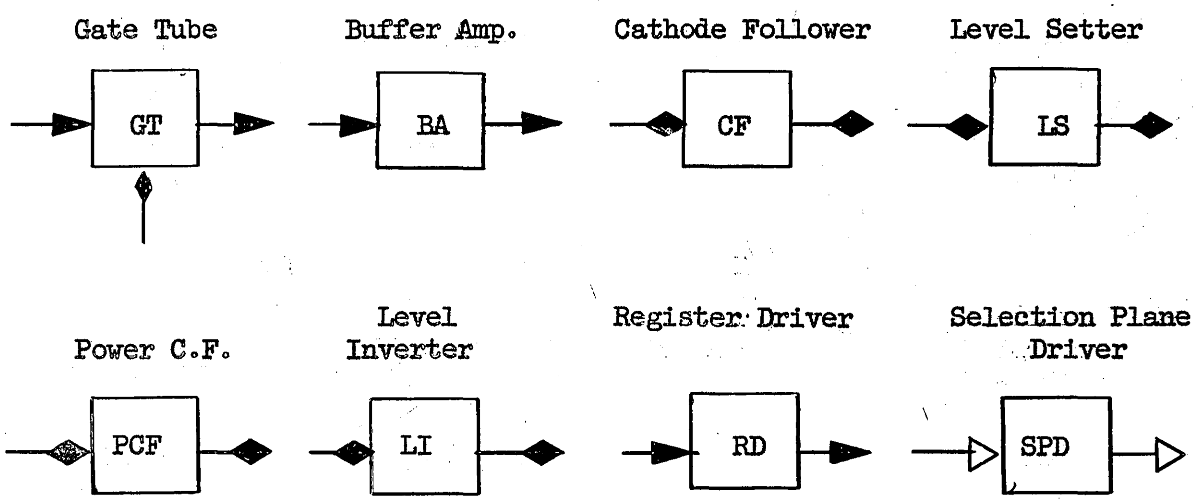
3. If the defective device is a plug-in-unit, it goes to the MTC technician in charge of plug-in-units, along with the pink and yellow copies of the Component Test Report. He will test it and remove the defective tube or component, adding what he can to the report and making out additional ones if more than one tube or component is removed. Any suspect tubes and components are treated as in 1 and 2 above. The plug-in-unit is retained by the technician until the reports come back from the tests; then the unit is retested, and replaced in the computer. As before, pink copies of the reports are filed in the MTC office, while yellow copies return to the MTC technician for his records.

MTC Publications on Preventive Maintenance and Marginal Checking

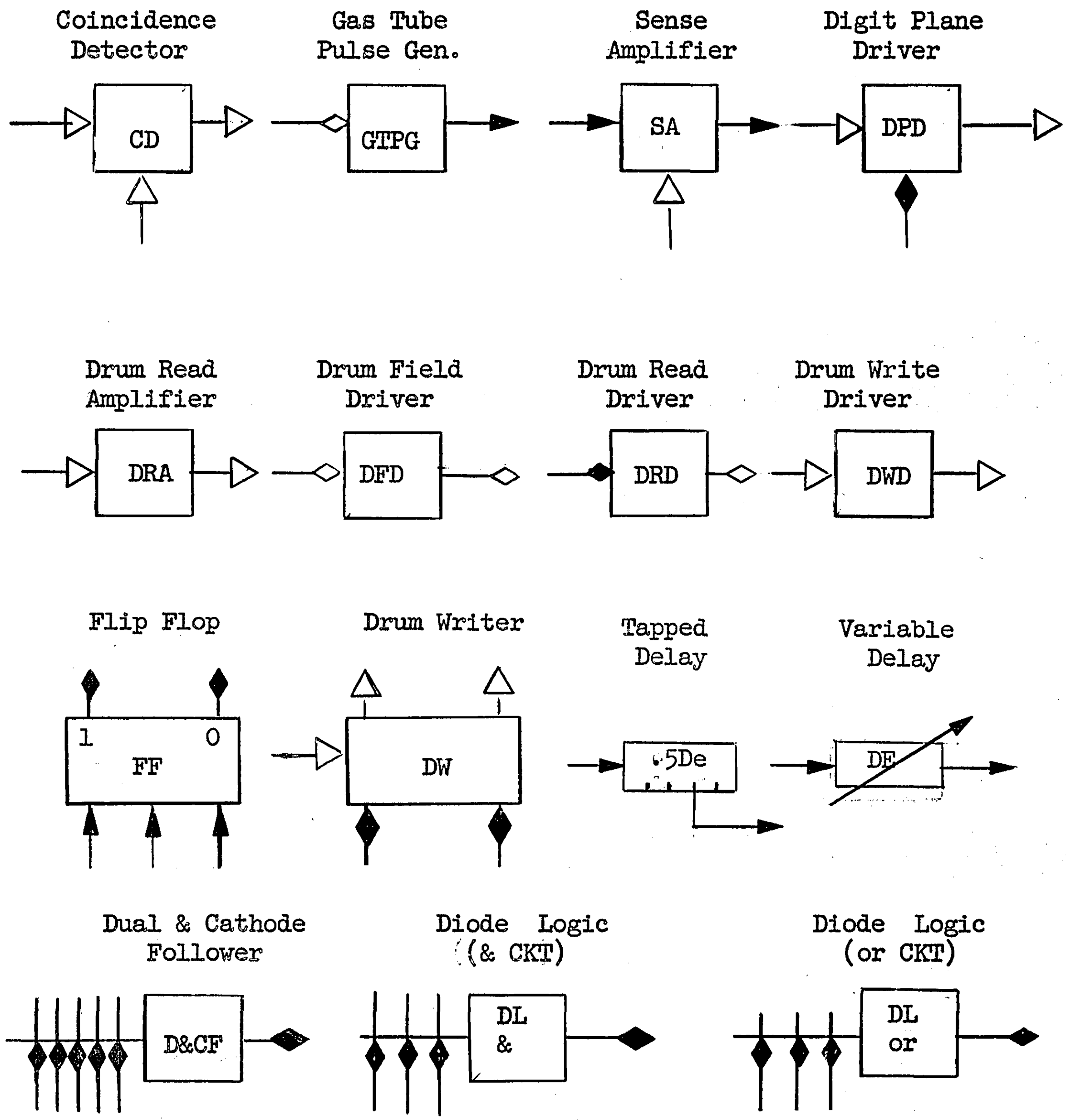
PM Books	First, Marginal Check Program Second, Line Number	Location of all units on line. Function of units checked by the program under which the page is filed. Other programs for this line. Any pertinent prints. MC voltage. Limits. Danger points. Shows margins by date
M.C. Line List	First, Voltage Second, Line Number (should be same)	Locations checked Type of units checked Number of units checked Program used Has index by function Shows spares, fuses out, switches, etc.
Location List	Location	Margin Line that checks each location Type of unit Serial number Function of unit
P.I.U. Master	P.I.U. type, Serial	Location Program Line Change level

STANDARD SYMBOLS FOR LOGIC





STANDARD SYMBOLS FOR LOGIC



& and "or" circuits are positive unless otherwise specified.

6-12-57

MTC Service Manual, Section 4

COMPUTER AUXILIARIES

a. A.C. Distribution

b. D.C. Power Supplies

c. D.C. Power Control

d. D.C. Distribution

e. Marginal Checking System

f. Air-Conditioning System

g. Intercom

h. Probe System

i. Synch System

j. Cyclic Control

k. Monitors

AC DISTRIBUTION

The source of all power for MTC comes from 208V, 3Ø lines. These lines supply a maximum of 350A at 208V, 3Ø and are protected by two main circuit breakers, each rated at 175A, and connected so that when one trips, the other also trips. After the main circuit breakers, individual lines are tapped off for both the computer room and the power room as shown in the print on the next page, a reproduction of SA-82113.

Individual circuit breakers rated at 175A are provided for protection of AC circuits in both the computer room and the power room respectively.

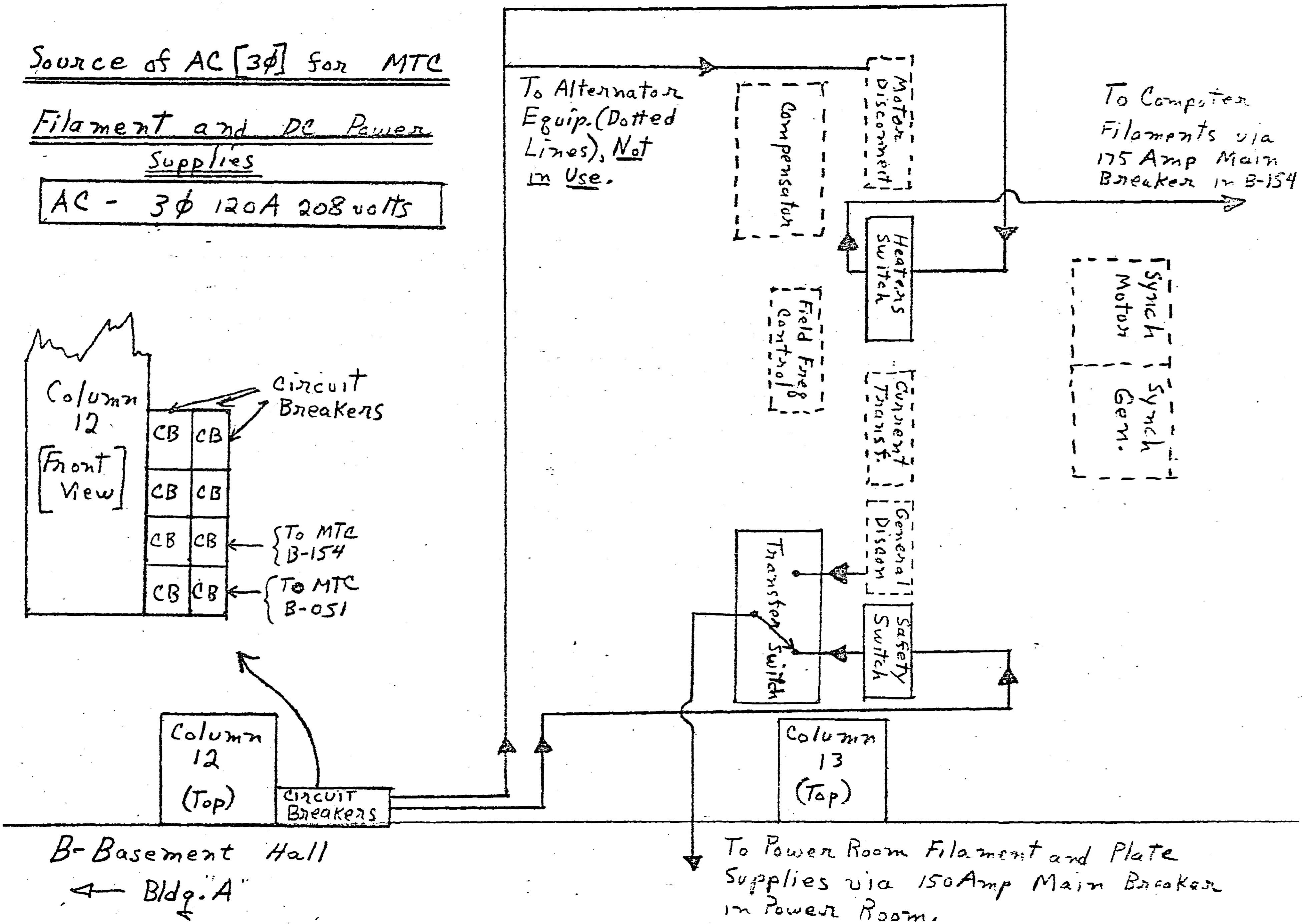
In the computer room the AC power requirements for the various frames are tapped off the output of the 175A circuit breaker, and are fed through individual 30A single phase circuit breakers for circuitry protection within a given frame. Circuit returns in all cases are wired through a neutral lead which comes directly off the input circuit mains. This power is independent of the relay control described below, except that the main breaker must be on before the relays will work.

In the power room the AC for the various power supplies is tapped off the output of the 175A circuit breaker and is fed through individual single-phase circuit breakers.

SUPPLY	BREAKER CAPACITY
+250	20A
-140, -180, -300	30A
+600	20A
-150	40A
+150	40A
+10, -15, -30, +90	30A

Source of AC [3φ] for MTC Filament and DC Power Supplies

AC - 3φ 120A 208 volts



DC POWER SUPPLIES

I. General

The Memory Test Computer uses ten basic standard voltages: -300V, -180V, -150V, -140V, -30V, -15V, +10V, +30V, +150V, and +250V. Nine of these voltages are obtained from three-phase rectifiers, while a tenth (-180V) is obtained a bleeder across the -300V supply. An AC and DC interlock system provides protection for computer equipment if one of the power supplies should fail. The interlock system automatically shuts off all DC voltages in proper sequence.

There are also several non-standard voltages supplied to the computer. One of these is +600V, which is obtained from a special bridge type vapor rectifier. Other special voltages supplied are -48V and -60V for the Tape Adapter Frame. These voltages are obtained from full wave germanium rectifier circuits. The -60V is not obtained as such, but as an isolated -30V DC source which is added in series with the standard -30V to obtain the -60V. There are other miscellaneous supplies which are not part of the regular MTC power supplies, but are included on the equipment which uses them. These supplies include the high voltage sources for display purposes and the separate supplies in some in-out equipment.

In general, the regulated power supplies meet the following specifications:

1. Ripple shall be less than 0.2% peak to peak at any load from no load to full.

2. The steady state regulation shall not vary more than 0.6% for any combination of the following:

   no load to full, and ± 5% line change.

3. The transient regulation shall not vary more than ± 0.3% as measured from the final steady state value for a 20% step of load or for a 5% step of line voltage above or below rated line voltage.

4. The regulating system shall be sufficiently stable to damp to within 5% of the steady state value within 3 cycles of the natural frequency of the regulator after a load or line disturbance.

5. The drift shall not exceed 1% per month, 0.3% per day.

II. Brief Description of Relay Control

Power for MTC is turned on through a series of interlocked relays and time delay controls. The relays are located in the racks to the left of the column in B-051; the circuit is shown on print D-47091. If all breakers are on, filament power may be applied to the power supplies by pushing the "standby" button. All A.C. relays are actuated and after a 5 second delay the power supply filaments are turned on. In order to allow all tubes to come up to their rated temperature, a minimum lapse of a minute and a half must be allowed at this point before the "Power on" switch is effective. Pushing "Power on" after the wait will cause the D.C. supplies to come on in the following order:

Sequence	Time
1. -30, -15, +10V on	0
2. -300, -180, -140V on	0.025 sec.
3. -150, +150V on	2.000
4. +250V on	2.025
5. +90V on	2.050
6. Sensitrols become active	3.000

If any DC supply should fail to come up to its rated voltage ± 5%, a Sensitrol relay will cause the entire set of relays to cycle back to a status which resembles "Standby" except that the "Reset" button must be pushed to set any relays that failed to go to "Standby" status when the incorrect voltage was detected. This condition is indicated by a "hi" or "lo" voltage light on the console and on the relay control panel in B-051.

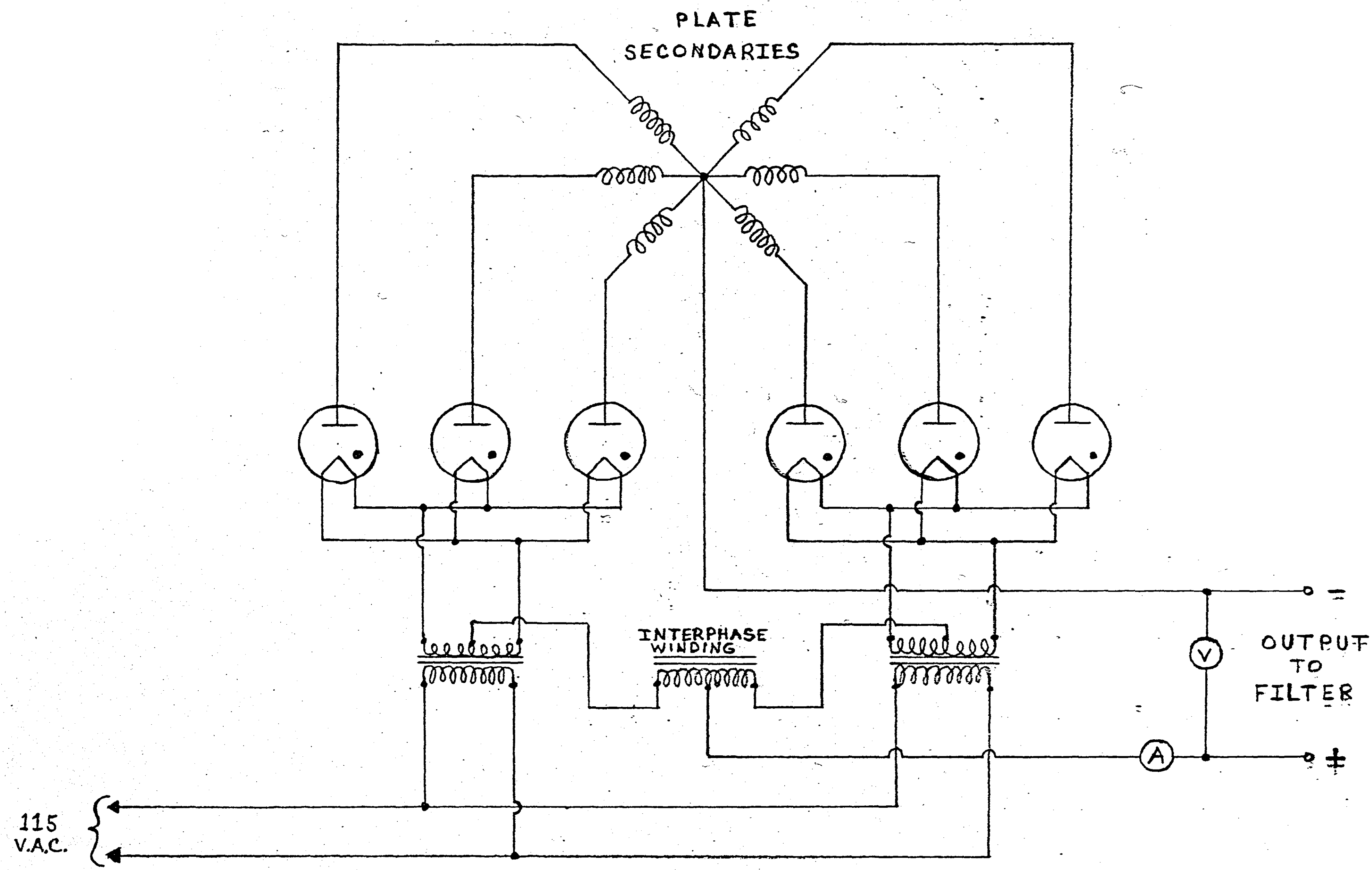
III Rectifiers

A. Basic Circuit

The basic power supply used for most of the MTC DC rectification is a three phase, star-connected circuit using an interphase winding connecting the outputs of the two sets of three rectifiers together. This is shown in the schematic on the next page.

