WHIRLWIND I MOVING, REASSEMBLY AND CHECKOUT PROGRESS REPORT

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by

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August 16, 1963

Mr. Alfred J. Wise
Special Representative
Office of Naval Research
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Mr. Wise:

We are enclosing a report on the current status of the moving, reassembly and check-out of the Whirlwind I Computer. This report summarizes the activities and events comprising the moving and reassembly phase and the check-out phase. The activities and events of these two phases are also portrayed by means of two PERT networks. The PERT network describing the check-out phase presents scheduled dates for completing the remaining events prerequisite to complete computer check-out. While these scheduled dates are based on our present best estimates, unforeseen problems may cause a further slippage in this schedule.

Although this report provides considerable detail as to the present status of computer checkout, a visual demonstration of actual computer operation is more impressive particularly now that we have a few of the Whirlwind display demonstration programs operating. We would therefore like to extend an invitation to you, Mr. Healy, Professor Wilson and other ONR personnel to visit us again soon for the purpose of such a demonstration.

Very truly yours,

W. M. Wolf

William M. Wolf
President

AVS/csn
Enclosures

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I INTRODUCTION

This memorandum summarizes the present status of Whirlwind I computer checkout and describes the work accomplished to date in moving, reassembling and checking out the Whirlwind I computer in its new location. In addition, items of equipment yet to be checked out are described and scheduled.

Section II describes the moving and reassembly phase which commenced on December 6, 1961, and was completed on December 13, 1962. A PERT network showing the interrelationships and completion dates of the events comprising the moving and reassembly phase is also presented.

Section III describes the computer checkout phase which commenced on December 19, 1962, and is scheduled for completion on November 15, 1963. This section describes both work accomplished to date and work to be accomplished by the scheduled date of November 15, 1963.

Section IV describes the major problems encountered to date in checking out the computer.

II MOVING AND REASSEMBLY

The moving and reassembly phase commenced on December 6, 1961, and was completed on December 13, 1962. Figure 2-1 is a PERT network which depicts the interrelationships of events comprising this phase. Events are described by the circular disks and the activities leading to these events are described by the printed paper tape whose length is proportional to the time required for the activity. Unprinted tape represents activities which require no time while unlabeled disks are merely connectors and do not represent events. Tables 2-1 through 2-4 inclusive identify each of the events in this network. The labeling of these events is similar to that used in our memorandum "Schedule for Moving and Reassembling the Whirlwind I Computer" dated October 6, 1960. Modification and additions to the tasks listed therein have been made where necessary.

A. Rigging and Moving

The events associated with rigging and moving are listed in Table 2-1. Moving of the air conditioning cooling towers (RM11) and ductwork (RM13) was accomplished on December 8, 1961, and the air handling units and associated controls (RM12A) were moved on January 16, 1962. Due to delays in building construction, the moving of the main computer racks (RM3, RM4, RM5 and RM7), which was originally scheduled for December, was delayed until February. Following this, the end wall of the computer section of the building was completed. The moving of rotating machinery and associated switch gear (RM14), DC power supplies (RM15), and air conditioning compressors (RM10) had to be delayed until the completion of the mechanical room section of the building. These latter units were moved and set up in place by the latter part of March, 1962. Due to internal construction work such as electrical, plumbing and heating, and painting, the equipment racks could not be spread out and positioned until early April. This was done during the period April 5, 1962 through April 13, 1962, inclusive, and is described by events RM6, RM8 and RM17. Other events listed under rigging and moving in Table 2-1 were accomplished at our convenience as the equipment was needed but were scheduled so as to vacate Navy Building 61 in South Boston before termination of our lease extension on June 30, 1962.

During the moving of additional equipment, it soon became obvious that additional storage space more convenient to Concord was a necessity. Consequently, 8400 square feet of warehouse space was leased in Maynard, Massachusetts. While not shown explicitly on the PERT network, the space at Building 61 in South Boston was vacated on or about May 29, 1962. Events RM1 and RM16 represent, respectively, the moving from Maynard to Concord of panels removed from the computer and the completion of the moving of additional equipment stored in our Boston office and in quarters adjacent to our new building in Concord.

B. Air Conditioning Installation

Table 2-2 describes the events associated with air conditioning equipment installation. The installation of the air conditioning equipment commenced on May 23, 1962, with the installation of ductwork (AC3A) and electrical switchgear and control wiring (AC4A). Installation of refrigerant piping (AC1) was started early in June and was completed on July 31. Completion of the majority of the ductwork (AC3C) and electrical wiring (AC4B) as well as pneumatic control installation (AC2B) was accomplished by August 2. Charging of the system with Freon and check out of the basic system (AC5B) was accomplished on August 4, 1962. Completion of remaining air conditioning work had to be delayed until receipt of a new cooling coil for the air handler which provides room air cooling. This coil was received during the latter part of September and completion of all air conditioning work (AC2C, AC3D, AC4C, AC4D, and AC5C) was accomplished on October 18, 1962.

C. Power Equipment

The tasks involved in installation of power equipment are listed in Table 2-3. Two of the twelve events listed in this table were purposely omitted from the reassembly phase of the project in order to permit an earlier start of the computer checkout phase. These two events, namely the wiring and checkout of the 400 amp alternator (PE1 and PE5B) affect only the special input-output equipment, particularly the magnetic drums and thus were not essential to the checkout of the main computer. These events are yet to be accomplished but are scheduled on the PERT network presented in

Section III. A third event listed in Table 2-3 (PE8) has been completed but is shown on the PERT network of Section III since it is more properly considered as a checkout event rather than a reassembly event.

The remaining events listed in Table 2-3 are portrayed in the PERT network of Figure 2-1. These commenced during the latter part of March, 1962 and were completed on December 13, 1962. These tasks involved the setup and wiring of the 400 amp standby alternator, associated power control racks and contactors (PE2, PE3A, PE3B, PE4, and PE5A), installation and wiring of computer DC power supplies (PE6A, PE6B, PE7, and PE9) and wiring, checkout, and distribution of laboratory DC power (PE10 and PE11).

D. Mechanical and Electrical Reassembly

The events associated with mechanical and electrical reassembly of the computer are listed in Table 2-4. All but the last four events in this table were completed during the moving and reassembly phase and are portrayed in the PERT network of Figure 2-1. The last four events are scheduled on the PERT network of Figure 3-1. One of these events (ME23) has been completed and the remaining three (ME24, ME25 and ME26) are scheduled for completion within the next ten days. These four events were purposely eliminated from the moving and reassembly phase since they could be conveniently postponed without delaying the start of the checkout phase of the project. The remaining events associated with mechanical and electrical reassembly were started early in April, 1962 and were completed on November 15, 1962.

It should be pointed out that one of these events (ME14) was intentionally deleted from the PERT chart, since after a few weeks of checking it was concluded that the error rate of Northeastern students in reconnecting cables was sufficiently low to make exhaustive checking of cables unnecessary. It was decided that if power connections were checked out in a fail-safe manner that signal cabling errors could be tolerated without damage to the computer. This decision to bypass checking of wire and cable reconnections in great detail saved considerable time and has been proven to be a correct decision during the checkout phase which is described in Section III. While exact figures on the error rate in reconnecting cables have not been kept, our best estimate is that this error rate was not more than 5% and was probably as low as 2 to 3%. Considering the semi-skilled personnel performing this task, the fact that two different groups disconnected and reconnected the cables, and inevitable human error in recording and interpreting cable termination data, we feel that this record is extremely good.