B. Need for an Interphase Transformer

A simple 3-phase system, although it results in the obtimum utilization of the plate transformer, gives rise to d-c saturation of the transformer core. It also introduces even harmonics in the primary current and a large ripple in the DC voltage. In order to overcome these difficulties it is necessary to make the number of secondary phases an even multiple of the primary phases. To accomplish this and still retain the advantage of the 3-phase system, it is customary to segre-



BASIC RECTIFIER SHOWING INTERPHASE WINDING

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gate 6- or 12-phase secondaries into 3-phase groups. This is accomplished by the use of an interphase transformer, sometimes called an absorption-reactance coil. The main advantage of the interphase transformer are:

1. it improves the utilization of the rectifier;
2. by reducing the peak value of the anode current, it lowers the arc drop and improves the efficiency;
3. it improves the utilization of the main transformer;
4. by reducing the amount of current being commuted at one time, it improves the regulation of the d-c voltage.

The midpoint of the interphase transformer constitutes the negative terminal of the rectifier unit. Each 3-phase winding with the rectifier elements connected to it constitutes a commutating group. The two commutating groups operate in parallel, each carrying one-half of the total direct current. The interphase transformer absorbs the difference between the instantaneous DC voltages of the two groups. The direct current flows in opposite directions in the two halves of the interphase transformer winding and therefore produces no DC magnetization in its core. The triple-frequency AC voltage applied across the interphase transformer causes a triple-frequency alternating magnetizing current to flow. This current, supplied by the filament circuits of the rectifiers, flows between the two commutating groups through the rectifying elements. It must therefore flow in the forward direction (anode to cathode) through the rectifying elements of one group, and in reverse direction (cathode to anode) through the rectifying elements of the other group. The full value of the magnetizing current can flow in the reverse direction only if the direct current through the rectifiers is equal to or greater than the peak value of this AC magnetizing current, so that the net current flow is in the forward direction. Below this value of direct current the interphase transformer is not fully magnetized; as the direct current approaches zero, the interphase transformer becomes practically ineffective, and the circuit behaves like a single commutating group of six phases. The DC load current at which the full magnetizing of the interphase transformer can flow is approximately .1% of the full-load current.

C. Properties of Thyratrons and Arc Rectifiers

The rectifiers in the MTC power supplies are electron tubes to which a small amount of gas has been added. This gas, ionized by the electron stream, increases conductivity. Gas triodes are called "grid-controlled rectifiers" or "Thyratrons"; gas diodes are simply called "arc rectifers".

These hot-cathode gas tubes are rated according to several voltage and current limits:

1. Peak inverse voltage is the maximum negative voltage that can be applied between anode and cathode, as limited by arc-back probability.

2. Peak forward voltage is the highest positive voltage between anode and cathode of a thyratron that can be controlled by the grid.

3. Average anode current is the highest average current that a tube can carry continuously without overheating.

4. Peak anode current is the highest instantaneous value of current that a tube can carry periodically, as limited by cathode emission.

5. Surge current is the maximum instantaneous transient current that a tube can carry during a fault, such as a DC short circuit, without immediate failure.

The heating current of a gas-tube filament must be applied for about a minute and a half before the tube is permitted to carry anode current; this wait allows the cathode to come up to the emission temperature, and, if the gas filling is mercury vapor, to vaporize the mercury. The arc-drop voltage of a gas tube is about 8 to 16 volts, depending on the vapor pressure. When the arc drop exceeds about 22 volts, the coating is sputtered off by ion bombardment; this removal shortens materially the life of the tube. The vapor pressure in a gas tube is a function of tube temperature and is therefore affected by ambient temperature. Excessive temperature and vapor pressure may cause arc-backs. Too low a temperature increases the arc drop and may cause disintegration of the cathode.

The possibility of an arc-back is the major fault of a power rectifier. An arc-back is defined as a failure of the rectifying section which results in the flow of a principal electron stream in the reverse direction, because of the formation of a cathode (emissive) spot on an anode. It can occur when the anode is at a negative potential with respect to the cathode. When a cathode spot is established on the anode surface, current from the other anodes of the rectifier flows to the faulty anode; this flow results in a short circuit of the DC winding of the rectifier transformer, limited only by the impedance of the transformer and the AC system and by the arc drop in the rectifying devices. The current to the faulty anode, and in the transformer winding to which it is connected, flows in the reverse direction from normal; it can attain magnitudes many times the rating of that winding. If other sources of AC power are connected to the same DC circuit as the rectifier, current from the DC circuit will also flow to the faulty anode through its cathode. The direction of current flow is from the positive side of the DC circuit, through the faulty rectifying device and its transformer winding, to the negative side of the DC circuit; this is the reverse direction from the normal flow of current from the rectifier to the DC circuit. If the ensuing reverse current is not interrupted immediately, equipment breakdown will more than likely occur. The three principal protective devices used for protection of the rectifier equipment and the AC and DC circuits against an arc-back are:

1. An AC breaker between the rectifier plate transformer and AC line,

2. an anode circuit breaker between the rectifier plate transformer and the rectifying devices, and

3. a DC breaker between the rectifier and the DC load circuit.

With suitable protection no damage is done to a rectifier unit by an arc-back, and the unit can resume normal operation immediately.

IV. Regulation of Supplies Using Mercury-Vapor Diodes

A. Series Regulator Tube Section

The purpose of the series regulator tube section is to provide a variable DC resistance in series with a supply, which can be varied automatically should the output voltage vary. Each series regulator panel consists of six 6080 type dual tubes as the variable resistance element. All twelve tube sections are connected in parallel to give sufficient current handling capacity. Although each tube section can handle a maximum of 125ma, for a total of 1.5 amperes per regulator panel, an attempt is made in MTC to limit the maximum current per panel to 1 ampere. This is necessary because, although all tube sections are paralleled, the distribution of current is such that some tubes will conduct more heavily than others. Each tube section is fused with a 150ma, slow-blow fuse. Blown fuses are indicated by means of NE2A neon lamps, which are normally lighted except when a fuse is open. There is also provision in the series regulator panels for monitoring the individual tube section currents. This is accomplished by plugging a 0-200ma DC milliammeter into the front of the panel at the appropriate jacks and varying the thirteen-position switch located on the panel. The switch shunts all currents except the tube section being monitored. Because of this, it is necessary to return the switch to its counterclockwise or "off" position, otherwise an open tube section will exist when the milliammeter is removed.

Servicing a series regulator panel often involves nothing more than replacing a burned out fuse or replacing a spent tube. The average drop across a series regulator tube from plate to cathode is approximately one hundred volts. The bias, which is obtained from a common bias bus in each respective power supply, varies depending upon the power supply and upon the current drain required. The range of bias normally encountered varies from about ten volts to fifty volts, with the heavily loaded panels having the least amount of grid bias. In the event of a grid-to-cathode short, the tube section which has shorted will cause that tube section to draw a large amount of current and the plate fuse for the section will open. However, due to the presence of a large isolating resistance of 100K in each grid circuit the grid-cathode short will not affect the voltage on the common grid bus and all other tubes will continue to operate normally. The series regulator control circuit is shown on print C-60957.

B. Amplifier, Regulator

The amplifier, regulator has a dual purpose. One of its uses is to supply a regulated DC voltage to be used as a reference for comparison with the supply which it is regulating. Its other purpose is that of a DC amplifier which amplifies the error voltage (the difference between its own reference and that of the power supply which it is regulating) and whose output is cathode-coupled to drive the common bias line of the series regulators.

The reference voltage for the amplifier, regulator is obtained from the full-wave stack of selenium rectifiers. This voltage is then filtered by an L-C filter and is regulated by 6073 and 5651 cold cathode voltage regulators. The tube drop across the 6073 is approximately 150V and the drop across the 5651 is approximately 85V. By using the proper attenuator circuit the voltage is bucked against the feedback voltage from the power supply which is being regulated. The only difference between the amplifier, regulators from the various power supplies in the attenuator circuit and regulator circuit. The +10, -15, and -30V amplifier, regulators contain one regulator tube ahead of the attenuator circuit. The +30, -140, 150V amplifier, regulators contain two regulator tubes and the +250, -300V amplifier, regulators contain four regulator tubes. The additional changes are summarized in the table below.

VOLTAGE	NUMBER OF 5651 REGULATORS	R4	R5	R6
+10	1	56K ± 1%	100 ± 10%	10K Pot. 4W
-15	1	56K ± 1%	8.2K ± 1%	10K Pot. 4W
-30	1	56K ± 1%	27K ± 1%	10K Pot. 4W
+30	2	68K ± 1%	75K ± 1%	50K Pot. 4W
-140	2	10K ± 1%	0.13M ± 1%	50K Pot. 4W
+150	2	100 ± 10%	0.15M ± 1%	50K Pot. 4W
-150	2	100 ± 10%	0.15M ± 1%	50K Pot. 4W
+250	4	82K ± 1%	0.22M ± 1%	50K Pot. 4W
-300	4	16K ± 1%	0.27M ± 1%	50K Pot. 4W

All amplifier regulators contain a switch, S2, which enables one to open the feedback loop and at the same time introduce a test voltage of a few volts which can be varied by means of a potentiometer, R7. This feature is very helpful when trouble-shooting the amplifier. The first two stages of the DC amplifier operate at a bias of approximately one volt and draw about ten milliamperes of plate current. The screens operate at 130V which is also a regulated voltage. The last stage of the amplifier contains two paralleled sections of a 6BL7 tube operated as a cathode follower. The combined tubes draw a total of approximately 10ma of plate current with the grid bias being about -5V and approximately 100V across the tube.

Print numbers for the amplifier, regulator schematics are as follows:

Supply	Circuit Schematic
-15V	C-60596
-30V	C-60660
+90V	C-61214
-140V	C-61217
-300V	C-61219
+10V	C-60658
+250V	C-61220

Regulators for the +150V and -150V supplies are shown on prints E-80430 and E-80429, respectivily.

V. Thyratron Supplies

A. Circuit

The +150V and -150V power supplies both contain thyratron rectifying elements. Schematics of both rectifier and control circuits are shown on print E-80429 for the -150V supply, E-80430 for the +150V supply. Each supply contains a three-phase 40A circuit breaker connected into the primary circuit of the plate transformer, which is connected in a delta configuration. The breaker has a slow-tripping characteristic to handle transformer inrush and capacitor charging current.

The plate transformer secondaries are connected in a forked-Y configuration; the rectified voltage is taken between the center connection and the thyratron cathodes.

B. Control

The phase positions of the pulses supplied to the thyratron grids determine the firing time and control the average value of the output voltage.

The rectified voltage is filtered by an L-C filter and passes to the output terminals through an ammeter and fuse. A voltage divider across the output provides a feedback voltage of approximately 75 volts. Another divider across a 5783 neon reference tube provides an adjustable reference voltage. These two voltages are subtracted, and the difference, or error, is fed to a filter circuit. The filter circuit is designed to allow the supply to regulate rapidly without being unstable. The filtered error voltage is amplified by a 6AU6 pentode and fed to the triggering circuit. The purpose of the triggering circuit is to generate a sharp 60-cycle pulse for each thyratron, the phase position of which is determined by the amplifier output voltage. To accomplish this, the grid of an 0528 triode is overdriven with a sine wave signal from one leg of a six-star connection of the trigger transformer secondaries. A 470,000 ohm resistor clips the grid voltage in the positive region. The resulting plate voltage is a rectangular wave, which is differentiated by an RC circuit to obtain the desired positive pulse. By varying the DC level of the trigger transformer signal, the pulse can be advanced or retarded. Each of the six trigger transformer legs drives a separate triode, which is connected to one of the six thyratrons in the proper sequence so that each thyratron will be fired when its plate voltage is near maximum. There is a special clamping circuit connected between the amplifier and the triggering circuit. This clamping circuit is actuated by an internal relay, K1; its purpose is to provide a means of bringing up the DC voltage gradually.

The only difference between the +150V and -150V supplies is the placement of the fuse, which is in the non-grounded bus.

VI Periodic Maintenance

Periodic Maintenance of the MTC power supplies consists of various routine checks. The following are the most important.

1. All mercury-vapor and thyratron rectifier tubes are inspected; they should all be glowing with approximately equal brilliance, and there should not be an excessive amount of flicker in the tubes.

2. All sensitrols are visually checked to see that they are centered. If not, a calibrated meter is used to measure the voltage of the supply in question and if necessary, the supply is reset to the proper voltage. The adjustment is made by varying the potentiometer with the screwdriver adjustment notch on the amplifier voltage regulator panel. This adjustment must be made with full load on the supply, either computer load or the dummy load box.

3. All series regulator plate fuses are checked to see that they are conducting properly. This is done by visually checking all neon indicator lights associated with the plate fuses. A glowing neon indicates that the associated plate fuse is conducting.

4. All amplifier and control tubes with the exception of the 6080 series regulator tubes, are checked periodically on a tube tester.

5. The 6080 series regulator tubes are checked by monitoring the individual plate currents. This is done with an external milliameter (0-200ma) by plugging it into the front of the series regulator panel and varying the switch on the right hand side of the panel. The switch has thirteen positions marked "off, 1-12". The panel is normally operated with the switch in the "off" position. The meter leads are then plugged in, the switch is varied through all positions, and the current is noted. All tubes with sections that conduct over 125ma are replaced. All tubes with sections that conduct considerably less than the average current for a tube section are replaced.

VII Repair of Supplies

A. Sensitrols

One of the more common ailments is malfunction of the sensitrol sensing device. This trouble will usually occur when DC power is being turned on. The failure can be easily determined by the successful cycling of several supplies up to a certain supply. Visual observation of the sensitrol when DC power is being put on is generally sufficient to determine if the sensitrol operating properly. If the sensitrol is damaged, its removal must be accomplished before DC power can be put on. MTC does not stock spare sensitrols so that the supply must be operated without the sensing protection until the faulty unit has been repaired.

B. Voltage Reference Tubes

Another common ailment is failure of the VR (voltage reference) tubes. These tubes provide a reference source of voltage which is usually compared with the DC supply voltage to obtain the error voltage which is amplified to provide a grid bias reference for the series control tubes. These VR tubes occasionally drift as they age, causing power supply drift. Unless this drift is corrected in normal maintenance periods, the sensitrols which are continuously sensing the supplies eventually will trip, causing unscheduled maintenance time.

C. Arc-Back

Arc-back is another common fault. Protection is provided against arc-back by the presence of plate fuses in each rectifier tube and by the use of a circuit breaker supplying the plate AC. In most cases the circuit breaker will trip first when an arc-back has occured.

VIII Trouble-Shooting the Power Supplies

There are two switches on each power supply which are useful for testing and trouble-shooting.

A. The "Automatic-Off-Maintenance" Switch.

1. In the "automatic" position, this switch connects the power supply to the relay control circuitry for normal operation.

2. In the "off" position the switch disconnects all plate power from the supply.

3. The "maintenance" position is for testing. If the fuse for the DC output of the supply going to the computer is removed from the DC distribution panel, the supply receives power independent of the relay control when its switch is in the "maintenance" position. It is necessary to remove both the +150V and -150V fuses before either of these supplies can be worked on.

B. On each amplifier, regulator panel there is a switch which prevents the amplifier from sensing the supply output voltage and feeds back an adjustable level in place of the error signal. On the older supplies with series tube regulators, this switch is labelled "Test-Regulate", the "Regulate" position being the normal one and the "Test" position having the effect described above. On the ±150V supplies this switch is labelled "Manual-Automatic".

The best way to trouble-shoot a supply is to remove the fuse, put it on "maintenance," and connect it to a dummy load. A resistance box, mounted on casters, is kept in the power room for this purpose. Various resistances are provided by switches, and the proper settings for each supply can be determined from typewritten labels on the box. After the switches have been thrown according to the voltage desired, it is well to check the resistance with an ohmmeter. The box should be connected across the power supply bleeder by means of its clip leads.

If trouble with the regulator section is suspected, it may be convenient to isolate the amplifier input by means of switch 2 above. With the switch in the "test" or "manual" position, the amplifier input is disconnected from the power supply and is taken from the potentiometer with the knob on it. The screwdriver-adjustment potentiometer on the amplifier panel varies the bias on the first amplifier stage. It is used to adjust the supply voltage in normal operation.

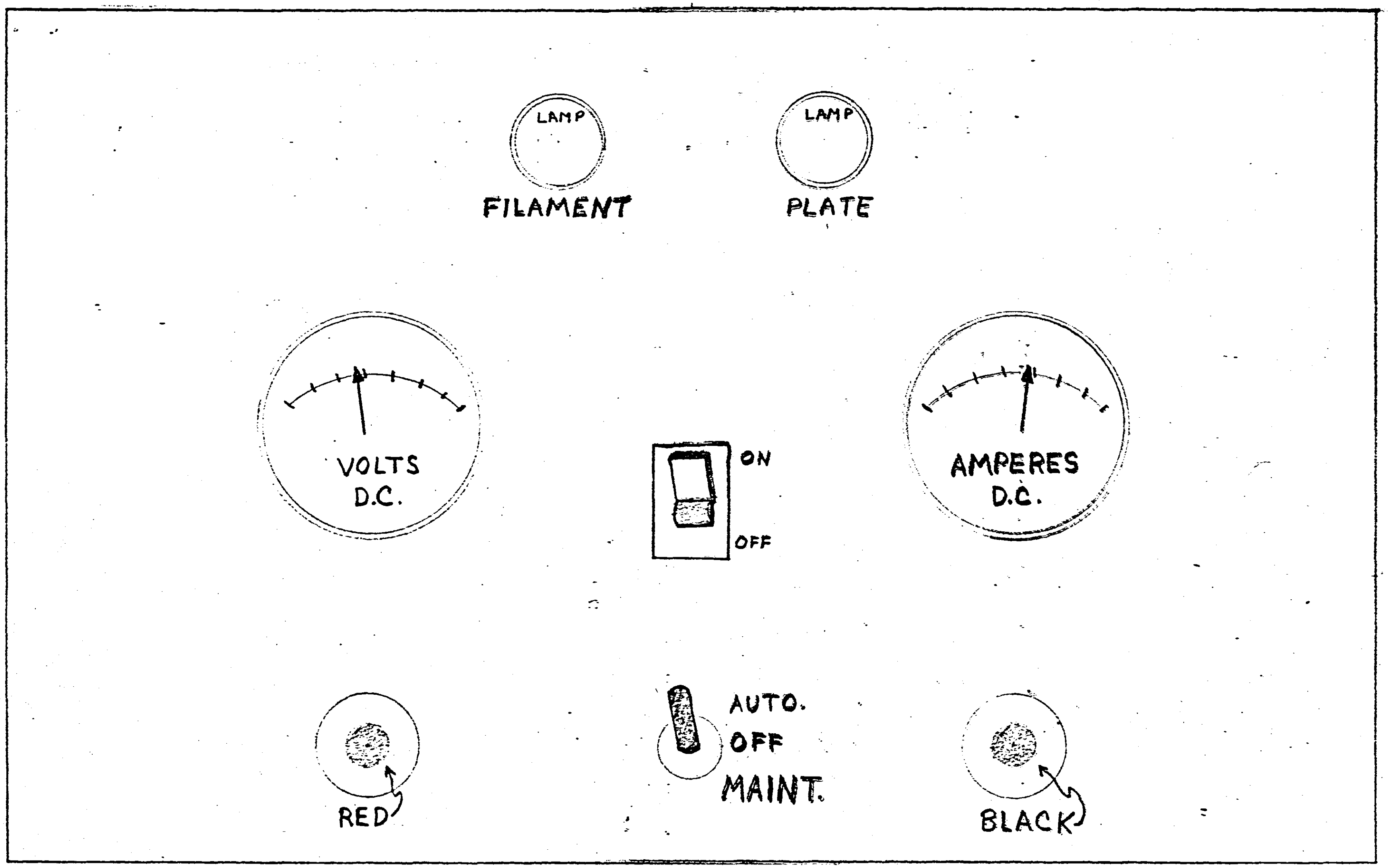
Typical maintenance procedure for the ±150V supplies might include replacement of faulty thyratrons. Thyratrons nearing end of life may glow above the anode, have a pink or yellow glow, or flicker excessively. However, some flickering is normal. The most common thyratron failure is loss of emission, which can be recognized by absence of blue glow and increased power supply 60-cycle output ripple.

Failure of the 6AU6 will cause loss of output voltage whereas failure of one 0528 will cause increased 60-cycle output ripple.

C. Reference Data

SUPPLY	BASIC RECTIFIER SCHEMATIC	AMPLIFIER REGULATOR SCHEMATIC	NORMAL CURRENT	NORMAL LOAD
+250V	C-57881	C-61220	7.1A	35 ohms.
-180V			0.1A	1800 ohms.
-300V	C-57881	C-61219	7.7A	39 ohms
-140V	C-57692	C-61217	0.70A	200 ohms
+10V	C-57692	C-60658	1.9A	5.3 ohms
-15V	C-57692	C-60596	1.7A	8.8 ohms
-30V	C-57692	C-60660	3.3A	9.1 ohms
+90V	C-57692	C-61214	2.9A	31 ohms
+600V	D-63465		0.85A	710 ohms
-150V	E-80429	E-80429	32.5A	4.6 ohms
+150V	E-80430	E-80429	28.1A	5.3 ohms

The schematic of the series tube panels for all supplies is given on print C-60957. On the following four pages are shown drawings of the panels to aid in locating adjustments.



BASIC RECTIFIER, MTC

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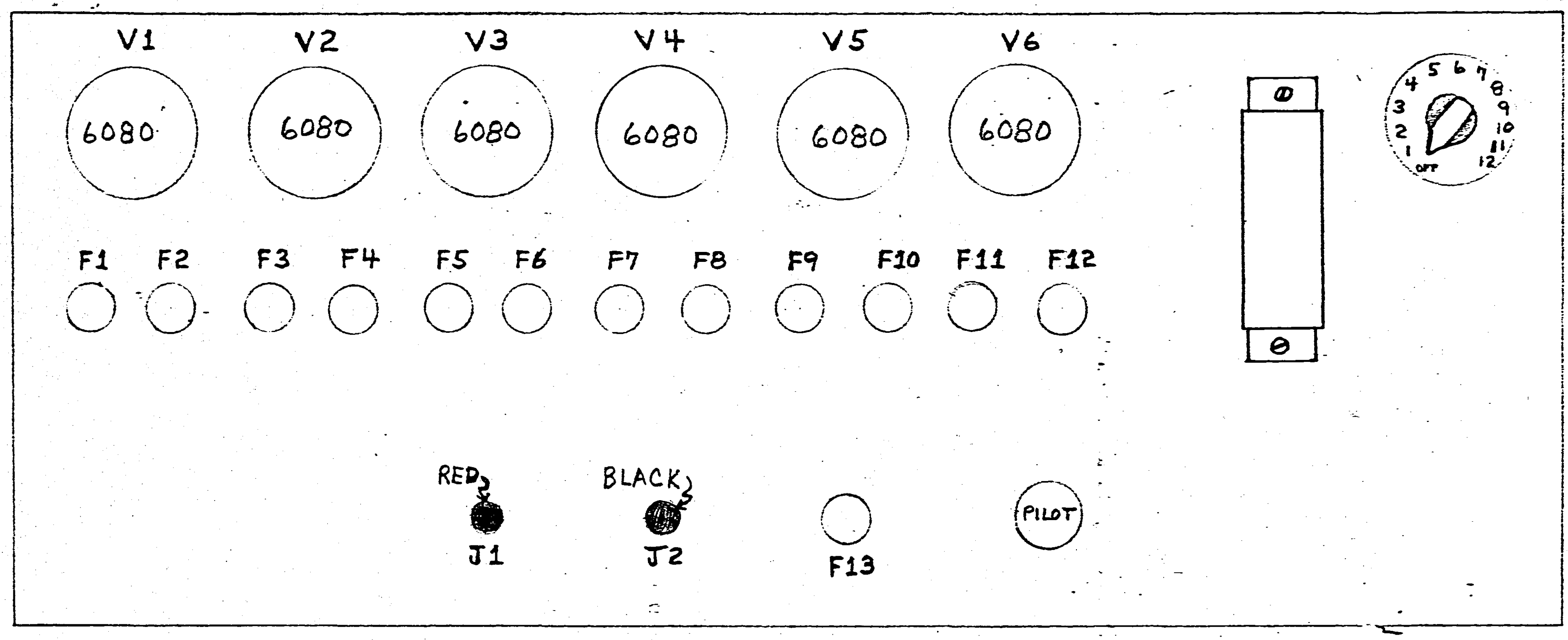

REGULATOR

SERIES TUBE SECTION, MTC

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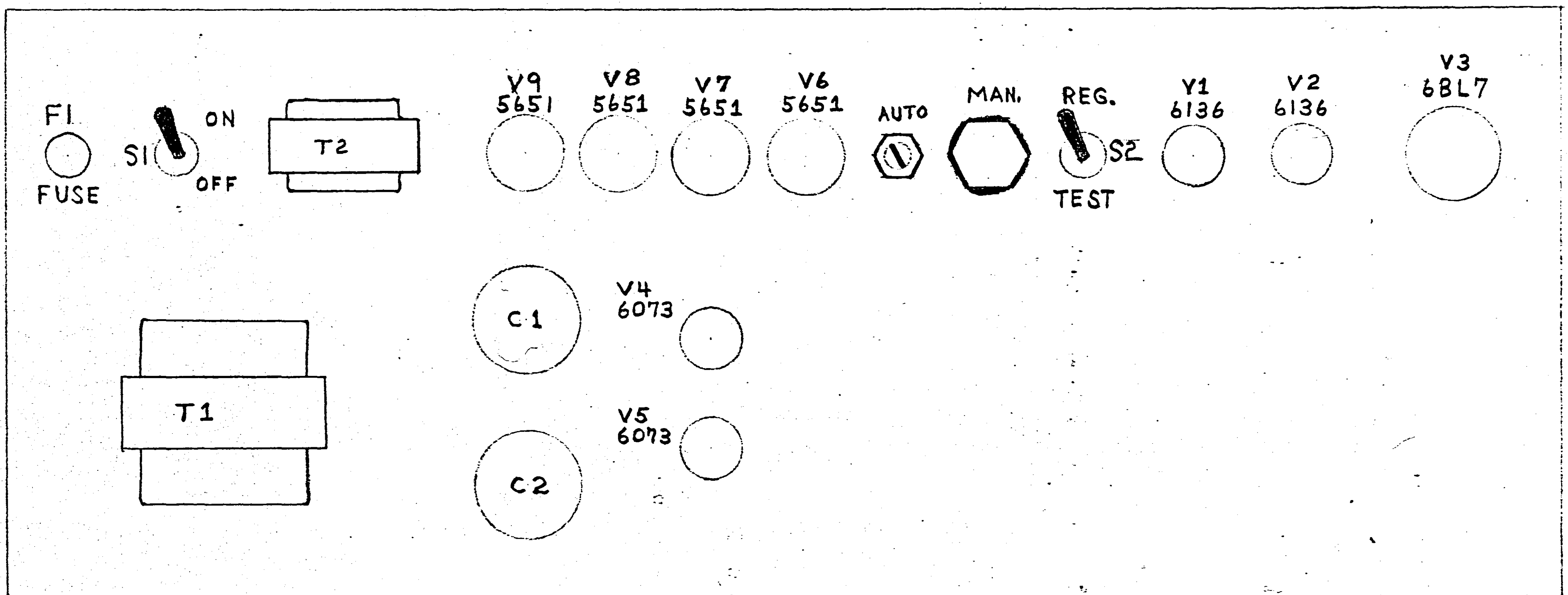
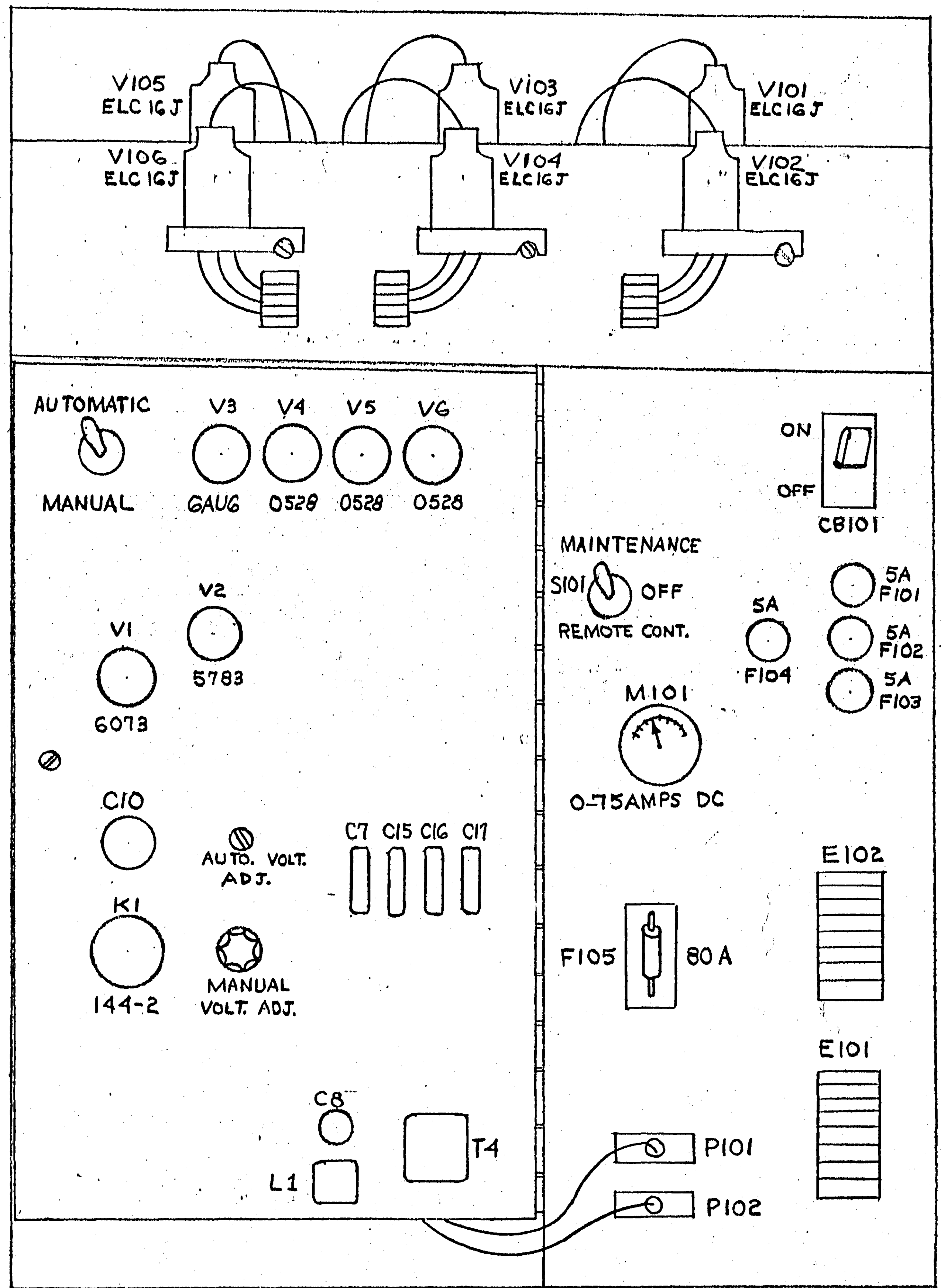


REGULATOR AMPLIFIER, MOD 2, MTC

150V, 50A POWER SUPPLY, MTC



DC POWER CONTROL

As originally conceived, MTC could use either three-phase lab power or a three-phase alternator located in the basement of the B-building. However, the alternator had to be discarded because of the increased loading, for the computer room and the power room together draw 210 amperes of 3 phase current while the capacity of the alternator is 143 amperes. In order to turn computer power on, it is necessary to go through a series of breakers and relay control circuitry:

1) Both main (175A) circuit breakers should be on. These are located in column 12 of the building B Basement, outside B-044.

2) Both 175A distribution circuit breakers should be on. One of these is located in the power room, B-051; the other one is in the computer room, to the right of the duty technician's desk.