While the mechanical and electrical reassembly phase consisted of about 25 different tasks, the major portion of the job involved reconnection of wires and cables (ME13). This task, which was started on April 30, was completed on October 29. It should be pointed out here that this reconnection included all the cables which were disconnected at Cambridge, not only in the main computer but in the input-output equipment area associated with drums, radar and teletype inputs, and digital outputs. Thus, this task involved about twice as much work as that defined as ME13 in our memorandum "Schedule for Moving and Reassembling the Whirlwind I Computer" dated October 6, 1960, wherein we had planned to reconnect only those cables associated with the central computer. Other factors tending to lengthen this task included the fabrication of new cables to replace ones which were badly frayed and tangled at Cambridge, extending or replacing cables which proved, in a few cases, to be too short due to our relocation of test control relative to the main computer, and time spent in pulse checking each video cable prior to reconnection. Pulse checking of video cables has proven valuable during the checkout phase since the only video cable failures found to date during checkout have been in cables which were disconnected only at one end and which could not be pulse checked since their destinations were not known without considerable checking of MIT records.

All other events associated with mechanical and electrical reassembly required relatively short times for their completion. For example, events ME1 through ME7 inclusive were completed during the month of April, 1962. Other events which appear later during the schedule shown in the PERT network of Figure 2-1 involved effort of a few days to two weeks and were accomplished as required and as time permitted. The activity paths to most of these events represent time delays primarily. For example, about 22 weeks elapsed between the installation of computer wireways and ground busses (ME5) and the completion of reconnecting computer wires which we had cut in Cambridge (ME11). This latter event (ME11) required about a week of effort for its accomplishment, but due to manpower limitations was not started until the middle of September, 1962. This manpower limitation was dictated primarily by efficiency considerations, since the size of the working crew was about optimum, an increase in its size would have resulted in decreased effectiveness of the group.

TABLE 2-1

Rigging and Moving (RM)

Event No.	Description	Date Completed or Scheduled
RM1	Removed Panels Moved	July 21, 1962
RM2	Transformer Panels Moved	April 15, 1962
RM3	Test Control, Core Banks and Drums Moved	February 13, 1962
RM4	Computer Racks 0-7 Moved	February 9, 1962
RM5	Computer Racks 8-15 Moved	February 9, 1962
RM6	Computer Racks Positioned	April 10, 1962
RM7	I/O Racks Moved	February 9, 1962
RM8	I/O Racks Positioned	April 13, 1962
RM9	Wire Boxes Moved	April 15, 1962
RM10	Compressors Moved and Set Up	March 26, 1962
RM11	Evaporators Moved and Set Up	December 8, 1961
RM12A	Air Handling Units and Control Boards Moved	January 16, 1962
RM12B	Air Handling Units Set Up	February 7, 1962
RM13	Ductwork Moved	December 8, 1961
RM14	Rotating Machinery and Switch-gear Moved and Set Up	March 26, 1962
RM15	DC Supplies Moved	March 23, 1962
RM16	Remaining Equipment Moved	June 12, 1962
RM17	TC Racks Positioned	April 5, 1962

TABLE 2-2

Air Conditioning Installation (AC)

Event No.	Description	Date Completed or Scheduled
AC1	Refrigerant Piping Completed	July 31, 1962
AC2A	Start Connecting Pneumatic Controls	August 1, 1962
AC2B	Complete all Pneumatic Controls Except Room and Mechanical Room	August 2, 1962
AC2C	Complete all Pneumatic Controls	September 27, 1962
AC3A	Start Ductwork Installation	May 28, 1962
AC3B	Complete Fresh Air And First Section Supply Ducts	July 6, 1962
AC3C	Complete all Ductwork Except Room and Mechanical Room	August 2, 1962
AC3D	Complete all Ductwork	September 27, 1962
AC4A	Start Electric Switchgear and Control Wiring	May 28, 1962
AC4B	Complete all Wiring Except Room and Mechanical Room Controls	July 29, 1962
AC4C	Start Remaining Wiring	October 12, 1962
AC4D	Complete all Wiring	October 15, 1962
AC5A	Start System Checkout	August 3, 1962
AC5B	Complete Basic System Checkout	August 4, 1962
AC5C	Complete System Checkout	October 18, 1962

TABLE 2-3

Power Equipment (PE)

Event No.	Description	Date Completed or Scheduled
*PE1	400A Alternator Wired	August 14, 1963
PE2	400A Standby Alternator Wired	June 22, 1962
PE3A	Power Control Racks Set Up	April 6, 1962
PE3B	Power Control Racks Wired	October 15, 1962
PE4	Filament Contactors Wired to Busses	October 26, 1962
PE5A	Standby Alternator Checked Out	December 13, 1962
*PE5B	400A Alternator Checked Out	August 20, 1963
PE6A	DC Supplies Installed in Racks	June 9, 1962
PE6B	DC Supplies Wired	October 12, 1962
PE7	AC Inputs to DC Supplies Wired	October 12, 1962
**PE8	DC Supplies Checked Out	January 17, 1963
PE9	DC Supplies Wired to Busses	August 17, 1962
PE10	Lab. DC Supplies Wired and Checked Out	June 29, 1962
PE11	Lab. DC Distribution Completed	October 16, 1962

*Incomplete as of July 31, 1963. Described and scheduled in Section III.

**Described and scheduled in Section III.

TABLE 2-4

Mechanical and Electrical Reassembly (ME)

Event No.	Description	Date Completed or Scheduled
ME1	Floor Marked for Computer Racks	April 6, 1962
ME2	Floor Marked for TC Racks	April 2, 1962
ME3	Floor Marked for I/O Racks	April 10, 1962
ME4	Junction Box Mount Completed	April 18, 1962
ME5	Computer Wireway and Ground Bus Installed	April 26, 1962
ME6A	Start Test Control Wireways	April 16, 1962
ME6B	Test Control Wireways Installed	April 27, 1962
ME7	I/O Wireways and Ground Bus Installed	April 27, 1962
ME8	Removed Panels Replaced	July 26, 1962
ME9A	Transformer Panels Replaced	April 20, 1962
ME9B	Transformer Panels Rewired	August 10, 1962
ME9C	Filter Panels Replaced	November 15, 1962
ME10	Bus Bars Installed	July 18, 1962
ME11	Computer Cut Wires Reconnected	September 26, 1962
ME12	I/O Cut Wires Reconnected	September 27, 1962
ME13A	Start Reconnection of Wires and Cables	April 30, 1962
ME13B	Reconnection of Cables Completed	October 29, 1962
ME14	Reconnection of Cables Checked Out	Deleted
ME15	Intercom Reconnected and Checked Out	September 14, 1962

TABLE 2-4

Mechanical and Electrical Reassembly (ME) (Cont'd)

Event No.	Description	Date Completed or Scheduled
ME16	Transformers in Banks A and B Replaced	October 25, 1962
ME17	Core Stacks A, B and C Installed	October 29, 1962
ME18	Drum Bearings Checked and Replaced if Required	September 24, 1962
ME19	Drums Installed	September 28, 1962
ME20	AC and DC Power for TC Installed	October 3, 1962
ME21	Junction Boxed Repositioned	October 5, 1962
ME22	Test Bench for Drum Chassis Installed	September 24, 1962
**ME23	Construct Anelex Transition Panel	April 11, 1963
*ME24	Install Anelex Cabling	August 9, 1963
*ME25	Repair Brush Boxes on 400A Alternator	August 9, 1963
*ME26	Recable 3 Display Consoles	August 2, 1963

*Incomplete as of July 31, 1963. Described and scheduled in Section III.

**Described and scheduled in Section III.

III COMPUTER CHECKOUT

The checkout phase commenced on December 19, 1962 with the completion of checking the standby alternator cycling system from the alternator output to the computer busses and thence to the computer racks. That is, filament power was applied to all of the main computer racks. Checkout is scheduled to be completed on November 15, 1963 with the completion of checkout of the teletype input subsystem. Presented in Figure 3-1 is a PERT network which describes the activities and events comprising this phase of the project. All but seven of the events in this network are listed in Table 3-1. As mentioned in Section II, the remaining seven events (PE1, PE5B, PE8, ME23, ME24, ME25, and ME26) have been carried over from the moving and reassembly phase as their accomplishment was not essential to the start of the checkout phase and it was more convenient to defer action on these tasks. These tasks are described in Tables 2-3 and 2-4 of Section II. Two of these seven events (PE8 and ME23) have already been accomplished; the remaining five are scheduled to be completed within the next three weeks. It should be noted that our October, 1960 moving schedule memorandum has no counterpart of Table 3-1, since the 1960 memorandum scheduled only the moving and reassembly but not the checkout of the computer.

Section A below describes equipment already checked out during the checkout phase, while Section B describes tasks involving equipment yet to be checked out.

A. Equipment Checked Out

1. Power Equipment

a. Standby Alternator and Filament Power Distribution System

As mentioned above, the checkout phase began on December 19, 1962 with the successful completion of checking of cycling of the standby alternator to the computer busses (CO1) and thence to the computer racks (CO2). These two events were completed with very little difficulty. Power was cycled on to groups of eight racks at a time with several personnel standing by to warn of trouble so that power could be removed immediately, thereby minimizing damage to the computer panels. As power was applied successfully to each group of eight racks, the filament voltage was then cycled down, eight more racks were turned on and observed for signs of trouble as the filaments were cycled back on. This procedure of adding modules of eight racks to previously checked racks with alternate cycling on and off of the filament power was repeated until filament power was successfully applied to all the racks in the main computer including the core memories. The success of this operation is indicated by the fact that the entire process was completed in a period of about four hours. Other than a difficulty due to voltage breakdown in the standby alternator slip rings, which occurred on April 12 and which is described in Section IV-B, and a few blown filament fuses due to loose connections, the filament alternator cycling and power distribution system has worked exceedingly well to date.

b. DC Power Supplies

Checkout of the computer DC power supplies with dummy loads (PE8) was accomplished on January 17, 1963. While this task was rather time consuming, it was accomplished with very little difficulty. Of the twelve supplies involved, trouble was encountered with only about three of them and these were cured by replacing tubes and/or wire-wound resistors. The problem of open wire-wound resistors in the power supplies is similar to that encountered elsewhere in the computer and this problem is described more fully in Section IV-A. With the exception of the -48 volt supply which has a warm-up problem which existed at MIT and the occassional tripping of the main circuit breaker on the +150 volt supply due to a weak breaker, these equipments have worked extremely well ever since they were first checked out. The -48 volt supply problem is due to a thermistor in the regulator circuit which must be preheated by a light bulb before it will regulate properly. These two problems can probably be cured by replacing the thermistor and the circuit breaker, but their replacement is of fairly low priority at present, since they cause very slight inconvenience when first turning on the computer.

c. DC Power Distribution System

After checking out the DC power supplies with dummy loads, the next step was to check the connections of these supplies to the computer busses and thence through the power distribution circuits to the individual computer racks. These tasks (CO3 and CO4) were accomplished during the period from January 17 to February 28, 1963. Checking the connections of the supplies to the computer busses involved checking the proper sequencing of the power supply timers to ensure that the voltages were applied to the busses in their proper sequence. This task (CO3) required but four days.

The task of checking the distribution of DC voltages from the busses through the power distribution system to the individual racks was considerably more complicated. Several precautions had to be taken to prevent damage to the computer panels due to incorrect voltages being applied as a result of wiring errors in reconnecting the cables. As mentioned in Section II-D, extensive checking of power cabling reconnections was bypassed after determining that the error rate was extremely small. However, errors were known to exist and in checking the DC distribution to the individual racks not a single error could be tolerated. Since most of the panels had never been disconnected from their respective rack terminal strips, the connections from these terminal strips to the individual panels were known to be correct. However, the connections from the power distribution circuits to the rack terminal strips had been disconnected and required thorough checking. A simple means for making this check was devised which enabled us to apply power to the rack terminal strips without simultaneously applying power to the individual panels. This procedure was to open up the fuse links in the rack terminal strips by placing wooden coffee stirrers between the line side of the fuse and the terminal to which it is normally connected. This disabled the power connections to the panels without removing the fuses and the voltage at each terminal of each rack was checked with a voltmeter and verified with the MIT rack wiring schedules to ensure that all the voltages were applied at the proper points. Fewer than twenty wires were found to be in error out of a total of 7000 to 10,000 terminals which had to be checked. A few racks were found to have no voltage and these troubles were usually traced to wiring errors in the power distribution system. The operation of the power distribution system which contains somewhere in the order of 2000 relays has been extremely good. Not a single relay had to be replaced due to faulty operation during checkout and none have had to be replaced since.

d. Marginal Checking System

Checkout of the marginal checking system was not essential to initial checking of the computer circuits and was therefore postponed until April 1. Another reason for delaying the checkout of this equipment is that the motor which drives the amplidyne generator was wound for 115 volt, three phase operation. In Cambridge this motor was fed from a 230 volt, three phase transformer bank through a small 230/115 volt, three phase transformer bank. As MIT retained the 230 volt transformer bank at the Barta Building, we had no means of feeding the 230 volt input to the 230/115 volt transformer bank associated with the marginal checking equipment. It was found to be more desirable and less expensive to have the motor of the amplidyne generator rewound for 120/208 volt, three phase operation and the spare amplidyne unit was sent to General Electric to be rewound in this fashion. Having received the rewound amplidyne from GE, and having encountered difficulty with marginal flip flops in checking the computer circuits, it was decided on April 1 to concentrate our efforts on making the marginal checking system operational.

The greatest difficulty with the marginal checking system was encountered with the regulator which controls the output of the amplidyne. Due to interruptions caused by shorting of the slip rings on the 400 amp standby alternator and the burning up of a wire from the filament busses to the magnetic tape units as well as concurrent work on checking of the storage switch, work on the marginal checking regulator panel was not completed until the latter part of April. When a recheck of the regulator panel was made at that time, it was determined that the trouble was a parasitic oscillation whose cause was traced to a wiring error we had made earlier in replacing the open 8 watt wire-wound resistors in the panel. After correcting this trouble, the marginal checking system worked properly and its operation has been very satisfactory since then. During the period from about April 8 to April 30, the marginal checking system was usable but was failing to return to zero from a positive margin. Other troubles with the marginal checking system corrected during the month of April were cured by replacing a broken wire, cleaning some relay contacts in the marginal checking control rack, replacing a shorted electrolytic capacitor and a faulty thyratron and correcting two other wiring errors.