3) All other distribution breakers should be on. Those in the computer are all rated at 30 amperes while those in the power room vary depending upon the individual requirements of the various power supplies.

4) The console circuit breaker should be on. This breaker supplies power to the relay.

When reading the following description of the control circuitry, one should refer to print D-47098.

Turning on the console breaker actuates relay K1, closing its contacts and applying power to the fuse interlock chain in the computer room. If all fuses are closed, power cycling will proceed as normal, if not, a fuse alarm will be indicated on the console. The "normal" indicator light will then be lighted.

5) The "Standby" button is then pushed, either on the computer console or in the power room.

Pushing the "Standby" button actuates relay K16, closing its contacts and applying power to K3 and TD 11, which is a one minute 15 second time delay. After the time delay, power will be applied through the closed TD-11 contacts to actuate K6. Also actuated are the K2 and K14 coils and the "filament on" light. Power then flows through the closed K3 and K6 contacts to actuate the transfer contactor coils. The transfer contactors were formerly used to transfer power from building lines to alternator lines; however, the coils are inactive now, because the alternator is no longer used. Also actuated at this time are the time delays of 1 minute 30 seconds in each power supply, which control the relays that apply AC voltage to the mercury vapor rectifiers. The K-2 relay is also actuated, to supply a hold circuit across the standby switch to keep it permanently closed after it is pushed. Power flows through the closed contacts of the K10 and K14 relays, lighting the standby lights in both the computer room and the power room.

6) After a two minute wait to allow the temperature of the mercury vapor rectifier tubes come up to normal, the "power on" switch is pushed. This applies power to the K18 hold relay and time delay TD 15 (5 sec.).

A warning horn sounds for 5 seconds until the contacts on TD 15 open, stopping the horn. However, a different set of contacts on the TD 15 relay closes: they actuate the K 10 and K 8 relays and light the "dc power on" lights in the computer room and power room. For this circuit to be completed, the fuse interlock system, the sensitrol interlocks, and the ac distribution interlocks must all be closed. The K 5 relay is actuated when the "DC power on" lights go on, closing the K 5 contacts and actuating K 200. Power is also applied to the sensitrol reset coils through the closed contacts of K 201. Time delay TD 214, approximately 1 sec., is actuated through the closed contacts of K 200. After about one second the contacts of TD 214 close, actuating K 201. One set of contacts on K 201 opens, removing power from the sensitrol reset coils, and ending the sensitrol reset operation. Relays K 207, K 208, and K 203 are actuated through a closed set of contacts on K 201. Power is also applied to the plate contactor coils in the -30V, -15V, and +10V power supplies through the closed contact of K 207. If the +10V, -15V, and -30V supplies come on successfully, relays K 204, K 205, and K 206 will be actuated. A.C. power will be supplied through these contacts, actuating the K 202 relay, closing its contact, and supplying power permanently to the plate contactor coils of the -30V, -15V and +10V power supplies. The "on" light for the +10V, -15V and -30V supplies will come on, indicating successful cycling for those supplies. Relay K 210 will also be actuated, and together with its contact, form a hold circuit for the +10V, -15V, -30V "on" lights. All hold circuits for indicator lights will hold for approximately one second after d-c power comes on even if the cycling operation is incomplete. This enables one to see where the cycling chain has broken.

If the +10V, -15V, and -30V supplies have cycled on successfully, power will be applied through the closed contact of K 207 to actuate K 202 and the plate contactor coils in the -300V, -180V, and -140V power supplies. This closes the contacts on K 202, permanently actuating the plate contactor coils on the -30V, -15V, and +10V power supplies. If the -300V, and -140V come on successfully, relays K 211, K 212, and K 213 will be actuated; the -140V, -180V, and -300V "on" light will be lighted, and the relay K 222 in the hold circuit will be actuated. Power will also be applied through the closed contact of K 208 to relay K 203 and the plate contactor coils of the +150V and -150V supplies. This closes the contacts of K 203, applying power permanently to the -300V, -180V, and -140V supplies. If the +150V and -150V supplies cycle on successfully, relays K 220 and K 221 will be actuated, applying power to the +150V, -150V "on" light and the K 223 hold circuit. Power will also be applied through the closed contact of K 208 to actuate K 224, K 226, and the plate contactor coils of the +250V power supply. If the +250V supply cycles on successfully, K 221 will be actuated and power will flow through the closed contacts K 221 and K 226, to light the +250V "on" light and actuate the K 229 hold circuit. Relay K 227 will also be actuated through the closed contacts of K 209, actuating K 227 and the plate contactor coil of the +30V supply.

Trouble-shooting Power Control

Power Control is essentially a series of relays, sensitrols, and other associated circuitry which cycle on or off the various power supplies. The location of a faulty component in power control is not a simple matter because one has no record of the state of the circuit when the failure occurred. However, power control can be simplified if it is thought of as two separate parts - AC control and DC control. The AC cycling must be successfully completed before DC control takes over. DC control includes the DC sensing relays as well as the sensitrol system. Each supply, as it successfully comes on, is sensed by a DC relay which closes and allows power to be applied to the next supply. The successful cycling of a group of supplies is indicated by the "power group" lights. The failure of any group lights to light indicates either trouble in AC control or failure of one of the supplies in the first group, which includes the +10V, -15V, and -30V supplies. Since the group lights do not remain on after failure has occurred, the indication is of short duration. Additional trouble shooting aids can be gleaned from the sensitrol indicators (if the cycling got that far) or from the DC meters themselves.

Fuses in Power Control

The power control panel in T7 obtains its power from one of the three phases of the 175amp circuit breaker located in the computer room AC distribution panel to the right of the duty technician's desk. This line is protected with 15A fuses both behind the power control panel and at the AC distribution panel. Both these fuses must be in place and the console circuit breaker must be "on" in order to obtain AC power in the power room.

CYCLIC CONTROL

I. Purpose

During troubleshooting, and especially when using the test oscilloscope, it is desirable to perform selected portions of a program repeatedly at a repetition rate that permits observation of indicator light patterns and circuit waveforms with the oscilloscope. This can be done with the MTC Cyclic Control in T8 which provides periodic pulses for "Start Over", "Clear CPC", "Stop", and "Restart". The advantage of the technique is that between pulses all parts of the computer, including the clock and other control units, are operating in completely normal fashion; hence subtle malfunctions can be "caught in the act" under realistic conditions.

II. Use

Typically, computer trouble is first manifested as a failure traced by the programmer to one section of his program. In that case Cyclic Control enables the trouble-shooter to perform the same fragment over and over again, perhaps varying the pulse repetition rate by varying the pulse generator frequency. Synchronizing pulses for the oscilloscope can be derived from cyclic control or from a sequence gate of the instruction in which an error is detected, and the operations of the computer just before the time of failure studied in minute detail.

III. Equipment

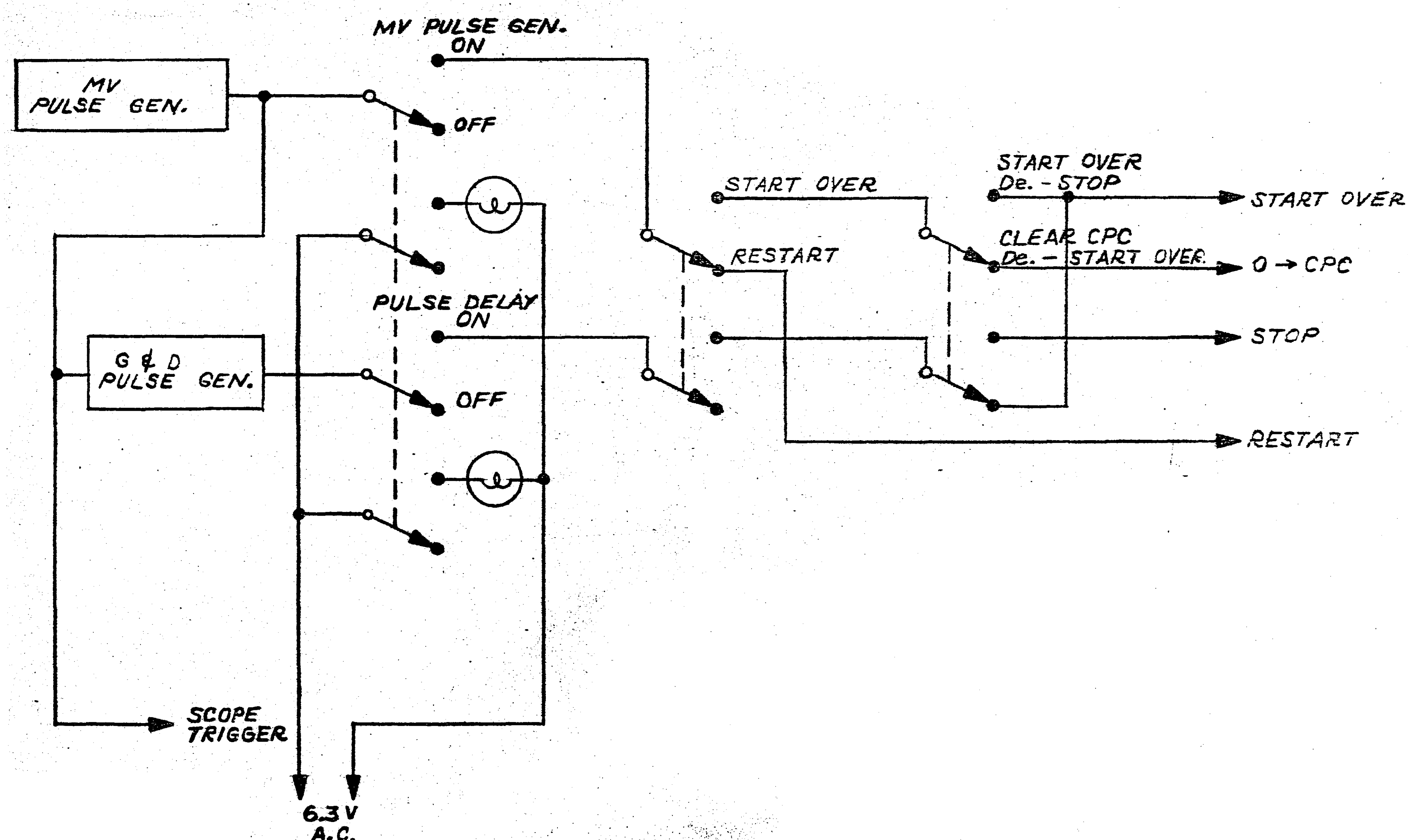
The Cyclic Control unit consists of a Multivibrator Pulse Generator (MVPG) and a Gate and Delayed Pulse Generator (GDPG). The Multivibrator and the Gate and Delayed Pulse Generator each have two knobs on the front panel, with those for the GDPG above and to the right of those for the MVPG. Of these, the right knob in each case is a fine frequency adjustment, and the left knob is a five position switch, with position one fully counterclockwise. The following timing table is very approximate:

Coarse Setting	MVPG Period	GDPG Delay
1	5 - 75 ms	1 - 22 µs
2	5 - 7.5 ms	10 - 250 µs
3	50 - 750 µs	90 µs - 2 ms
4	6 - 90 µs	85 - 17 ms
5	1.5 - 15 µs	9 - 80 ms

IV. Modes of Operation

Reference to the schematic on the next page shows that, besides the "On-Off" switches, there are two switches on the Cyclic Control Panel that control its connection to the computer. With these switches 3 modes of operation are possible:

A. When the "Start Over - Restart" switch is thrown to "Restart", the "Start Over; Delay Stop - Clear CPC, Delay Start Over" switch


MV PULSE GEN.
ON
MV PULSE GEN.
OFF
G & D PULSE GEN.
PULSE DELAY ON
OFF
SCOPE TRIGGER
6.3 V A.C.
START OVER
RESTART
START OVER De. - STOP
CLEAR CPC De. - START OVER
START OVER
0 → CPC
STOP
RESTART

is ineffective; in this mode the MVPG supplies Restart pulses. A program may be synchronized to the MVPG by using this switch and interspersing the program with halt instructions so that the running time between adjacent stops is less than the period of the pulse generator.

B. With the "Start Over - Restart" switch on "Start Over", two modes are possible. In the "Start Over, Delay Stop" mode, the "Start Over" frequency is adjusted by the pulse generator. The delay is adjusted to stop the program after the point of interest has passed. If the delay is short compared with the pulse generator period, the indicator lights will show the place in the program where the stop occurred.

C. With certain malfunctions involving In-Out equipment or the clock itself, the computer may put itself into a condition such that it cannot be started over until Clock Pulse Control (CPC) has been cleared. In this situation one must use the "0 → CPC, Start Over" mode, with the pulse generator period longer than the program duration, and the delay set at minimum.

V. "Step by Step" and "Instruction by Instruction" Switches

There are two other switches on the Cyclic Control panel, both of which stop the computer periodically and require it to wait for a "Restart" pulse.

The "Step by Step" switch, when up, stops the computer after every clock pulse, that is, after every step of the Sequence Switch.

The "Instruction by Instruction" switch, when up, will allow the computer to complete each instruction, but will cause it to stop just before the next Program Timing cycle and wait for a "Restart" pulse.

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FUNDAMENTALS: MATHEMATICS, LOGIC, CIRCUITS

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a. Number Systems

b. Choice of a Number Base

c. Conversions Between Binary and Decimal Numbers

d. Binary Addition

e. Binary Subtraction (Complements)

f. Binary Multiplication

g. Binary Division

Logic

h. Mechanizing Mathematical Operations

i. Bi-Stable Devices

j. "AND" Logic

k. "OR" Logic

l. Time Sequence

m. Multiple-position Switches

Circuits

n. Flip-flops

o. Gates

p. "Diode Logic" Units

q. Driving Circuits

r. Delay Units

s. Special Circuits

t. Multiple-circuit Combinations

MTC Service Manual, Section 6

INTERNAL MEMORY

a. Function of Internal Memory

b. Logical and Physical Arrangement

c. Field Selection

d. Program Counter

e. Memory Control

f. Parity Checking

Panel Memory

g. Panel Address Register

h. Panel Memory Matrix Switch

i. Toggle Switch Registers

j. Plugboard Storage

k. Live Registers

Core Memory

l. Principles of a Coincident-Current Magnetic-Core Memory

m. The Memory Stack

n. Memory Address Register

o. Core Memory Matrix Switch

p. Selection Plane Drivers

q. Read-Write Gate Generators

r. Digit Plane Drivers

s. Inhibit Gate Generator

t. Sensing Amplifier

u. Operation During Copy Block Instruction

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MTC Service Manual, Section 7
MAIN CONTROL

General

a. Function of Main Control

b. The Master Clock and Clock Pulse Control

c. The Sequence Switch

d. The Control Switch

e. Function Buffers

f. Program Timing and FX

g. Operation Timing; Memory, and Non-Memory Instructions

h. Extended Control Switch

i. Establishing Initial Conditions

Individual Instructions

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l. Control of Input Devices; ri, op, pf

m. Storing into Memory; st, ra, rf, ao, cb

n. Transfer Instructions; tr, tro, tn, tno, to

o. Reading from Memory; ca, ad, cs, su, ao, cb

p. Arithmetic Operations; mh, cr, sr

q. Comparisons; id, sm, et

r. Control of Output Devices; ds, ch, pr, op, pf

s. The Halt Instruction; ha

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MTC Service Manual, Section 8

THE ARITHMETIC SECTION

a. The "A" Register

b. The Accumulator; Partial Sum, and Carry

c. Mechanics of Addition (with variations)

d. Overflow

e. The "B" Register

f. Sign Control

g. Shifting Operations

h. The Step Counter

i. Multiplication

MTC Service Manual, Section 10

THE MAGNETIC DRUM

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b. Logical and Physical Arrangement

c. Addressing Drum Registers

d. Writing

e. Reading

f. Drum Read Switch

g. Drum Field Switch

h. Drum Diode Matrix

i. Drum Control

j. Drum Alarms

k. Erasing of Drum and Rewriting of Special Tracks

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MTC Service Manual, Section 14

CRT DISPLAYS AND AUXILIARIES

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a. Computer-Generated Displays

b. Display Tubes

c. Design Requirements

d. Intensification

e. Decoders

Display System, 12 1/2" Scope

f. The High-Voltage Distribution Panel

g. Cathode High-Voltage Supply

h. Post-Accelerator High-Voltage Supply

i. Scope Intensification

j. Deflection Amplifiers

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l. The Console Display Scope

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a. The Audio Zero-Crossing Detector

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b. Physical Location of Points in MTC

GENERAL TERMS USED IN THE COMPUTING FIELD
(From Proceedings of the IRE, September 1956, pp 1167-1173. Reprinted by permission of the IRE.) Terms marked with an asterisk (*) are those referred to quite frequently in conjunction with MTC.

Access Time*. A time interval which is characteristic of a storage unit, and is essentially a measure of the time required to communicate with that unit. Many definitions of the beginning and ending of this interval are in common use.

Accumulator*. A device which stores a number and which, on receipt of another number, adds it to the number already stored and stores the sum. Note: The term is also applied to devices which function as described but which also have other properties.