2. Control Element

Having checked DC connections to the computer racks on Frbruary 28, 1963, the next step was to check the logical operation of the computer. At this point, the obvious step was to try to operate the entire central computer exclusive of magnetic core storage and input-output, even though the probability of success was extremely low. This was tried but was unsuccessful as was expected, and it was then necessary to investigate the basic components of the system in more detail starting with the Control Element. The first step was to check the Pulse Generator, Frequency Divider, and Restorer Pulse Generator (CO6) which are the primary sources of all pulses used in the machine. Having done some checking of these units last summer using laboratory DC power and unregulated filament power, it was not unexpected that these were found to be operating properly. In addition, Clock Pulse Control (CO7), the Time Pulse Distributor (CO8), and the Test Control Synchronizers (CO9) which had also been checked last summer were found to be operating properly.

The next items to be checked were the Control Switch (CO11), the Operation Matrix (CO12), and the Control Pulse Output Units (CO13). These units, which decode the five-bit operation code portion of the Whirlwind instruction word and transmit pulses to appropropriate sections of the computer on the various time pulses of the selected instruction, were checked out by March 15, 1963 with only slight difficulties which included replacing a shorted tube, a shorted diode in the matrix, and a loose video cable connector. Very little difficulty has been encountered with these units since that time.

The next major unit within the Control Element to be checked was the Program Counter. It was at this point that we encountered our first major obstable to checking out the computer. The Program Counter, which determines the location in storage from which the next instruction is to be taken, was found to have trouble with certain of its flip-flops, which developed a parasitic oscillation, when pulsed at certain frequencies, typical of those to be encountered in computer operation. This difficulty was found to be caused by the 2000 ohm ten watt resistors which had been used to replace the open 2000 ohm eight watt resistors in all the computer flip-flop circuits. This difficulty is described in more detail in Section IV-A. After replacing all of the 2000 ohm ten watt resistors with 2000 ohm twelve watt resistors and replacing several pairs of flip-flop tubes, the Program Counter was made operational on April 23, 1963.

The remaining units of the Control Element, namely the Check Register (CO20) and the Alarm System (CO10) were checked out a couple of weeks later in connection with checking of the Arithmetic Element and the Storage Element. This was necessitated by the fact that the Check Register is used to check transfers of data between the Arithmetic, Control and Storage elements of the computer. Thus, we had to be able to transfer information between these elements before determining the proper operation of the Check Register. In order to obtain proper operation of the flip-flops in the Check Register panels it was also found necessary to replace the 2000 ohm ten watt resistors with 2000 ohm twelve watt resistors, and in addition, several pairs of flip-flop tubes and a few gate tubes had to be replaced. Checkout of the Alarm System was accomplished by correcting a few wiring errors.

3. Arithmetic Element

Initial checking of the Arithmetic Element was started around the middle of April and was completed on May 16, 1963. This initial check was concentrated on operation of the addition and subtraction instructions, proper transfer of information into and out of the Arithmetic Element, and improvement of the stability and operating margins of the flip-flops within the Arithmetic Element. Minor attention was given to the multiply, divide and shifting operations and further work on the Arithmetic Element was suspended until mid-July in order to proceed with the checkout of the core memory, the input-output, and a few basic input-output devices. More detailed checking of the multiply, divide and shift operations was again undertaken on July 15 and was completed on July 30, 1963. During the initial check of Arithmetic Element operation (CO17A) most of the troubles were corrected by replacing all the 2000 ohm ten watt wire-wound resistors with 2000 ohm twelve watt wire-woundresistors and replacing several of the matched pairs of flip-flop tubes. The few remaining troubles were corrected by replacing a small quantity of gate tubes and rectifying a few video cabling errors. During the recent final check of the Arithmetic Element (CO17B) troubles with the multiply, divide, and shift instructions were found to be caused by pulse repetition frequency sensitivity when shifting alternate 1's and 0's through the flip-flops of the B-Register and Accumulator. Further investigation revealed that this sensitivity could be eliminated by replacing the 1600 ohm ten watt resistors in the flip-flop circuits with 1600 ohm twelve watt resistors. Since multiplication is basically an add and shift operation, and since divide is basically a subtract and shift operation, elimination of the shifting problems also cured the multiply and divide problems.

4. Storage Element

a. Toggle Switch Storage and Parity Register

Checkout of Toggle Switch Storage and the Parity Register (CO15) as well as the Storage Switch was performed concurrently with the initial check of the Arithmetic Element and the checkout of Flip-Flop Storage. This event was accomplished on April 22, 1963. Troubles with the Toggle Switch Storage Registers and the Storage Switch were corrected by replacing ten watt resistors with twelve watt resistors, replacing several defective 6Y6 tubes, and by replacing several wires which had been cut when the computer was moved and which had been poorly butt connected. Troubles with the Parity Register were cleared up mainly by replacing flip-flop tubes and/or flip-flop plug-in units.

b. Flip-Flop Storage

Checkout of Flip-Flop Storage (CO16) also proceeded concurrently with the initial check of the Arithmetic Element. As with the Arithmetic Element, most of the troubles with Flip-Flop Storage were corrected by replacing 2000 ohm ten watt resistors with twelve watt resistors and replacing several matched pairs of 6145 flip-flop tubes. A few other troubles were corrected by replacing defective crystal diodes and correcting two wiring errors in the Flip-Flop Storage reset switches.

c. Core Memory

AC and DC power were initially applied to core memory Banks A and B on May 15 and to core memory Bank C two days later. After correcting two video cabling errors and replacing a defective video cable, proper operation of the Memory Address Registers was accomplished. At this point it was then possible to attempt writing into and reading from registers in each core bank. Parity errors were encountered in Banks A and B but a check of a few registers in each of the four core fields in Bank C seemed to indicate that this bank was working perfectly. The initial success of operation of Bank C and initial failure of Banks A and B was due, in part, to adjustment of read and write currents. Read and write current controls in Banks A and B had been misadjusted during the move, whereas the controls in Bank C are locked and had not been disturbed by the moving process. The current controls in Banks A and B had been roughly reset in accordance with some photographs we had taken in Cambridge prior to computer disassembly. More precise adjustment of the read and write current controls in Banks A and B with an oscilloscope made some improvement in operation of these cores but did not entirely correct the problems. It was then discovered that most of the remaining troubles in Banks A and B were due to faulty operation of digit plane driver plug-in units which were failing to provide proper inhibit currents and were causing parity alarms. Troubles with these plug-in unit digit plane drivers were found to be due to open ten watt non-inductively wound resistors. Since we had good operation from the 4000 core registers in Bank C at that point, it was decided to reduce our efforts on checking core memory so that checkout of the input-output system, the Flexowriter and photoelectric tape reader could be expedited.

Further checking of Bank B suddenly revealed that the parity error problems were not entirely due to faulty digit plane driver operation when it was discovered that the cables from the digit plane drivers to the core planes had been completely reversed. Correcting this cabling error and repairing the digit plane drivers seemed to clear up all core memory troubles for a period of about two weeks. However, with the onset of very hot weather toward the latter part of June, troubles developed in all core banks and we were suddenly forced to concentrate all our efforts on checking core memory again. Some of the troubles were evidenced by blown fuses, probably due to overheating, which resulted from a lack of Freon in the air conditioning system. The system, as described in Section IVC, had been found to have lost all Freon during the latter part of May. Overheating problems during the hot weather at the end of June subsequently revealed that we had underestimated the Freon capacity of the system and had replaced only about half of the required amount of Freon. During the first week of July, a more exhaustive check of all core banks was made. Troubles with Bank C were cleared up by replacing two broken tubes, two blown fuses, correcting an open circuit in a common ground line on a selection plane driver due to a poor solder joint, and replacement of a burned out 5998 tube in a selection plane driver panel.

5. Input-Output Element

a. Control

Checkout of the In-Out Element (CO19) was accomplished with very little difficulty by June 5, 1963. The only difficulty encountered with the In-Out Register was the failure of one flip-flop which was corrected by replacing the flip-flop tubes with a new matched pair of 6145's. Troubles with the In-Out Delay Counter were corrected by replacing a missing gate tube and two defective video cables which were responsible for failure to terminate block transfer instructions. Difficulties with the In-Out Switch were corrected by replacing a missing 6Y6 tube which drives the clear line to the flip-flops of the In-Out Switch and by replacing an open 22,000 ohm twelve watt wire-wound resistor in a cathode follower. This cathode follower was failing to shut off a gate tube in the clear line to the In-Out Switch flip-flops and was thus permitting spurious clear pulses to interfere with proper operation of the In-Out Switch. Operation of the In-Out Element to date has been excellent and no failures have been encountered since the above troubles were corrected.

b. Peripheral Equipment

1) Flexowriter Keyboard Input, Reader/Printer, and Punch

Checkout of the Flexowriter direct keyboard input, direct printer and punch output and mechanical paper tape reader input (CO22) was accomplished on June 5, 1963. The only difficulties encountered here were caused by two wires which were incorrectly connected.

2) Photoelectric Tape Reader

Checkout of the Ferranti Photoelectric Tape Reader (CO23) was also accomplished with very little difficulty. Three troubles were encountered here, two due to missing DC voltages, the third due to failure of one of the digits to read to the In-Out Register. One of the missing voltages was due to a wiring error, the other was due to a broken wire. The failure to read one of the digits to the In-Out Register was corrected by tightening a tube which was loose in its socket in an In-Out Register Input Mixer panel.

3) Real Time Clock

Checkout of the Real Time Clock (CO32) was completed on June 13, 1963. Trouble with the clock was corrected by rectifying one video cabling error and replacing an indicator light bracket.

4) Test Control Display Scopes

Successful completion of event CO27A was accomplished on June 19, 1963. This task included checkout of all the control elements of the display subsystem as well as the two display scopes in Test Control. Troubles encountered in this area included failure of the vertical deflection signal which was caused by a bad 5651 voltage regulator tube in the Vertical Decoder, failure of vertical deflection on one scope due to a loose wire on a binding post, and a cabling error which caused the horizontal and vertical deflection signals on one scope to be interchanged. Troubles with the individual scopes were encountered in the Dumont high voltage power supplies and in the deflection amplifiers. Troubles with the Dumont high voltage supplies were corrected by replacing a broken high voltage coil and two open wire-wound potentiometers. Malfunctions in one of the horizontal deflection amplifiers were corrected by replacing defective tubes. After correcting these difficulties, proper operation of point displays, character displays, and vector displays was accomplished by aligning the deflection decoders, the decoder output amplifier, and the scope deflection amplifiers in accordance with procedures established at MIT.

5) Intervention and Activate Registers

The Intervention and Activate Registers (CO28) were also checked out on June 19. The only difficulties encountered with these subsystems were caused by missing voltages on the switches in Test Control, two video cabling errors, and a fuse blowing problem associated with the cathode followers which enable the read-out gates of the individual Intervention Registers. The fuse involved kept blowing repeatedly and the trouble was finally cleared up by replacing it with a larger size fuse after determining that the fuse rating was too low for the amount of current being drawn by these cathode followers.

B. Equipment to be Checked Out

Several more units of input-output equipment remain to be checked before the computer can be considered to be completely checked out. These include principally the magnetic tape units, the IBM card machines, the Anelex printer, three additional display consoles, and the two magnetic drums. In addition, the 400 amp alternator which provides filament power to the magnetic drums and associated input-output equipment requires some repair and must be rewired. Also, the power distribution system, both AC and DC, for the magnetic drums and associated equipment must be checked out. Some checkout work has been done in each of these areas with the exception of the drums. Many of these jobs are scheduled to be completed within the next few weeks and present indications are that all work should be completed on or about November 15, 1963.

1. Power Equipment

a. 400 Amp Alternator and Filament Power Distribution System

Work on repairing the brush boxes on the 400 amp Alternator (ME25) is scheduled to start the latter part of this week. Preliminary investigation into this problem indicates that replacing of the slip rings may be a more desirable long-term solution. We are awaiting information from the manufacturer, which will determine just how much wear on the slip rings has occurred. After talking with the manufacturer's local representative, there is a slight possibility that the solution to the problem may be merely the use of a different type of brush than that used by MIT. Data from the factory giving original dimensions of the slip rings will be the deciding factor on whether or not these will be replaced. If it is necessary to replace the slip rings, there is a good possibility that a new pair may be available from stock. If the slip rings are not available from stock, then a two week delivery period is quoted. In this latter event, it would be necessary to postpone further work on the slip rings for two weeks. However, other tasks associated with the alternator could be performed sooner so that the two week delivery delay will not impose any slippage on the existing schedule.

Reconnecting the cables from this 400 amp alternator (PE1) has been planned and presently is scheduled to be accomplished after the slip ring problem is corrected. However, if it is necessary to wait the two weeks for slip ring delivery, the wiring of the alternator can be done first.

Checkout of the 400 amp alternator (PE5B) is presently scheduled to be completed by August 20. No difficulty is anticipated in accomplishing this task as scheduled, even if it is necessary to wait two weeks for delivery of slip rings.

After checking out the operation of the 400 amp alternator, the next tasks will be to check the 400 amp alternator cycling system and connections to the in-out filament busses (CO34) and the filament connections to the individual in-out equipment racks and to the drum bays (CO35). With the exception of the feeder cables from the 400 amp alternator, all the necessary filament power cycling and distribution wiring was completed during the moving and reassembly phase last year. Thus, little difficulty is foreseen in completing these two tasks by the end of August.

b. DC Power Distribution System

After checking filament power connections to the in-out equipment racks and drums, it will be necessary to check the DC connections to these equipments. Two tasks are involved—the first, checking of the DC supplies to the in-out equipment busses (CO36) and the second, checking the

DC power distribution to the individual racks and drum bays (CO37). The only difficulties anticipated in connection with these two tasks are in checking DC power connections to the drum bays and the connection of rack DC switches which control the outputs of the power distribution panels to the associated racks and drum bays. Connection of the outputs of the power distribution panels to the individual racks should give no trouble, since unlike the racks in the main computer, most of this DC wiring did not have to be disconnected. The scheduled date of September 20 for completion of DC checking should be accomplished without difficulty.