Accuracy. The quality of freedom from mistake or error, that is, of conformity to truth or to a rule. Accuracy is distinguished from "Precision" as in the following example: A six-place table is more precise than a four-place table. However, if there are errors in the six-place table, it may be either more or less accurate than the four-place table.

Adder. A device which can form the sum of two or more numbers or quantities.

Address*. An expression, usually numerical, which designates a particular location in a "Storage" or "Memory" device or other source or destination of information. See also "Instruction Code".

Address Part*. In an instruction, any part that is usually an "Address". See also "Instruction Code".

Analog (in Electronic Computers). A physical system on which the performance of measurements yields information concerning a class of mathematical problems.

Analog Computer. A physical system together with means of control for the performance of measurements (upon the system) which yield information concerning a class of mathematical problems.

And-Circuit*. Synonym for "And-Gate".

And-Gate*. A gate whose output is energized when and only when every input is in its prescribed state. An "And-Gate" performs the function of the logical "And".

Arithmetic Element*. Synonym for "Arithmetic Unit".

Arithmetic Unit*. That part of a computer which performs arithmetic operations.

Automatic Check. See "Check", "Automatic".

Band (in Electronic Computers). A group of "Tracks" on a magnetic drum.

Base. See "Positional Notation".

Binary*. See "Positional Notation".

Binary Cell. An elementary unit of storage which can be placed in either of two stable states. (See Bit)

Binary-Coded-Decimal System. A system of number representation in which each decimal digit is represented by a group of binary digits (e.g., "Excess-Three Code").

Binary Number System*. See "Positional Notation".

Binary Point. See "Point".

Bit (in Electronic Computers)*. 1) An abbreviation of "Binary Digit". 2) A single "Character" of a "Language" employing exactly two distinct kinds of characters. 3) A unit of storage capacity. The capacity, in bits, of a storage device is the logarithm to the base two of the number of possible states of the device. See also "Storage Capacity".

Block*. A group of "Words" considered as a unit.

Borrow. See "Carry".

Branch. Synonym for "Conditional Jump".

Break Point. A place in a "Routine" at which a special instruction is inserted which, if desired, will cause a digital computer to stop for a visual check of progress.

Buffer*. 1) An isolating circuit (sometimes an amplifier) used to avoid reaction of a driven circuit on the corresponding driving circuit. 2) A storage device used to compensate for a difference in rate of flow of information or time or occurrence of events when transmitting information from one device to another.

Bus* (in Electronic Computers). One or more conductors which are used as a path for transmitting information from any of several sources to any of several destinations.

Carry*. 1) A signal, or expression, produced as a result of an arithmetic operation on one digit place of two or more numbers expressed in "Positional Notation" and transferred to the next higher place for processing there. 2) Usually a signal or expression as defined in 1) above which arises in adding, when the sum of two digits in the same digit place equals or exceeds the "Base" of the number system in use. If a carry into a digit place will result in a carry out of the same digit place, and if the normal adding circuit is bypassed when generating this new carry, it is called a High-Speed Carry, or Standing-on-Nines Carry. If the normal adding circuit is used in such a case, the carry is called a Cascaded Carry. If a carry resulting from the addition of carries is not allowed to propagate (e.g., when forming the partial product in one step of a multiplication process), the process is called a Partial Carry. If it is allowed to propagate, the process is called a Complete Carry. If a carry generated in the most significant digit place is sent directly to the least significant place (e.g., when adding two negative numbers using nines complements) that carry is called an End-Around Carry. 3) In direct subtraction, a signal or expression as defined in 1) above which arises when the difference between the digits is less than zero. Such a carry is frequently called a Borrow. 4) The action of forwarding a carry. 5) The command directing a carry to be forwarded.

Cascaded Carry. See "Carry".

Cell. An elementary unit of storage (e.g., binary cell, decimal cell).

Channel*(in Electronic Computers). That portion of a storage medium which is accessible to a given reading station. See also "Track".

Character*(in Electronic Computers). One of a set of elementary marks or events which may be combined to express information.

Note: A group of characters, in one context, may be considered as a single character in another, as in the "Binary-Coded-Decimal System".

Check*. A process of partial or complete testing of 1) the correctness of machine operations, 2) the existence of certain prescribed conditions within the computer, or 3) the correctness of the results produced by a "Routine". A check of any of these conditions may be made automatically by the equipment or may be programmed. See also "Marginal Checking"; "Verification".

Check, Automatic. A "Check" performed by equipment built into the computer specifically for that purpose, and automatically accomplished each time the pertinent operation is performed. Sometimes referred to as a built-in check. Machine Check can refer to an automatic check, or to a "Programmed Check" of machine functions.

Check Digits. See "Check", "Forbidden-Combination".

Check, Forbidden-Combination*. A "Check" (usually an "Automatic Check") which tests for the occurrence of a nonpermissible code expression. A Self-Checking Code (or Error-Detecting Code) uses code expressions such that one (or more) error(s) in a code expression produces a forbidden combination. A Parity Check makes use of a self-checking code employing binary digits in which the total number of 1's (or 0's) in each permissible code expression is always even or always odd. A check may be made for either even parity or odd parity. A Redundancy Check employs a self-checking code which makes use of redundant digits called Check Digits.

Check Problem. See "Check", "Programmed".

Check, Programmed. A "Check" consisting of tests inserted into the program of the problem and accomplished by appropriate use of the machine's instructions. A Mathematical Check (or "Control") is a programmed check of a sequence of operations which makes use of the mathematical properties of that sequence. A Check Routine or Check Problem is a routine or problem which is designed primarily to indicate whether a fault exists in the computer, without giving detailed information on the location of the fault. See also "Diagnostic Routine"; "Test Routine".

Check Routine. See "Check", "Programmed".

Check, Selection. A "Check" (usually an "Automatic Check") to verify that the correct register, or other device, is selected in the performance of an instruction.

Check, Transfer. A "Check" (usually an "Automatic Check") on the accuracy of the transfer of a word.

Circulating Register (or Memory). A register (or memory) consisting of a means for delaying information and a means for regenerating and reinserting the information into the delaying means.

Clear*. To restore a storage or memory device to a prescribed state, usually that denoting zero. See also "Reset".

Clock*. A primary source of synchronizing signals.

Code* (in Electronic Computers). 1) A system of "Characters" and rules for representing information. 2) Loosely, the set of characters resulting from the use of a code. 3) To prepare a "Routine" in "Machine Language" for a specific computer. 4) To encode; to express given information by means of a code. See also "Language".

Column*. Synonym for "Place".

Command*. 1) One of a set of several signals (or groups of signals) which occurs as a result of an "Instruction"; the commands initiate the individual steps which form the process of executing the instruction. 2) Synonym for "Instruction".

Complement*. 1) A number whose representation is derived from the finite "Positional Notation" of another by one of the following rules: a) True complement--Subtract each digit from one less than the base, then add 1 to the least significant digit, executing all carries required. b) Base minus one's complement--Subtract each digit from one less than the base (e.g., "9's complement" in the base 10, "1's complement" in the base 2, etc.). 2) To form the complement of a number.

Note: In many machines, a negative number is represented as a complement of the corresponding positive number.

Complete Carry. See "Carry".

Computer*. 1) A machine for carrying out calculations. 2) By extension, a machine for carrying out specified transformations on information.

Conditional Jump. An instruction which will cause the proper one of two (or more) addresses to be used in obtaining the next instruction, depending upon some property of one or more numerical expressions or other conditions.

Conditional Transfer Of Control*. Synonym for "Conditional Jump".

Control*. 1) Usually, those parts of a digital computer which effect the carrying out of instructions in proper sequence, the interpretation of each instruction, and the application of the proper signals to the arithmetic unit and other parts in accordance with this interpretation. 2) Frequently, one or more of the components in any mechanism responsible for interpreting and carrying out manually-initiated directions. Sometimes called manual control. 3) In some business applications of mathematics, a "Mathematical Check".

Copy. See "Transfer".

Correction. See "Error".

Counter*. 1) A device capable of changing from one to the next of a sequence of distinguishable states upon each receipt of an input signal. 2) Less frequently, an "Accumulator".

Counter, Ring. A loop of interconnected bistable elements such that one and only one is in a specified state at any given time and such that, as input signals are counted, the position of the one specified state moves in an ordered sequence around the loop.

Cyclic Shift. An operation which produces a "Word" whose "Characters" are obtained by a cyclic permutation of the characters of a given word.

Decimal Number System*. See "Positional Notation".

Decimal Point*. See "Point".

Decoder*. A network or system in which a combination of inputs is excited at one time to produce a single output. Sometimes called "Matrix".

Delay Line (in Electronic Computers)*. 1) Originally, a device utilizing wave propagation for producing a time delay of a signal. 2) Commonly, any device for producing a time delay of a signal.

Delay-Line Memory. Synonym for "Delay-Line Storage".

Delay-Line Storage. A storage or memory device consisting of a delay line and means for regenerating and reinserting information into the delay line.

Diagnostic Routine. A "Routine" designed to locate either a malfunction in the computer or a mistake in coding. See also "Check", "Programmed".

Differentiator (in Electronic Computers). A device, usually of the analog type, whose output is proportional to the derivative of an input signal.

Digit*. See "Positional Notation".

Digital Computer*. A computer which operates with information, numerical or otherwise, represented in a digital form.

Double-Length Number. A number having twice as many digits as are ordinarily used in a given computer.

Double-Precision Number. Synonym for "Double-Length Number".

Encoder. A network or system in which only one input is excited at a time and each input produces a combination of outputs. Sometimes called "Matrix".

End-Around Carry. See "Carry".

Error*. 1) In mathematics, the difference between the true value and a calculated or observed value. A quantity (equal in absolute magnitude to the error) added to a calculated or observed value to obtain the true value is called a "Correction". 2) In a computer or data-processing system, any incorrect step, process, or result. In addition to the mathematical usage, in the computer field the term is also commonly used to refer to machine malfunctions as "Machine Errors" and to human mistakes as "Human Errors". It is frequently helpful to distinguish between these as follows: . errors result from approximations used in numerical methods; Mistakes result from incorrect programming, coding, data transcription, manual operation, etc.; Malfunctions result from failures in the operation of machine components such as gates, flip-flops, amplifiers, etc.

Error-Detecting Code. See "Check", "Forbidden-Combination".

Excess-Three Code. A number "Code" in which the decimal digit n is represented by the four-bit binary equivalent of n + 3. See also "Binary-Coded-Decimal System".

Extract*. To form a new "Word" by juxtaposing selected segments of given words.

Fixed-Point System*. See "Point".

Flip-Flop*. 1) A device having two stable states and two input terminals (or types of input signals) each of which corresponds with one of the two states. The circuit remains in either state until caused to change to the other state by application of the corresponding signal. 2) A similar bistable device with an input which allows it to act as a single-stage binary "Counter".

Floating-Point System*. See "Point".

Flow Diagram (in Electronic Computers)*. A graphical representation of a "Program" or a "Routine".

Forbidden-Combination Check*. See "Check", "Forbidden-Combination".

Four-Address Code. See "Instruction Code".

Gate (in Electronic Computers)*. A circuit having an output and a multiplicity of inputs so designed that the output is energized when and only when certain input conditions are met. See also "And-Gate; "Or-Gate".

Note: Sometimes "Gate" is used for "And-gate".

Half Adder. A circuit having two input and two output channels for binary signals (0, 1) and in which the output signals are related to the input signals according to the following table:

A+B Inputs		Outputs	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

(So called because two half adders can be used in the construction of one binary "Adder").

Hexadecimal. See "Positional Notation".

High-Speed Carry*. See "Carry".

Inhibiting Input. A "Gate" input which, if in its prescribed state, prevents any output which might otherwise occur.

Instruction*. See "Instruction Code".

Instruction Code*. An artifical "Language" for describing or expressing the instructions which can be carried out by a digital computer. In automatically sequenced computers, the instruction code is used when describing or expressing sequences of Instructions, and each instruction word usually contains a part specifying the operation to be performed and one or more "Addresses" which identify a particular location in storage. Sometimes an "Address Part" of an instruction is not intended to specify a location in storage but is used for some other purpose.

If more than one address is used, the code is called a Multiple-Address Code. In a typical instruction of a Four-Address Code the addresses specify the location of two operands, the destination of the result, and the location of the next instruction in the sequence. In a typical Three-Address Code, the fourth address specifying the location of the next instruction is dispensed with and the instructions are taken from storage in a preassigned order.

In a typical One-Address or Single-Address Code, the address may specify either the location of an operand to be taken from storage, the destination of a previously prepared result, or the location of the next instruction. The arithmetic element usually contains at least two storage locations, one of which is an accumulator. For example, operations requiring two operands may obtain one operand from the main storage and the other from a storage location in the arithmetic element which is specified by the operation part.

Integrator (in Electronic Computers). 1) A device whose output is proportional to the integral of an input signal. 2) In certain digital machines, a device for numerically accomplishing an approximation to the mathematical process of integration.

Jump. To (conditionally or unconditionally) cause the next instruction to be selected from a specified storage location.

Language (in Electronic Computers). 1) A system consisting of a) a well defined, usually finite, set of characters; b) rules for combining characters with one another to form words or other expressions; and c) a specific assignment of meaning to some of the words or expressions, usually for communicating information or data among a group of people, machines, etc. 2) A system similar to the above but without any specific assignment of meanings. Such systems may be distinguished from 1) above, when necessary, by referring to them as formal or uninterpreted languages. Although it is sometimes convenient to study a language independently of any meanings, in all practical cases at least one set of meanings is eventually assigned. See also "Code"; "Machine Language".

Logic*. See "Logical Design".

Logical Design*. 1) The planning of a computer or data-processing system prior to its detailed engineering design. 2) The synthesizing of a network of "Logical Elements" to perform a specified function. 3) The result of 1) and 2) above, frequently called the Logic of the system, machine, or network.

Logical Diagram*. In "Logical Design", a diagram representing the "Logical Elements" and their interconnections without necessarily expressing construction or engineering details.

Logical Element*. In a computer or data-processing system, the smallest building blocks which can be represented by operators in an appropriate system of symbolic logic. Typical logical elements are the and-gate and the flip-flop, which can be represented as operators in a suitable symbolic logic.

Logical Operation*. 1) Any nonarithmetical operation. Examples are: "Extract", logical (bit-wise) multiplication, "Jump", data transfer, etc. 2) Sometimes, only those nonarithmetical operations which are expressible bit-wise in terms of the propositional calculus or a two-valued Boolean algebra.

Logical Symbol. A symbol used to represent a "Logical Element" graphically.

Machine Check. See "Check", "Automatic".

Machine Language. 1) A "Language", occurring within a machine, ordinarily not perceptible or intelligible to persons without special equipment or training. 2) A translation or transliteration of 1) above into more conventional characters but frequently still not intelligible to persons without special training.

Major Cycle. In a storage device which provides "Serial" access to storage positions, the time interval between successive appearances of a given storage position.

Malfunction. See "Error".

Marginal Checking*. A preventive maintenance procedure in which certain operating conditions, e.g., supply voltage or frequency, are varied about their normal values in order to detect and locate incipient defective units. See also "Check".

Marginal Testing*. Synonym for "Marginal Checking".

Master Routine. See "Subroutine".

Mathematical Check. See "Check", "Programmed".

Matrix (in Electronic Computers)*. 1) Any logical network whose configuration is a rectangular array of intersections of its input-output leads, with elements connected at some of these intersections. The network usually functions as an "Encoder" or "Decoder". 2) Loosely, any encoder, decoder, or "Translator".

Memory*. See "Storage".

Memory Capacity*. Synonym for "Storage Capacity".

Minor Cycle. In a storage device which provides "Serial" access to storage positions, the time interval between the appearance of corresponding parts of successive words.

Mistake. See "Error".

Multiple-Address Code. See "Instruction Code".

Multiplier*. A device which has two or more inputs and whose output is a representation of the product of the quantities represented by the input signals.

Number*. 1) Formally, an abstract mathematical entity which is a generalization of a concept used to indicate quantity, direction, etc. In this sense a number is independent of the manner of its representation. 2) Commonly: A representation of a number as defined above (e.g., the binary number "10110", the decimal number "3695", or a sequence of pulses). 3) An expression composed wholly or partly of digits which does not necessarily represent the abstract entity mentioned in the first meaning.

Note: Whenever there is a possibility of confusion between meaning 1) and meaning 2) or 3), it is usually possible to make an unambiguous statement by using "number" for meaning 1) and "numerical expression" for meaning 2) or 3).

Number System*. See "Positional Notation".

Octal*. See "Positional Notation".

Octonary. See "Positional Notation".

One-Address Code*. See "Instruction Code".

Operation Code*. 1) The list of "Operation Parts" occurring in an "Instruction Code", together with the names of the corresponding operations (e.g., "add", "unconditional transfer", "add and clear", etc.). 2) Synonym for "Operation Part" of an instruction.

Operation Part. In an instruction, the part that usually specifies the king of operation to be performed, but not the location of the operands. See also "Instruction Code".

Or-Circuit*. Synonym for "Or-Gate".

Order*. 1) Synonym for "Instruction". 2) Synonym for "Command". 3) Loosely, synonym for "Operation Part".