2. Input-Output Equipment

With the exception of the Anelex printer, magnetic drums, teletype input, and teletype output on which no checking has yet been done, checkout of remaining input-output units has been done to some degree.

a. Display Consoles

Three display consoles, in addition to the two in Test Control already checked out, are planned. Two of these have been recabled and checkout is nearly completed. The third display console recabling has just been started. When cabling of this scope is completed, event ME26 will have been accomplished. Completion of this event is scheduled for August 2, but may slip one or two days. Complete checkout of these three display consoles will accomplish event CO31 on or about August 7. The only difficulties anticipated in checking these three displays are troubles with the Dumont high voltage power supplies, alignment problems in the deflection amplifiers, and a few minor wiring errors.

b. Indicator Light Registers

Completion of checkout of all Indicator Light Registers required at present (CO30) is expected to occur concurrently with the completion of the checkout of three display consoles mentioned in a. above. Most of these registers have been checked and it is felt that remaining troubles are due to defective thyratrons in these registers or to one or two wiring errors.

c. Light Guns

Three light guns are being checked out for use with the three display consoles mentioned in a. above. Two light guns have been reconnected and one of these has been checked out completed while the third is being connected with the third display console. Completion of light gun checkout (CO29) is also scheduled to coincide with the completion of checkout of the three display consoles. No difficulties other than tube failure and minor wiring errors are anticipated.

d. Magnetic Tape Units

Checkout of the magnetic tape units (CO26) is scheduled to be completed on August 12. Mechanically these units are operational as are all the manual controls. Thus, all the remaining troubles with these units are electronic and it is not anticipated that any serious difficulties will be encountered here.

e. IBM Card Machines

All the wiring for the IBM card machines was checked very thoroughly during the moving and reassembly phase last fall. The IBM 523 gang summary punches used with this system are in good mechanical shape. These two machines, which were specially modified by MIT for use with Whirlwind, were being leased from IBM by MIT. The Wolf Research and Development Corporation took over the lease from MIT and has since purchased the machines outright from IBM. Since the wiring associated with these card machines has been thoroughly checked, checkout of the Whirlwind card machine system (CO24) should be a fairly straightforward task and should be completed around August 15.

f. Anelex Alphanumeric Printer

The Anelex Alphanumeric Synchroprinter used with Whirlwind was not acquired from Lincoln Laboratory until September, 1962. As the task of reconnecting computer wires and cables was nearly completed at that point, it was decided to defer recabling of the Anelex printer until the checkout phase. All units of the Anelex printer system were acquired from Lincoln with the exception of the transition panel which could not be located in their warehouse. Thus, it was necessary to build a new transition panel and this task (ME23) was completed on April 11 of this year. Recabling of the Anelex equipment has been partially completed over the past couple of months as time permits. Presently, this task (ME24) is about half completed and is scheduled for final completion on August 9. Operational checkout of the Anelex system will be accomplished during the last two weeks of August with a scheduled date of August 30. Here again, little difficulty is anticipated particularly since one of our engineers has had considerable experience with the operation of this printer at MIT.

g. Test Control Camera

Some difficulties with the checkout of the Test Control camera subsystem were encountered during June when the Test Control Display Scopes were checked out. This is not a very complicated system, but MIT's drawings and records associated with this system are in very poor shape and apparently a few wiring errors were made in reconnecting the camera. At present, the camera can be indexed manually but not by program command. One of the known troubles is that about six plug-in units are missing from this subsystem and were missing, according to our records, when we acquired responsibility for the computer. Also, because of the poor records involved, about two dozen wires will have to be traced manually before the camera can be checked out. Since this is a relatively low priority item, it has been deferred until the first week of September and this task (CO27B) is scheduled for completion on September 4. While this job will not take more than two or three days, the amount of effort is out of proportion relative to the complexity of the system due to the poor records available.

h. Magnetic Drums

Checkout of the Auxiliary Drum (CO38) is scheduled for October 11 while checkout of the Buffer Drum (CO39) is scheduled for November 8. These two tasks cannot be started until AC and DC checkout (CO34, CO35, CO36, and CO37) of the drum bays and associated input-output equipment is completed. It is somewhat more difficult to anticipate what troubles may be encountered in checking out the drums, but possible trouble sources include adjustment and alignment of read and write heads, cabling errors between the drums and the main computer, troubles with the electronic chassis in the drum bays, and possible difficulties with drum bearings.

A preliminary check of the condition of the drum bearings was made during the moving and reassembly phase. This check indicated that the drum bearings are in good shape and that the oil leakage problem was due to over filling of the oil reservoirs at MIT. Although we have not been able to obtain mechanical assembly drawings for the drums from Sperry Rand, we do know that the bearings are commercially available. We have also been advised by Sperry Rand that the run down time from full speed to rest when power is removed should not be less than 2-1/2 to 3 minutes after the drum has been running for one hour. A shorter run down time would indicate bearing troubles. As for bearing life, Sperry Rand indicated that the bearings should be good for at least another ten years on the basis of usage to date by MIT. We feel that our present schedule makes ample provision for any difficulties which may be encountered in checking out the drums.

i. Teletype Input and Output

Thorough checking of teletype input and output subsystems requires a teletype transmitter distributor, a typing reperforator, and a Type 28RO teletypewriter. Since we have no immediate plans for use of these subsystems, we will be able to check out only those portions of these subsystems which can be checked without the teletype equipment mentioned above. A reasonably thorough check of the electronics can be made by means of the Teletype Test Message Generator on a closed loop basis with a computer program and this type of checking is all that is planned for the accomplishment of events CO33 and CO40. Checking of the teletype input subsystem which uses slots on the buffer drum cannot be started until checkout of the buffer drum is completed, however.

TABLE 3-1

Check Out (CO)

Event No.	Description	Date Completed or Scheduled
CO1	Standby Alternator Cycling to Computer Bus	December 19, 1962
CO2	AC to Computer Racks	December 19, 1962
CO3	DC Supplies to Computer Busses	January 21, 1963
CO4	DC to Computer Racks	February 28, 1963
CO5	Marginal Checking System	April 30, 1963
CO6	Pulse Generator, Frequency Divider, and Restorer Pulse Generator	February 28, 1963
CO7	Clock Pulse Control	February 28, 1963
CO8	Time Pulse Distributor	February 28, 1963
CO9	Test Control Synchronizers	February 28, 1963
CO10	Alarm System	May 10, 1963
CO11	Control Switch	March 15, 1963
CO12	Operation Matrix	March 15, 1963
CO13	Control Pulse Output Units	March 15, 1963
CO14	Program Counter	April 23, 1963
CO15	Toggle Switch Storage and Parity Register	April 22, 1963
CO16	Flip Flop Storage	May 16, 1963
CO17A	Initial Check Arithmetic Element	May 16, 1963
CO17B	Final Check Arithmetic Element	July 30, 1963
CO18A	Initial Check Core Memory	June 4, 1963
CO18B	Final Check Core Memory	July 3, 1963

TABLE 3-1

Check Out (CO) (Cont'd)

Event No.	Description	Date Completed or Scheduled
CO19	In-Out Element	June 5, 1963
CO20	Check Register	May 10, 1963
CO21	Start I/O Equipment Check	June 5, 1963
CO22	Flexowriter Keyboard Input, Punch, Reader and Printer	June 5, 1963
CO23	Photoelectric Tape Reader	June 5, 1963
* CO24	IBM Card Machines	August 15, 1963
* CO25	Anelex Printer	August 30, 1963
* CO26	Magnetic Tape Units	August 12, 1963
CO27A	Test Control Displays	June 19, 1963
* CO27B	Test Control Camera	September 4, 1963
CO28	Intervention and Activate Registers	June 19, 1963
* CO29	Light Guns	August 7, 1963
* CO30	Indicator Light Registers	August 7, 1963
* CO31	Display Consoles (3)	August 7, 1963
CO32	Real Time Clock	June 13, 1963
* CO33	Teletype Output	September 13, 1963
* CO34	400A Alternator Cycling to Bus	August 23, 1963
* CO35	AC to I/O Racks	August 30, 1963
* CO36	DC Supplies to I/O Busses	September 6, 1963

TABLE 3-1

Check Out (CO) (Cont'd)

Event No.	Description	Date Completed or Scheduled
* CO37	DC Supplies to I/O Racks	September 20, 1963
* CO38	Auxiliary Drum	October 11, 1963
* CO39	Buffer Drum	November 8, 1963
* CO40	Teletype Input	November 15, 1963

*Incomplete as of July 31, 1963

IV MAJOR PROBLEMS ENCOUNTERED TO DATE

During the checkout phase, we have encountered several major problems. Two of these, namely troubles with defective wire-wound resistors and phenolic breakdowns had been anticipated. Two other difficulties, one with slip rings on the 400 amp standby alternator, and the other, troubles with the air conditioning equipment, occurred unexpectedly. We felt that we had solved the wire-wound resistor problem last Summer when we replaced all the existing 8 watt wire-wound resistors in the computer, but unexpected difficulties were encountered with these new resistors. Phenolic breakdowns did not occur initially and for several months. We had finally reached a point where we felt the problem did not exist when a rash of such troubles occurred. Except for wire-wound resistor problems, failure rates of other electronic components have been much lower than we had anticipated. In particular, vacuum tube failure has been extremely low as has failure of crystal diodes. Relay operation has also been excellent and we have encountered trouble with only one relay out of more than 2000.

A. Wire-Wound Resistors

Tests of wire-wound resistors at Navy Building 61 during the Summer of 1961 indicated a need for replacing all such resistors in the computer panels. The sample tested indicated about 75% of these resistors had opened up since the computer was shut down in May, 1959. During the Summer of 1962, new military RW31G ten watt wire-wound resistors were purchased to replace the 8 watt resistors in the computer panels. These resistors were carefully bridged on a Wheatstone Bridge and matched to within 1% tolerance of nominal value and of each other as specified in Whirlwind records. Two students from Wentworth Institute were hired for the Summer and were assigned the task of replacing these resistors. Although MIT had replaced some of the 8 watt resistors with 12 watt resistors of a type similar to that which we purchased, our decision to purchase 10 watt rather than 12 watt resistors was based on two factors.

First, the 10 watt resistors which we purchased were the same physical size as the 8 watt resistors to be replaced, whereas the 12 watt resistors are longer and present some mechanical problems in mounting. Second, it was known that 12 watt wire-wound resistors were a standard stock item at Lincoln Laboratory and were therefore easier to obtain than the 10 watt resistors. Although it was obvious that 10 watt resistors would certainly handle the power dissipation since the original resistors were only rated at 8 watts, we did compute the power dissipation in these resistors and found that the results, namely dissipations ranging from 2 to 4 watts, confirmed our conclusions. At this point we felt that we had solved the problem and due to other urgent tasks we assigned the resistor replacement job to the Wentworth students. During the latter part of the Summer of 1962, some pulse checking was done on the Control Element and the resistors which had been replaced here seemed to give very satisfactory performance.

However, in the Spring of 1963 while checking the operation of the Program Counter, difficulty was encountered with self-sustained oscillations in many of the flip-flops in the Program Counter. After a few days of intensive bench testing of one of the Program Counter panels, and review of early MIT records and memos for indications of such troubles in the past, it was determined that the cause of the trouble was primarily the 2000 ohm 10 watt resistors. Although each flip-flop contains two, 2000 ohm resistors, two 5000 ohm resistors, and two 1600 ohm resistors, in the vast majority of cases proper operation of flip-flops with voltage margins of plus or minus 30 to 40 volts has been accomplished merely by replacing the 2000 ohm ten watt resistors with 2000 ohm twelve watt resistors. Recently, however, it has been necessary to change the 1600 ohm resistors in the Accumulator Parital Sum flip-flops and the B-Register flip-flops to obtain proper shifting operations.

A series of tests on ten and twelve watt wire wound resistors run by the manufacturer at our request revealed the probable cause of the problem. These tests measured the resistance and inductance of both ten and twelve watt resistors at 1, 2 and 5 megacycles. The results showed that the effective AC resistance as a function of frequency increased much faster in the case of the ten watt resistors than in the case of the twelve watt resistors. This was particularly true in the case of the 2000 ohm resistors and the trouble is assumed to be due to the smaller wire size used to get the same resistance in the smaller ten watt resistors. While most computer operations are performed at a maximum speed of 1 megacycle, shifting in the Accumulator and B-Register is done at 2 megacycles and thus the 1600 ohm resistors also had to be replaced to cure this latter problem.

While most of the open wire-wound resistors found to date have been of the eight watt Navy-type, there have been other instances of open wire-wound resistors. Several commercial ten watt, non-inductive wire-wound resistors in the digit plane drivers of Core Memory Banks A and B were found to be open, and one 22,000 ohm, twelve watt resistor used in a cathode follower in In-Out Control was also found to be open. Just this week, trouble developed in an A-Register panel and this was traced to an open 2000 ohm twelve watt resistor which had been installed at MIT in place of an eight watt resistor. Environmental conditions to which the computer was subject during the storage period are felt to be the cause of open wire-wound resistors. Since the computer was stored in unheated space, it is felt that the low temperatures encountered during the winter months caused the wire to become brittle and that contraction of the wire at these low temperatures caused it to break.

B. <u>400 Amp Standby Alternator Slip Rings</u>

On April 12, after nearly two months of trouble-free operation, difficulty was encountered with the 400 amp standby alternator. This trouble was evidenced by a higher than normal field current which could not be adjusted downward to give proper operation. Field resistance from pole to pole was checked and found to be additive in a non-linear fashion, despite the fact that the individual pole resistances were measured to be two ohms, which is the correct value. The inescapable colusion was that somehow additional parallel resistance was being interposed between the two field terminals. Further checking revealed that the screws supporting the slip rings were too long and nearly shorted the slip rings together. A carbon buildup on the ends of these screws was producing a twelve ohm resistance between the slip rings with the field disconnected. The screws were removed and replaced with shorter ones and this corrected the trouble. While the long screws were obviously a manufacturing defect, the elapsed time meter indicated that the machine had run for some 17,000 hours prior to occurrence of this trouble. While this trouble would have occurred eventually, its onset may have been hastened by an accident which occurred a few days earlier. At that time, it was noticed that power was being applied to a relay associated with the magnetic tape racks. When the filament switch for the tape racks was switched to what was thought to be the off position to turn off this relay, two No. 10 filament wires suddenly burned up. When this switch was thrown, it effectivley placed a short across the output of the 400 amp standby alternator, due to some temporary jumpers which had been installed last summer and which had not been removed. This sudden overload on the alternator burned up these wires, rather than blowing the 600 amp fuse in the output of the alternator. Thus, this accidental overload probably hastened the breakdown between slip rings. Although the slip ring breakdown was in the motor exciter, investigation of the alternator exciter revealed that oversized screws had been used there as well. To prevent future troubles, the screws in the alternator exciter were also replaced with shorter ones at that time.

C. Air Conditioning Equipment Trouble

During the week of May 20 to May 24 we encountered our first heat wave of the summer season. Twice during the week the computer shut itself down as a result of excessive temperature in the vicinity of the overheat thermostat. We concluded, at first, that the trouble was due to dirty filters in the liquid line which were causing inefficient operation of the air conditioning system. On May 24, however, the air conditioning contractor, who had installed the system, came to replace the filter elements. We were told that the difficulty was due to a nearly complete loss of Freon in the system. Consequently, the system had to be completely leak checked and then refilled with Freon. While leak checking, a few small leaks were found and corrected and it was concluded that the Freon loss must have occurred over a long period of time due to these small leaks. To prevent future losses of such proportion, a schedule of periodic leak checking was instituted.