Note: The use of "Order" in the computer field as a synonym for terms similar to the above is losing favor owing to the ambiguity between these meanings and the more common meanings in mathematics and business.

Or-Gate*. A gate whose output is energized when any one or more of the inputs is in its prescribed state. An or-gate performs the function of the logical "inclusiveor".

Overflow*. 1) The condition which arises when the result of an arithmetic operation exceeds the capacity of the number representation in a digital computer. 2) The "Carry" digit arising from this condition.

Parallel (in Electronic Computers)*. Pertaining to simultaneous transmission of, storage of, or logical operations on the parts of a word, character, or other subdivision of a word, using separate facilities for the various parts.

Parallel Digital Computer*. One in which the digits are handled in parallel. Mixed serial and parallel machines are frequently called serial or parallel according to the way arithmetic processes are performed. An example of a parallel digital computer is one which handles decimal digits in parallel although it might handle the bits which comprise a digit either serially or in parallel. See also "Serial Digital Computer".

Parity Check*. See "Check", "Forbidden-Combination".

Partial Carry. See "Carry".

Place*. In "Positional Notation", a position corresponding to a given power of the base. A digit located in any particular place is a coefficient of a corresponding power of the base.

Point*. In "Positional Notation", the "Character", or the location of an implied symbol, which separates the integral part of a numerical expression from its fractional part. For example, it is called the Binary Point in binary notation and the Decimal Point in decimal notation. If the location of the point is assumed to remain fixed with respect to one end of the numerical expressions, a Fixed-Point System is being used. If the location of the point does not remain fixed with respect to one end of the numerical expressions, but is regularly recalculated, then a Floating-Point System is being used.

Note: A fixed-point system usually locates the point by some convention, while a floating-point system usually locates the point by expressing a power of the base.

Positional Notation*. One of the schemes for representing numbers, characterized by the arrangement of digits in sequence, with the understanding that successive digits are to be interpreted as coefficients of successive powers of an integer called the Base of the Number System*.

In the Binary Number System the successive digits are interpreted as coefficients of the successive powers of the base two just as in the Decimal Number System they relate to successive powers of the base ten.

In the ordinary number systems each Digit is a "Character" which stands for zero or for a positive integer smaller than the base.

The names of the number systems with bases from 2 to 20 are: Binary, Ternary, quaternary, quinary, senary, septenary, Octonary, (also Octal), novenary, decimal, undecimal, duodecimal, terdenary, quaterdenary, quindenary, Sexadecimal (also Hexadecimal), septendecimal, octodenary, novendenary, and vicenary. The sexagenary number system has the base 60. The commonly used alternative of saying "Base-3", "Base-4", etc., in place of tenary, quaternary, etc., has the advantage of uniformity and clarity.

Precision. The quality of being exactly or sharply defined or stated. A measure of the precision of a representation is the number of distinguishable alternatives from which it was selected, which is sometimes indicated by the number of significant digits it contains. See also "Accuracy".

Program*. 1) A plan for the solution of a problem. 2) Loosely, a synonym for "Routine". 3) To prepare a program.

Programmed Check*. See "Check", "Programmed".

Radix. Synonym for "Base".

Read*. To acquire information, usually from some form of storage. See also "Write".

Redundancy Check. See "Check", "Forbidden-Combination".

Regeneration (in Electronic Computers). In a storage device whose information storing state may deteriorate, the process of restoring the device to its latest undeteriorated state. See also "Rewrite".

Register*. A device capable of retaining information, often that contained in a small subset (e.g., one "Word") of the aggregate information in a digital computer. See also "Storage".

Register Length*. The number of characters which a register can store.

Reset*. 1) To restore a storage device to a prescribed state. 2) To place a binary cell in the initial or "Zero" state. See also "Clear".

Rewrite*. In a storage device whose information storing state may be destroyed by reading, the process of restoring the device to its state prior to reading.

Ring Counter. See "Counter", "Ring".

Routine*. A set of instructions arranged in proper sequence to cause a computer to perform a desired operation, such as the solution of a mathematical problem.

Selection Check. See "Check", "Selection".

Self-Checking Code. See "Check", "Forbidden-Combination".

Serial. Pertaining to time-sequential transmission storage of, or logical operations on the parts of a word, using the same facilities for successive parts.

Serial Digital Computer. One in which the digits are handled serially. Mixed serial and parallel machines are frequently called serial or parallel according to the way arithmetic processes are performed. An example of a serial digital computer is one which handles decimal digits serially although it might handle the bits which comprise a digit either serially or in parallel. See also "Parallel Digital Computer".

Set*. 1) To place a storage device in a prescribed state. 2) To place a binary cell in the "One" state.

Sexadecimal. See "Positional Notation".

Shift*. Displacement of an ordered set of characters one or more places to the left or right. If the characters are the digits of a numerical expression, a shift may be equivalent to multiplying by a power of the base.

Sign Digit*. A character used to designate the algebraic sign of a number.

Single-Address Code*. See "Instruction Code".

Standing On-Nines Carry. See "Carry".

Staticizer. A storage device for converting time sequential information into static parallel information.

Storage*. 1) The act of storing information. (See also "Store".) 2) Any device in which information can be stored, sometimes called a Memory device. 3) In a computer, a section used primarily for storing information. Such a section is sometimes called a Memory or a "Store" (British).

Note: The physical means of storing information may be electrostatic, ferroelectric, magnetic, acoustic, optical, chemical, electronic, electrical, mechanical, etc., in nature.

Storage Capacity*. The amount of information that can be retained in a storage (or memory) device, often expressed as the number of "Words" that can be retained (given the number of digits, and the base, of the standard word).

When comparisons are made among devices using different bases and word lengths, it is customary to express the capacity in "Bits". This number is obtained by taking the logarithm to the base 2 of the number of distinguishable states in which the storage can exist.

Note: The "Storage (or memory) capacity of a computer" usually refers only to the principal internal storage section.

Store*. 1) To retain information in a device from which it can later be withdrawn. 2) To introduce information into such a device. 3) British synonym for "Storage" 3).

Subroutine*. 1) In a "Routine", a portion that causes a computer to carry out a well-defined mathematical or logical operation. 2) A routine which is arranged so that control may be transferred to it from a Master Routine and so that, at the conclusion of the subroutine, control reverts to the master routine. Such a subroutine is usually called a closed subroutine. A single routine may simultaneously be both a subroutine with respect to another routine and a master routine with respect to a third. Usually control is transferred to a single subroutine from more than one place in the master routine and the reason for using the subroutine is to avoid having to repeat the same sequence of instructions in different places in the master routine.

Ternary. See "Positional Notation".

Test Routine. 1) Usually a synonym for "Check Routine". 2) Sometimes used as a general term to include both check routine and "Diagnostic Routine".

Track (in Electronic Computers)*. That portion of a moving-type storage medium which is accessible to a given reading station; e.g., as on film, drum, tapes, or discs. See also "Band".

Transcriber. Equipment associated with a computing machine for the purpose of transferring input (or output) data from a record of information in a given language to the medium and the language used by a digital computing machine (or from a computing machine to a record of information).

Transfer*. 1) To transmit, or Copy, information from one device to another. 2) To "Jump". 3) The act of transferring.

Transfer Check. See "Check", "Transfer".

Transfer Control*. Synonym for "Jump".

Translator. A network or system having a number of inputs and outputs and so connected that signals representing information expressed in a certain code, when applied to the inputs, cause output signals to appear which are a representation of the input information in a different code. Sometimes called "Matrix".

Unconditional Jump*. An instruction which interrupts the normal process of obtaining instructions in an ordered sequence, and specifies the address from which the next instruction must be taken.

Unconditional Transfer of Control*. Synonym for "Unconditional Jump".

Unit*. A portion or subassembly of a computer which constitutes the means of accomplishing some inclusive operation or function, as: "Arithmetic Unit".

Verification. The process of checking the results of one data transcription against the results of another data transcription. Both transcriptions usually involve manual operations. See also "Check".

Volatile. A term descriptive of a storage medium in which information cannot be retained without continuous power dissipation.

Note: Storage devices or systems employing nonvolatile media may or may not retain information in the event of planned or accidental power removal.

Williams-Tube Storage. A type of electrostatic storage.

Word (in Electronic Computers)*. An ordered set of "Characters" which is the normal unit in which information may be stored, transmitted, or operated upon within a computer.

Word Time. Synonym for "Minor Cycle".

Write*. To introduce information, usually into some form of storage. See also "Read".

II. Terms Used in MTC

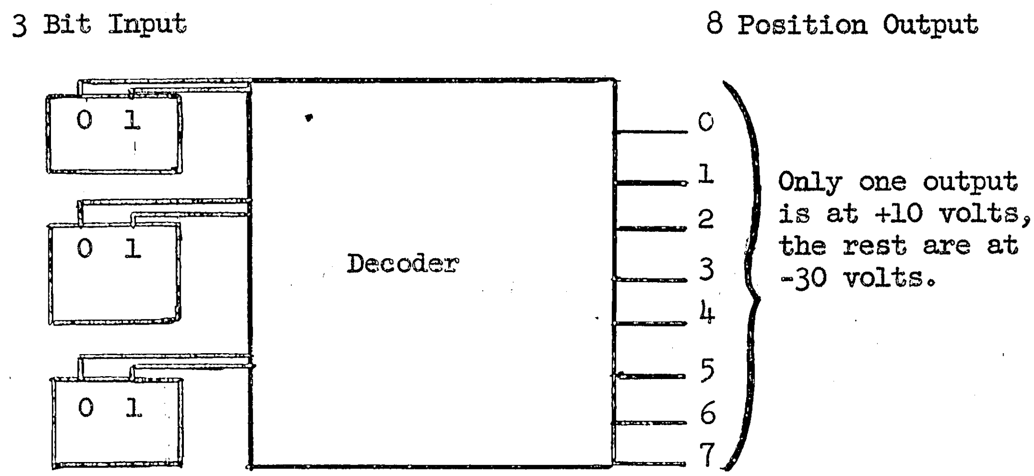
Many of the general terms in I are used in MTC. In addition, there are special terms frequently used.

<u>AND Circuit</u>. Usually a diode circuit with two or more "level" inputs and one "level" output. If all inputs are at +10 volts, the output will be at +10 volts. If any one input is at -30 volts, the output will be at -30 volts.

<u>Breaker</u>. A circuit breaker. A switch usually for AC that can be used to make or break a heavily loaded circuit. Usually the breaker has an overload feature that opens the circuit when the breaker's current rating is exceeded.

<u>Decode</u>. To perform the necessary manipulation in order to designate <u>one</u> unique output for an input of several separate units. For binary decoding this implies examining a binary word of n bits and designating one of 2^n outputs. (See "Decoder".)

<u>Decoder</u>. A device which decodes. A binary decoder would appear as follows:



Input Words	Output Line Selected
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

Diode. A two-terminal device that offers a high resistence to current flow in one direction but a low resistence to current flow in the other direction.

Display. A picture on a Cathode-Ray Tube; or the Cathode-Ray Tube, itself, with the associated circuitry necessary to provide control of the electron beam in the tube.

Field. A group of storage registers, usually containing 2048 registers. Also, the words that would go into a field of storage might be called a field.

Flexo. The Flexowriter printing or punching device.

Incident. An occurrence of failure of the MTC computer or some part of the computer or its associated equipment.

Jack. A connector (male or female) used with "video cable" to bring the end of the cable into a circuit.

Level. A voltage of +10 or -30 used throughout MTC to control the passage of "pulses" through gate tubes. A voltage of +10 on the suppressor of a gate tube allows passage of the pulse through the tube; a voltage of -30 prevents passage of the pulse.

Live Register. A register of flip-flops that can be substituted for a register of Panel Memory.

Magnetic-Core. A small toroid of ferro-magnetic material that is a permanent magnet. It can be magnetized for computer purposes in one of two directions and switched from one direction to the other.

Matrix. A group of properly connected AND circuits to perform some function, usually to decode.

Mixer. One or more diodes with appropriate circuitry to provide passage for two or more input "pulses" into a single output, but preventing the passage of a pulse on one input from travelling out on another input. Also called an "OR" circuit.

MTC. The Memory Test Computer named for its original function, to test a magnetic-core memory. MTC has since outgrown its original function. Also, the personnel and organization forming the section in Group 64 for operating and maintaining The Memory Test Computer.

OR Circuit. A "mixer".

PETR. The Photo-Electric Tape Reader made by Ferranti Ltd. for reading punched paper tape.

PIU. Plug-In Unit, a circuit wired onto a unit with a male plug, such that it can be easily connected or disconnected from the wires on the female plug leading into or out of the circuitry.

PIUMP. Plug-In Unit Mounting Panel, a number of female plug connectors mounted on a special panel for incorporation into racks in MTC. PIU's plug in PIUMP's.

Plugboard. A board with many holes where special "Plug-wires" can be installed. The configuration of plugwires can be fixed when the plugboard is connected into a female receptacle and perform a particular storage. Plugboards are used in Panel Memory and with the card machine.

Plug-wire. A wire or device which provides rigid pins for use with a plugboard.

Pulse. A 0.1 μs burst of voltage starting at 0 volts, reaching a peak of several volts in about 0.05 μs and then falling off to 0 volts again in an additional 0.05 μs. These pulses can be considered as being half sine waves.

SAP. Symbollic Address Program, a program for MTC for converting instructions punched in Hollerith code on IBM cards into 4-6-6 tape, or binary IBM cards for reading directly into MTC. See Section 23.

Sequence. One of 8 possible steps of an instruction or Program Timing of MTC. An instruction may use two or more sequences.

SYAAP. Symbollic Address Assembly Program, a program for MTC for converting flexo tape of a particular format into 4-6-6 tape for reading directly into MTC.

Sequence Pulse. The pulse that appears for the performance of a given sequence of an instruction.

TAF. The Tape Adapter Frame, a piece of SAGE equipment bought from IBM to provide an intermediate control for communication between MTC and tape units.

Terminator. A resistor used between the signal lead and ground (or shield lead) at the end of a video cable to provide the cable with the proper end impedence. Terminators may appear as bare resistors or as small metal units on male "jacks".

Toggles. A set of toggle switches, usually those used with Panel Memory.

Transfer. The instruction used to jump program control of MTC from one address to another. Also, the act of performing the jump.

Transient Error. A failure of MTC which appears for a short time, interrupting operation, but not preventing further proper operation.

Video Cable. A special cable consisting of a wire surrounded by a shield, with appropriate insulation, used for piping pulses around MTC. The characteristic impedence of the cable for 0.1 µs pulses in 93 ohms.

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UTILITY PROGRAMS

Input

a. "4-6-6 tape"---Read-in---Auto Start
b. Binary Cards---Binary-Card Load
Binary Card Corrector

Conversion

c. Basic Conversion
d. Symbolic Address Assembly Program (SYAAP)
e. Symbolic Assembly Program (SAP)

Post Mortems

f. Magnetic Tape
g. Octal Scope
h. Octal Card
i. Decimal Card
j. Octal Flexo

Punchout

k. 4-6-6 tape
l. Binary card
m. 4-6-6 Relocation

Clear Core Storage

n. Clear Fields Tape
o. Clear Memory Card

STRUCTURE OF CONVERTED (4-6-6) TAPE

Tapes produced by MTC conversion and assembly programs are called "4-6-6" tapes. This format was chosen so that the tape can be read into the computer by a simple plugboard program. The binary value of a "word" is punched on it with a punch standing for a one, and no punch for a zero. The Photoelectric Tape Reader is wired so that it will ignore all information not accompanied by a punch in the seventh position. Hence a line of tape can store only six digits, and three successive lines of tape are required to store a sixteen-bit MTC word. A word is punched on tape in the following fashion:

```
   hole no.
1 2 3 . 4 5 6 7
- - A . B C D X
E F G . H J K X
L M N . P Q R X
      ^
  feed holes     7th holes accompanying
                 a word are always punched.
```

16-digit word

A B C D	E F G H J K	L M N P Q R
4 digits	6 digits	6 digits

The name "4-6-6 tape" originates from the fact that a 16 bit word is broken into successive groups of 4, 6, and 6 bits.

Reading 4-6-6 tape, reassembling the 16-digit words, and storing them in their proper locations in the computer are accomplished by the "4-6-6 Read-in Program". This program is stored semi-permanently in the computer in registers with octal addresses 0-40 through 0-77, "Plugboard Storage". Pushing the button labeled "Start (over) at 40" (octal) on the computer control panel causes the computer to start performing the 4-6-6 Read-in Program. The photo-electric tape reader is under the control of the Read-in Program.

Normally, the 16 bit words are read from the tape, assembled one word at a time, and stored in consecutive memory registers in the computer. There are three circumstances, however, which require that the 4-6-6 input program be able to perform other functions:

1) At the beginning of the tape, and frequently elsewhere, it is necessary to specify an address at which the Read-in Program is to start storing words.

2) At the end of a tape, and occasionally elsewhere, it is necessary to direct the computer to leave the 4-6-6 input program and to start taking instructions from a particular address in the main program. This is called "changing control to the main program".

3) A checking procedure known as "sum-check" is used to check the reliability of the tape punching and reading equipment. This is done by accumulating the arithmetic sum of all words read in since the previous check sum. Each word read in is added to the cumulative sum, and "overflow"

(any part of the sum which is greater than unity) is neglected. This sum accumulated by the Read-in Program is compared with a supposedly identical sum which is punched on the tape. If the sums do not agree, a mistake has been made and the Read-in Program stops with a "programmed" alarm.

Each of these three special situations is controlled by "key words" on the 4-6-6 tape. The first of each group of three lines on tape has two positions which are not required by the 16-bit binary word. The second of these spare positions is not used, but the first position is occupied by a single bit called the "directive bit". If the directive bit is a "0", the accompanying word is a key word -- in reality an instruction which will be performed by the Read-in Program. If the directive bit is a "1", the accompanying word is to be handled by the Read-in Program in accordance with the most recent pair of key words.

The 4-6-6 tape is divided into blocks by the different key words. There are four types of blocks on 4-6-6 tape.

a. Store Block

A block, or group of words to be stored, begins with a pair of key words: sof a and st x, which designate that the first word of the block is to be stored in register x of field a, and that the block is a store block. In the absence of other key words, the Read-in Program will automatically store the succeeding words in successive registers.

b. Transfer Block

This group of words stops the Read-in Program and starts the main program ("changes control to the main program"). The entire block consists of two key words, sof a and tro x, which will set the computer up to take the next instruction from register x of field a, the address of the first instruction of the main program.

It is sometimes desirable to "nullify" a transfer block: that is, to make it have no effect on the Read-in Program. This can be done manually by punching a single hole in position "c" which will change the second key word from tro x to sof x. The result is a "nullified transfer block".

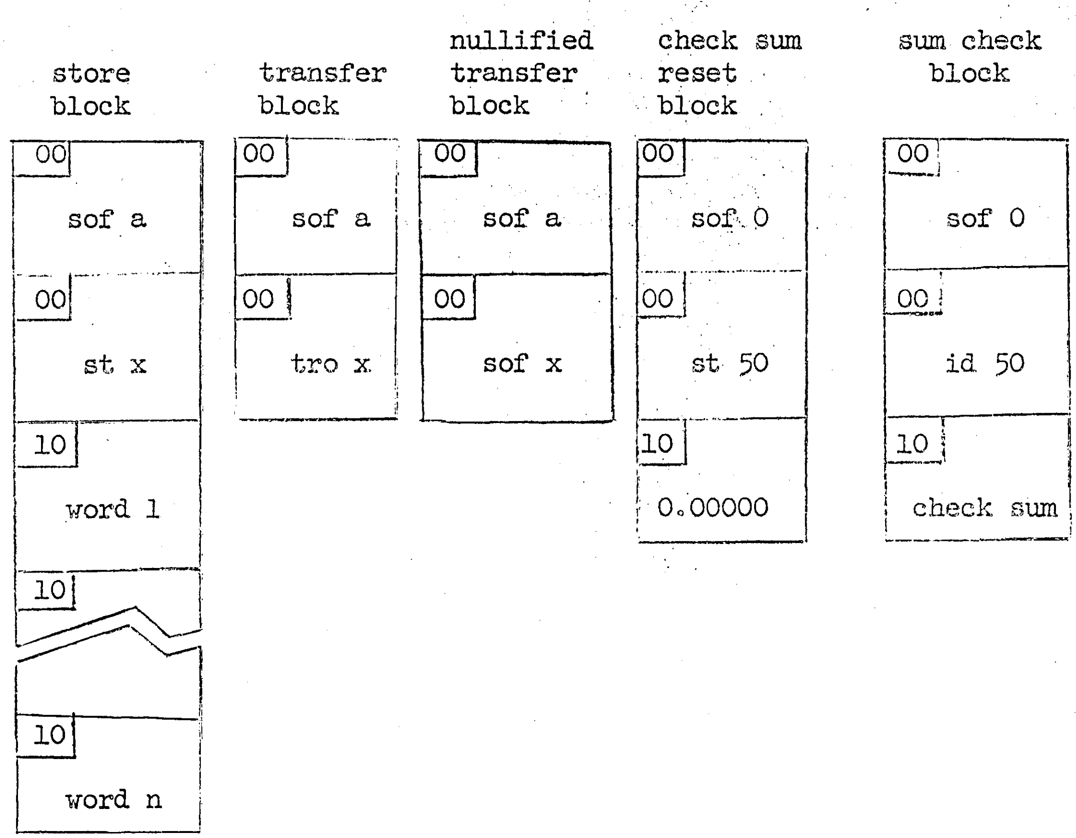
c. Sum Check Block

A sum check block consists of two key words followed by a check sum word. The key words are sof 0 and id 50 (octal). These words direct the Read-in Program to compare the check sum (#1) it finds on tape with the check sum (#2) which the Read-in Program has accumulated in register 0-50 (octal).

d. Check Sum Reset Block

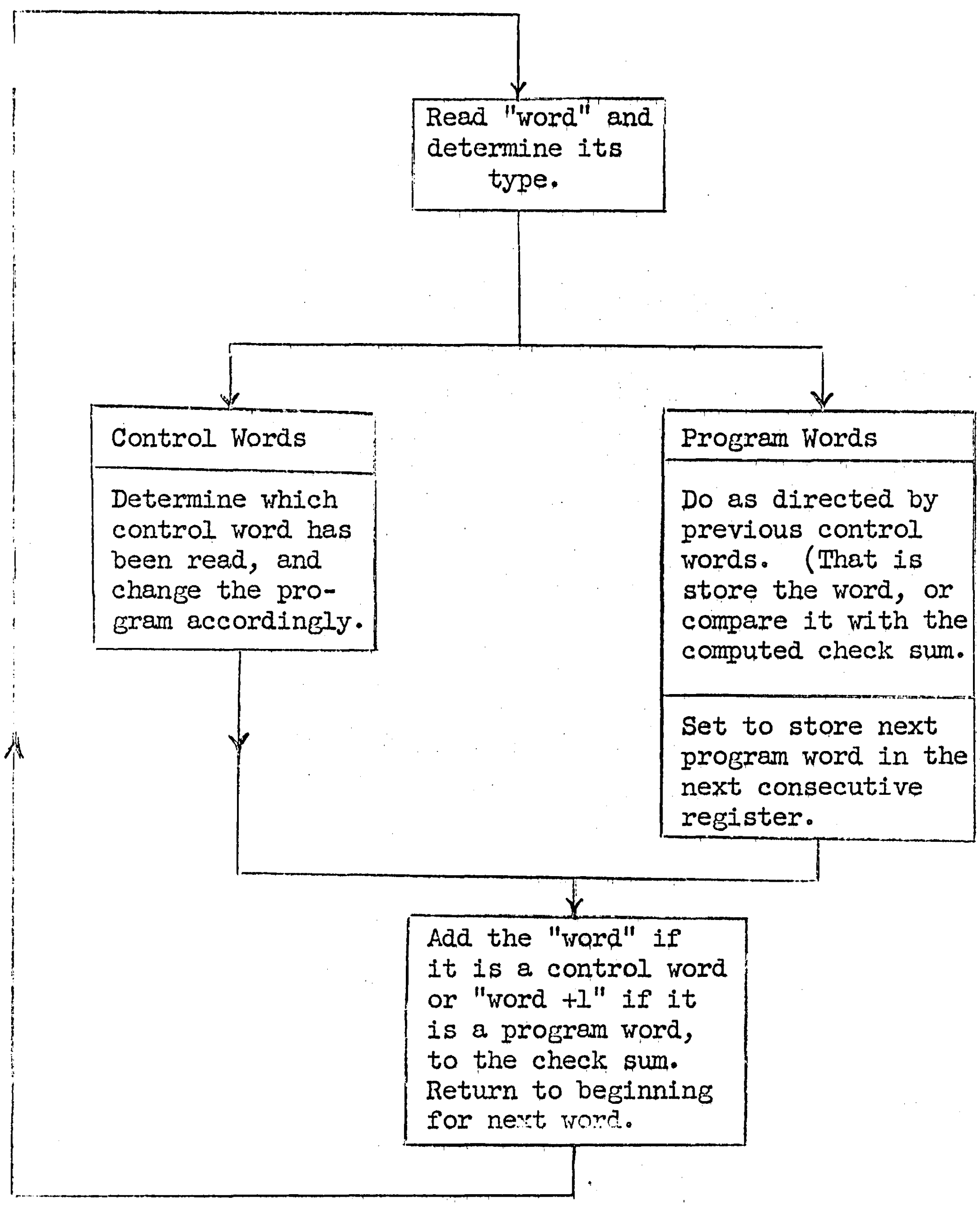
Because of space limitations, the Read-in Program is unable to set the check sum to zero, hence the need for a "check sum reset block". The reset block is in reality a store block which stores the quantity zero in 0-50, the register assigned for the check sum. Following reading in of a reset block, the Read-in Program will accumulate a sum of all words and their directives which are read from tape. After an appropriate number of words on tape, a sum check block will be found. When the sum check block is encountered by the Read-in Program, the sum accumulated thus far will be checked. If there is more data on the tape, a reset block should occur so that a new sum may be begun.

A graphic representation of the various kinds of blocks is given below:



READ-IN PROGRAM

The Read-in Program is the most frequently used program in MTC. The program is quite compact because of space limitations. Its flow diagram follows:



KEY WORDS

Key words are distinguished by the positions of the "ones" in the instruction code. This is especially easy since there are only 4 key words:

```
sof = 10101
tro = 10001
st  = 00100
id  = 00011
```

These are always stored in LR2, 0-62, when they are encountered.

a. If the key word in the accumulator is positive, it is assumed that the word is either st x or id 50. In either case, this key word need then only be added to the check sum, since it is already stored in LR2.

b. If the key word in the accumulator is negative, however, it must be tested to distinguish between sof = 10101 and tro = 10001; this can be done quite easily by cycling the word to the left two places, i.e. to the right 30 places, and sensing the "sign bit". If it is a "1", the word is sof and should be stored in LR1, 0-61, before it is added to the check sum. If it is a "zero" simply halt the Read-in Program.

If the transfer block is correct after reading in a tape, the program can be restarted merely by hitting the restart button. Because the halt of the Read-in Program is in register 0-57, restart will start at register 0-60, perform a senseless cycle left 2 and then perform the key words in live registers one and two, which are sof a, tro x respectively.

```
40 ri 32        read in 3 lines of tape with directive bit
41 ri 32        in sign bit
42 ri 22
43 tn 60        if negative, directive bit, present program word
44 cr 2036      put key word in AC
45 st 62        store in LR2
46 tn 55        if negative word is either sof or tro
47 tr 73        if positive word is either st or id add to checksum
50 (LR 5)       (temporarily used as check sum)
51 (LR 3)
52 cr 2002      put word back in AC
53 st 61        store in LR1
54 tr 73        add to check sum and repeat
55 cr 36        cycle left 2
56 tn 52        if negative word is sof
57 ha 1         if positive word is tro, halt read-in
60 cr 2036      cycle word left 2 to put word in the accumulator
61 (LR 1)       perform key words
62 (LR 2)
63 tr 65
64 sof 2000     if id block failed give programmed alarm
```

```
65 cr 20          put word in B-Register temporarily
66 sof 0
67 ao 62          index LR2 to prepare to store next word
70 cr 2020        put word back in AC and clear B-Register
71 ad 57          rc +1 to count directive bit
72 to 73
73 ad 50          add check sum
74 to 75
75 st 50
76 tr 40          Repeat
77 (LR 4)
```

AUTO START

Because of the structure of the Read-in Program, it is possible to attempt to store information in the plugboard. Information will be stored only in live registers, but each word and directive bit will be added to the check sum. By attempting to store a block of words in panel memory, we can modify the Read-in Program sufficiently to produce an automatic start; that is, control will be automatically transferred to the main program and started immediately after the last word is read in.

The auto-start block attempts to store in field zero, beginning at register 50, the following words:

```
50 ha 0
51 tro x                     x is the core starting address
52 tno 3777-x                x and 3777-x are used to keep check sum of
                             these two words constant
53 ha 0, ha 1, or ha 2       0, 1, or 2 depending on field desired
54 op 3715
55 ha 0
56 ha 0
57 ha 0
60 ca 3772
61 pf 5
62 tr 47
63 0
```

Note that:

```
ha  0  in 50 (check sum register)
tro x  in 51
pf  5  in 61
```

and tr in 62 are the only words actually stored. The other words serve two functions: first, they aid the Read-in Program to store pf 5 in 60 and tr 47 in 61; and second, they assist in getting the check sum equal to sof a (a = 0, 1, 2).

After tr 47 is stored in 62 and added to the check sum, register 50 will contain sof a. Register 62 will be indexed automatically by the Read-in Program to contain tr 50. Since the last ha 0 has a directive bit, the Read-in Program performs the instructions in live registers one and two, as it normally does. However these instructions now read:

```
61 pf 5          set id to not stop
62 tr 50
50 sof a
51 tro x
```

After the last two instructions, the computer will continue with the instructions in field a, beginning with register x.

READING BINARY CARDS

Punched cards can be used as input and output to the computer in much the same manner as punched paper tape. MTC's punched card equipment is designed to use normal IBM cards which measure approximately 3.3 x 7.4 inches. An IBM card has 80 columns, each of which has 12 rows of punch positions. The same physical card is used for two fundamentally different conventions: "standard" or "Hollerith" cards, and "binary" cards. A "standard" or "Hollerith" card is one in which the configurations of punches in a column represents one character in accordance with the IBM card code shown on page 3-i-13 of this manual. A binary card contains numbers or instructions in pure binary form arranged in 12 horizontal rows of four words each. In this form a punch stands for a "one" and no punch for a "zero".

The MTC card machine is part of an IBM 513 Reproducing Punch modified to produce proper signals to the computer; it transmits to the computer only 64 columns of the card, normally columns 17-80. A card is read as though it contained 16-bit binary words in columns 17-80 in twelve rows of four words each, starting with the "9" or bottom row. The card reader is actuated by the MTC instructions op 1000+n and op 1400+n (octal). Each operate instruction reads into the B-Register the word in either position 0, 1, 2, or 3 according to the value of "n" modulo 4.

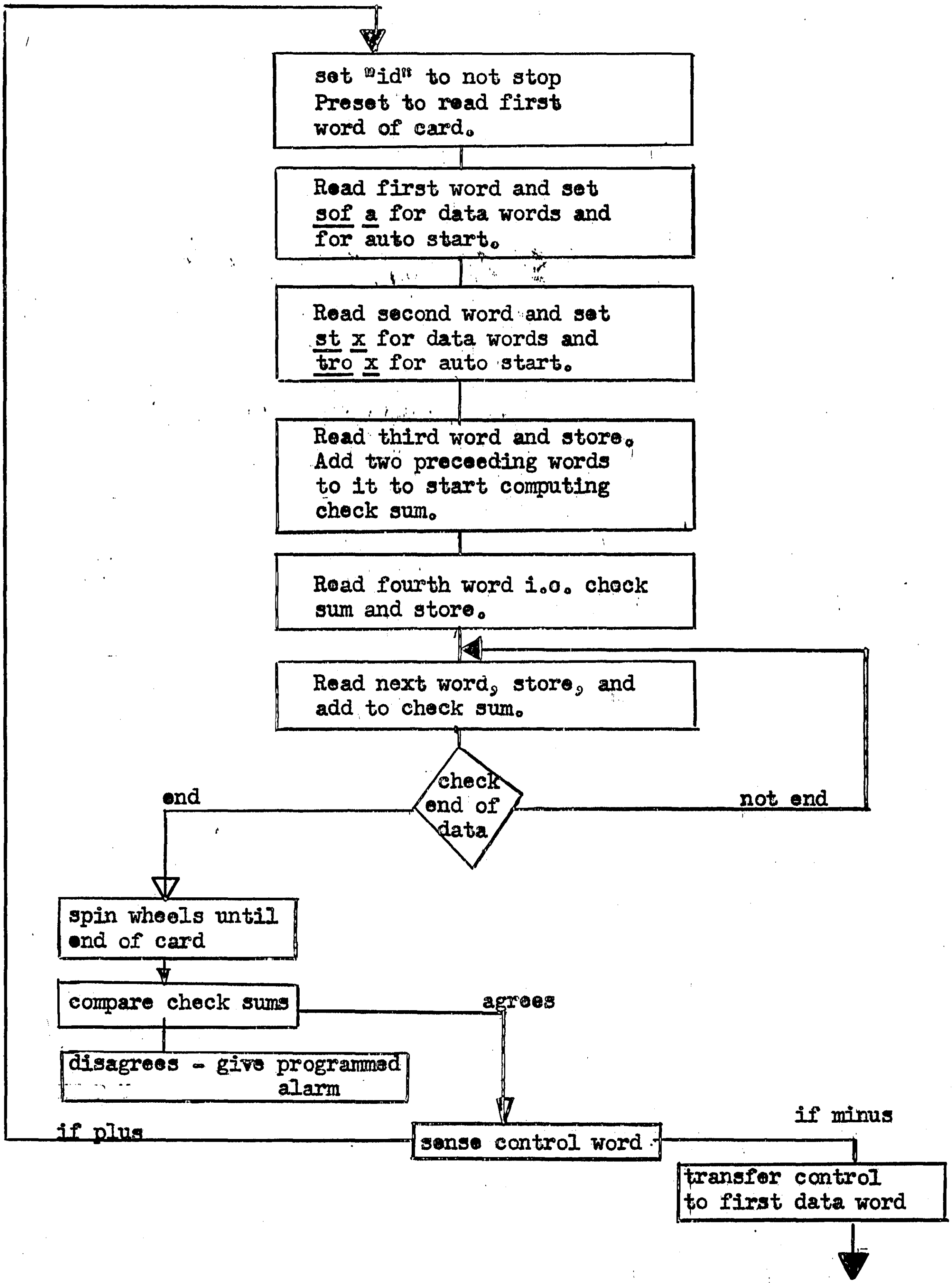
The "binary card read-in program" or "binary card load program" written by Ray Olsen will read into the computer binary cards with the following structure:

The "9" or bottom row of the card contains the control words or key words. The key words are as follows:

Key Word 1	This word is always an sof a, where "a" designates the field in which the data on the card is to be stored.
Key Word 2	This word is always st x, where "x" is the address to which the first data word, word "0", is to be stored. The remaining words will be stored in consecutive memory locations.
Key Word 3	This word is the word count; that is, the number of data words punched on the card. The word count can be any number from 1-53 (octal). The sign bit of this word is used as a control bit.
Key Word 4	This word is the check sum of the first three key words and all the data words on the card.

STRUCTURE OF BINARY CARD

row 12	Data Word 40	Data Word 41	Data Word 42	Data Word 43
row 11	Data Word 36	Data Word 37	Data Word 38	Data Word 39
row 0	Data Word 32	Data Word 33	Data Word 34	Data Word 35
row 1	Data Word 28	Data Word 29	Data Word 30	Data Word 31
row 2	Data Word 24	Data Word 25	Data Word 26	Data Word 27
row 3	Data Word 20	Data Word 21	Data Word 22	Data Word 23
row 4	Data Word 16	Data Word 17	Data Word 18	Data Word 19
row 5	Data Word 12	Data Word 13	Data Word 14	Data Word 15
row 6	Data Word 8	Data Word 9	Data Word 10	Data Word 11
row 7	Data Word 4	Data Word 5	Data Word 6	Data Word 7
row 8	Data Word 0	Data Word 1	Data Word 2	Data Word 3
row 9	Key Word 1	Key Word 2	Key Word 3	Key Word 4
These 16 cols. not read	Cols. 17-32	Cols. 33-48	Cols. 49-64	Cols. 65-80


set "id" to not stop
Preset to read first
word of card.
Read first word and set
sof a for data words and
for auto start.
Read second word and set
st x for data words and
tro x for auto start.
Read third word and store.
Add two preceeding words
to it to start computing
check sum.
Read fourth word i.e. check
sum and store.
Read next word, store, and
add to check sum.
check end of data
end
not end
spin wheels until
end of card
compare check sums
agrees
disagrees - give programmed
alarm
if plus
sense control word
if minus
transfer control
to first data word

Binary Card Load Program

00	pf 5	set id to not stop
	ca 65	preset read-in "op" instruction
	st 61	
	tr 53	read in first word
	st 26	set "sof" for data words and
	st 51	for auto start
	tr 53	read in 2nd word
	st 27	set "st" address
10	ra 52	and "tro"
	tr 53	
	st 70	read in 3rd word and store
	ad 27	add 2 preceeding words to third word
	ad 26	for check sum
	to 16	
	st 71	
	tr 53	read in check sum
20	st 72	
	ca 70	extract address of control
	et 66	word for word count
	ad 27	add it to st for st last +1
	st 73	
	tr 53	read in data words
	(sof a)	storing as reading in
	(st x)	
30	sof 1	
	ad 71	add check sum to word read in

```
to 33
st 71
ca 27
ad 67          ao store instruction
ra 27
su 73          check end neg = not
tn 25
tr 53          spin wheels until end
tr 41          of card
ca 72          check sum
id 71          71 contains computed check sum
tr 47          check sums agree
sof 2001       stop on error
cs 70
tn 0           neg. means no control bit
(sof a)        set by address of first word
(tro x)        set by address of second word
rf 63          read next word subroutine
ca 61          ao "op"
ad 67
st 61
id 64
tr 43          exit at end of card
op 1000 + n    read next word
cr 20
(tr 0)
op 1060        end check
```

	op 777	"op" preset
	ha 3777	mask
	ha 1	rc 1
70	(+0)	control word
	(+0)	computed check sum
	(+0)	read in check sum
	(+0)	end check on storing

The sign bit of key word 3 is used by the "Binary Card Load Program" to transfer control to the first data word after all the data words on the card have been stored. Whenever the sign bit of key word 3 is a "one", the Binary Code Load Program performs sof a tro x where a, are the addresses of the first two key words on the card. One data word will be stored even if a zero word count was given. Cards with a "one" in the sign bit of key word 3 are called control cards: Three typical control cards are the Start Card, Clear Memory Card, and the Binary Corrector Load Card.

Start Card

This card contains a two-instruction program which transfers control to the main program.

A. Key Words

sof 0

st 50

1.00002

check sum (changes with each card)

B. Data Words

sof a

tro x

a and x are the field and address at which the program starts

Clear Memory Card

This card contains a program which clears all of field two, all but the first hundred registers of field one. After clearing Memory it transfers back to the card load program and continues reading cards.

A. Key Words

sof 1

st 75

1.000 14

1.215 40

B. Data Words

75	tr 100
76	cb 100
77	tr 0
100	ca 107
1	sof 402
2	cb 0
3	sof 1
4	ca 110
5	sof 401
6	tr 76
7	0.0 4000
110	0.0 3700

"Bin Cor Load Card

This card contains a program which modifies the Card Load Program, so that the treatment of all following cards is as follows:

1. The first three words in the "9" row are read in with no check sum.

2. The first two words of the card are performed as instructions, with the third word in the accumulator.

3. The next card is treated as in steps 1 and 2.

Examples of correction cards to follow the Binary Corrector:

1. 1st word sof a

2nd word st x

3rd word et b

The instruction et b would be stored in register x of field a.

2. 1st word sof a

2nd word ra x

3rd word et b

The address b would replace the address contained in register x of field a.

3. 1st word sof a

2nd word tro x

3rd word et b

The control would be transferred to register x of field a. The third word has no effect in this case.

Any number of correction cards may be placed after the Bin Cor Card. However, only one correction can be made per correction card, and the last correction card of a series must either contain a halt instruction or be of the type illustrated in example 3. The regular Binary Card Load Program is available on a continuous loop of 4-6-6 tape in auto-start form. It is therefore possible to insert a Bin Cor Card and a number of correction cards in the middle of a deck, provided the last correction card starts with the words "sof 0, tro 40"; this last card will cause the regular Card Load Program to be returned to storage for normal reading of subsequent data cards.

A correction can also be made by inserting a normal card containing one or more data words anywhere in a deck after the erroneous card. Since the technique does not require the punching of a transfer- or halt-type correction card, and since the Bin Cor Card has no error-detecting device, it is recommended that the Bin Cor Card never be used.

The contents of the Bin Cor Load Card are as follows:

A. Key Words

sof 1

st 0

1.00022

1.5 0702

B. Data Words

0	ca 21
1	st 60
2	ca 65
3	st 61
4	tr 53
5	st 15
6	tr 53
7	st 16
10	tr 53
11	st 22
12	tr 53
13	tr 12
14	ca 22
15	( )
16	( )
17	sof 1
20	tr 0
21	tr 14

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TEST PROGRAMS

a. Marginal Check System Control Program

b. Drum Check, T15

c. Flexowriter Punch and Type Check

d. Scope Test, T5

MARGINAL CHECK PROGRAMS ON MAGNETIC TAPE

OPERATING INSTRUCTIONS

A. Read-In

1. Put the marginal check plugboard in the plugboard receptacle.
2. Load any tape drive with the marginal check tape and set it to 1.
3. Make sign bit of register 0-34 positive, and select the first program to be run. (See Program selection item #1).
4. Turn on the Flexowriter.
5. Start at 0-45. (0-0 tr 45)

The tape will be read in and stored on the drums. At the "end of file" record, the tape will be rewound and the control program will be selected and started.

B. Program Selection

1. The first bit set to a "one", counting from right to left in register 0-34, determines which Test Program will be selected from the drum and started. Only one program can be selected at a time. For example,

   A "one" in bit 15 will select MC 100

   A "one" in bit 14 will select MP 60

   A "one" in bit 13 will select T6 (Mag. Tape Check)

   A complete listing is given on the following page.

2. Start at 40. The control program will be read from drum field 16 and started. It in turn will select and start a check program.
3. Drum check (T15) is an exception; it can be run by setting the sign bit of 0-34 negative, and starting at 0-45.
   a. The drum check T15 is stored only in core memory, and may destroy itself during marginal checking. Therefore, after the program has been read from the tape, the tape is backspaced, and prepared for reading again.
   b. After running the drum check program it is necessary to read all the other programs in again by starting at 45 with 0-34 positive.

PROGRAM SELECTION LIST

BITS OF REGISTER 34	PROGRAM	COMMENTS
bit 15	MC 100	set ID to STOP
bit 14	MP 60	suppress overflow
bit 13	T6 (Mag tape check)	0-3 Select tape unit (ha 2 or ha 3) to select unit 1 first remove MC tape 0-20 left words (ha 77) 0-21 right words (ha 0) 0-36 +0 0-37 +0
bit 12	T12 (PETR Test Tape)	Load alternate hole tape in reader. If out of sync, push restart.
bit 11	"rf" check	
bit 10	Displays	Select proper display by a one in a bit of register 0-20. Bit 15 = Ziegler's scope test Bit 14 = 3 horizontal lines Bit 13 = 3 vertical lines Bit 12 = 2 diagonal lines Bit 11 = + and - zero lines Bit 10 = 3 horizontal, 3 vertical and 2 diagonal lines together Bit 9 = 1 horizontal line (max. positive) Bit 8 = 1 horizontal line (max. negative)

PROGRAM SELECTION LIST

BITS OF REGISTER 34	PROGRAM	COMMENTS
bit 10	Displays	Bit 7 = 1 vertical line (max. positive) Bit 6 = 1 vertical line (max. negative) Bit 0 = index the camera (if no other bit is selected the camera will be indexed 13 times; if another bit is selected, the camera will be indexed after each display cycle).
bit 9	Punch	punch alternate holes in blocks of 4.
bit 8	Type	alphabetic, numeric, and symbolic characters.

MARGINAL CHECK PROGRAM SYSTEM

Marginal checking is a means of anticipating certain types of computer failure; general comments about marginal checking may be found on page 1-m-1 of this manual. Because many programs are used during marginal checking, an attempt has been made to simplify the reading into the computer of these programs. A system which we shall call the Marginal Check Program System, or the MC Program System, was designed to incorporate all the check and test programs in one system. In this system magnetic tape is used as an auxiliary memory. Operating instructions for the program controlling this system will be found on page 24-a-1 of this manual.

During actual marginal checking, programs are stored on MTC's drum fields to eliminate time-consuming magnetic tape searching. To control the Marginal Check Program System a master control program was written. Part of the control program is stored on the magnetic tape and part on a plugboard. Part of this plugboard is used to read the control program on magnetic tape into field 2 and start the "read-in" sub-program.

The control program is divided into several non-overlapping sub-programs, whose starting addresses are given below:

0-40	Read the control program from drum field 16 (octal), and start it at 2-0.
0-45	Read the control program from magnetic tape, and start the read-in section at 2-110 if 0-34 is positive.
2-0	Start program selection, which is used by the marginal check program system to pick up and start individual check programs, according to the contents of 0-34. See page 24-a-1.
2-110	Read-in of magnetic tape is a continuation of the program starting on the plugboard, register 0-45.
2-3110	Write contents of field 1 onto a tape, selected as unit 2.
2-3117	Write contents of field 2 (control program) onto a tape, selected as unit 2; "end of file" will be written automatically.
2-2000	Write part of field 1 onto a drum field 3 with word count specified in 0-20 and starting address specified in 0-21.

2-2014	Read drum field 3 into field 1.
2-2100	Copy tape. Read unit "one" write unit two.
2-3000	Read unit 1 and write on unit 2. This program reads up to "end of file" then writes all but the last two records onto tape unit 2. It then rewinds tape unit 1.

The magnetic tape is written in full field-length (2048 words) records, which are read by the read-in part of the control program. Each record is read onto field 1 and then written onto a drum field. Read-in is programmed to stop on an "end of file" record. The system has been designed so that more than one program can be stored per record. Until the system is complete there will not be a fixed number of records, but because there are only twelve drum fields, there can be at the most only eleven records of test programs on the tape.

An exception to the system was made for the drum check program, because this program destroys all the drum fields. It was stored as the first record on the tape; it is selected by starting the plugboard program at 0-45 with 0-34 negative. The remainder of the magnetic tape has on it the following field-length records, in this order:

1. Control Program (for read-in of magnetic tape)
2. MC 100
3. MP 60
4. Magnetic Tape Check
5. PETR Test and "RF" Check
6. Control Program

The control program is the first of these records to provide a read-in program for the rest of the magnetic tape. Also, to be accessible for changes and insertions, it is made the last record. The latter control program is written on drum field 16 (octal) by the read-in sub-program, and used to control program selection. When a new program is written on the tape, it is either added to the second last record or written as a new record between the second last record and the control program. In either case, new constants must be inserted into the control program, which is then rewritten. To select a test program from the drums, the control program uses two tables, namely the Table of Drum Starting Addresses and the Table of Drum Fields. The first table occupies registers 300-317 of field 2; the second table occupies registers 400-417 of field 2. Whenever a program is added to the marginal check tape, appropriate entries must be made in these tables at the next unused register in each. The chart below contains current data about the control program and the storage requirements of the test programs. From it one can determine the constants necessary when a new program is added to the system.

Check Pro.	Drum Field Table		Drum Sta. Add. Table		Storage Req. (Octal Regs.)
MC 100	3	400	0	300	4000
MP 60	4	401	0	301	4000
Mag. Tape Check	5	402	0	302	4000
PETR	6	403	0	303	300
"RF" Check	6	404	300	304	300
Displays	6	405	600	305	500
Punch Check	6	406	1300	306	40
Type Check	6	407	1340	307	100

The left-hand entry in the "Drum Field Table" is the drum field on which the program is found; the left-hand entry in the "Drum Starting Address Table" is the starting address of the program on the drum field. The right-hand entries in both tables are the addresses of the registers in the control program in which the left-hand entries may be found.

GENERATION OF A NEW MARGINAL CHECK TAPE

To generate a new marginal check tape, a program entitled "copy tape", which is on "4-6-6 tape" for convenience, is used. The procedure is as follows:

1. The "old" file-protected tape is placed on a tape drive, which is then selected as unit 1.

2. The new tape is placed on a drive, which is selected as unit 2.

3. Read in "copy tape".

4. Start at 2-2100.

Tape unit "one" will be copied record for record onto tape unit "two". When the "end of file" record has been read tape unit "one" will be rewound, and an "end of file" record will be written on tape unit "two" which will also be rewound.

Since "Copy Tape" is a part of the marginal check program, it is available for use whenever the control program is in memory.

ADDITION OF A PROGRAM TO THE MARGINAL CHECK TAPE

Before a program is added to the marginal check tape, this question must be answered: Is there room in the second last record for the new program?

It is difficult to make a new tape, and dangerous to add to an existing tape; therefore, to add a program, generate a new marginal check tape. The procedure is as follows:

1. The "old" file-protected tape is placed on a tape drive, which is then selected as unit 1.

2. The new tape is placed on a drive, which is selected as unit 2.

3. Read in "add a program".

4. Start at 2-3000.

These steps will copy tape unit "one" onto tape unit two except for the last two records, using the drum for temporary storage. Then follow the procedure indicated by the manner in which the program will be added.

PROCEDURE A

If the new program will fit on the second last record, write the old record on drum field 3, by starting at 2-2000 with the number of registers filled by valuable information in 0-20 and ha0 in 0-21. The ha0 in 0-21 is the drum starting address of the information to be copied onto drum field 3. Then clear field 1 and read in the new program. Put the contents of register 0-20 into register 0-21, put the number of registers occupied by the new program into 0-20, and start at 2-2000. This stacks the two programs on drum field 3. To read the programs back into memory, start at 2-2014.

Then, insert the contents of 0-21 at the next available register in the Table of Drum Addresses, registers 300-317; and insert the same field number as that of the previous program in the next available register of the Drum Field Table, registers 400-417. (See chart)

Finally, write field one onto the tape by starting at 2-3110, and write field two onto the tape by starting at 2-3117. After field two has been written the "end of file" record will be written and tha tape rewound.

PROCEDURE B

If there is not enough room in the record start at 2-3110. Clear field 1, read in the new program and start at 2-3110. Then, store in the next position in the Drum Field Table, the address of the next consecutive drum field.

Finally start at 2-3117.