Prior to the Freon loss, the system was shut down each evening, merely by turning off the main circuit breaker to the air conditioning system. After replenishing the Freon supply, this procedure resulted in severe slugging of the compressors with liquid Freon during the night. To alleviate this slugging problem, it was decided to let the system run continuously, even though unattended, since it is more than adequately protected with fail-safe devices. On Monday, June 17, exactly one week after instituting twenty-four hour operation, we arrived to find the system shut down and the floor covered with oil. Sometime during the week-end the number 4 compressor had blown a flare fitting in an oil line which resulted in complete loss of oil in the entire system and very possibly simultaneous loss of a few cylinders of Freon. The oil fitting was replaced and fifty gallons of Capella oil were added to replenish the oil supply. Following the oil loss, twenty-four hour operation of the air conditioning system was abandoned and instead the system is shut down each evening after pumping the Freon back into the receiver to prevent slugging of the compressors. This procedure has worked reasonably well, but this was not the end of our air conditioning troubles.

During a heat wave at the end of June, it became obvious that the air conditioning system was still not operating properly and the computer again shut itself off due to overheating. After checking several possible causes of the trouble, it was finally concluded that additional Freon was required. More careful checking revealed that we had replenished only half the original supply of Freon at the time of the loss in May. Additional Freon was added to bring the system up to capacity and, in addition, the cooling coils were washed down and several adjustments made to the system. These measures have resulted in excellent operation of the air conditioning system during the month of July and particularly during the excessively hot days from Wednesday, July 24 through Friday, July 26.

During July we have had several occassions on which we thought additional Freon loss might have occurred. However, thorough leak checking and subsequent efficient operation indicate that these were false alarms. The most recent of these occassions was on Monday, July 29, the sixth and final day of a period of unseasonably hot weather. Due to the hot weather over the week-end with the system shut down, the system was taxed to its utmost to overcome the accumulated heat load of the week-end, without the additional heat load of the computer. Two small leaks were found on Monday and corrected, but low Freon indication at that time was followed by extremely good operation on Tuesday, which was a much cooler day. Low Freon indication on Monday is now felt to be due to some loss of Freon at the time of the oil leak in June, which means that two or three cylinders of Freon should probably be added to bring the system up to full capacity.

D. Phenolic Breakdowns

Our first encounter with what recent experience indicates was probably a phenolic breakdown occurred on May 20, nearly three months after power was first applied to the computer panels. No further trouble was encountered until July 11, when we encountered the first of six phenolic breakdowns in a two week period, four of which occurred in one panel. The phenolic breakdown problem had been a matter of considerable concern to MIT and, as mentioned in previous progress reports, was felt by us to be a major difficulty to be encountered during computer checkout. However, since nearly five months of continuous power application had elapsed since turning on the computer with only one possible phenolic breakdown, we had thought that this would not be a serious problem. However, recent experience has reversed our thinking on this problem and we now feel that phenolic breakdown may be a serious difficulty which may increase in frequency as time goes on.

Investigation of this problem during July has resulted in the conclusion, however, that the phenolic breakdown problem is not a disastrous one because there is a relatively inexpensive solution. The conclusion that this problem is tending to increase in frequency is based on a fairly thorough search of MIT's records which failed to reveal any two week period in which as many as six breakdowns occurred. Our investigation generally concurs with earlier investigation by MIT which indicated that phenolic breakdown is due to silver migration and that this is predominantly a surface effect. The first four breakdowns we encountered in July on one panel occurred on the component side of the phenolic and tended to confirm an MIT opinion that cool air heavily saturated with moisture at the air duct outlet was a major contributing factor. MIT records on this particular panel reveal about a half dozen previous breakdowns, whereas records on an identical panel at the top of the same rack show that no breakdowns have ever occurred. Consequently, the flow of cold air to the component side of this panel was blocked and no further breakdowns have occurred.

We feel, on the basis of the two more recent breakdowns, however, that cool air laden with moisture may not be as important a factor as we had originally thought. The two latter cases occurred on the back side of the phenolic board in panels which were remotely located from the cool air ducts. The latter of these two panels, B-Register digit 15, was removed from the computer and examined closely. After removing the phenolic board from the aluminum panel it was evident that several potential trouble spots existed which were not in evidence on the component side of the phenolic. Both sides of the phenolic panel are covered with dirt which is probably soot from Cambridge and a film whose composition is unknown. Cleaning with a good solvent removes both the soot and the film as well as deposits of silver, and in areas where breakdown has occurred, cleaning of the surface appears to restore the insulation resistance of the phenolic. Cleaning is a very tedious task when done manually due to the necessity for opening up the panel and the complex layout of components and wires. Thought was given, therefore, to cleaning in an ultrasonic bath, but pricing of this procedure reveals it to be extremely expensive and cleaning of all computer panels would be costly in terms of time as well. Furthermore, MIT's chemical analysis revealed that some silver migration occurs within the phenolic material itself, although to a considerably lesser degree. Since cleaning is an expensive process, and since body migration would not be cured by cleaning, consideration was given to a more effective way of eliminating the problem entirely.

MIT's solution of correcting each breakdown as it occurs by replacing one of the affected lugs with an insulated standoff lug is acceptable provided the frequency of occurrence does not increase. Phenolic breakdown can be located and corrected quickly by this means without excessive computer down time. However, if the frequency increases a more effective solution is required. Examination of the panel taken from B-Register digit 15 revealed that the problem exists only between terminals having a relatively high potential difference in the order of 150 to 250 volts. Thus, a solution which effectively inhibits migration between such terminal pairs will eliminate the problem. After further consideration, it was concluded that the most effective and simplest method for eliminating migration between these terminal pairs is to cut a slot in the phenolic board between these terminals thus imposing an air gap between them. While this in itself would be a fairly time consuming task, it is felt to be the fastest, most effective, and least expensive solution. While there are somewhere in the order of 170 panels affected by this problem, there are only about 35 different types of panels. Thus, it would be a fairly reasonable task to check the assembly drawings for each of these panel types, locate all potential trouble spots, and then proceed to cut air gaps between all potentially troublesome terminal pairs in all panels. This task, which might require in the order of one or two weeks of computer shutdown, will be instituted if it becomes necessary due to a sharp increase in the frequency of occurrence of phenolic breakdowns. In the meantime, however, we plan to follow MIT's procedure of correcting each trouble as it occurs.

E. Power Failures

Two outside power failures have occurred during the checkout period. The first of these occurred on May 20 when some of Boston Edison's underground power lines were flooded in Maynard. The second failure occurred on July 18 when lightning struck a Boston Edison substation in Burlington, Massachusetts. On both occassions the computer under-voltage sensing mechanism worked correctly and cycled the computer down in the proper fashion. Both of these failures were external to the building and were due to circumstances beyond our control. Such failures cause a certain amount of inconvenience and delay as they did at Cambridge. This problem could be eliminated by the installation of diesel generators, but this is an expensive solution to be resorted to only if the priority of future work demands it. No action on this matter is contemplated at the present time and this subject is mentioned here only for the purpose of documenting a major trouble encountered during checkout. Another reason for including it here is to emphasize the fact that to date no internal power failures have occurred.

V SUMMARY

This progress report describes, in some detail, the moving, reassembling, and checkout of the Whirlwind I computer from the commencement of its move from Navy Building 61 in South Boston on December 6, 1961 until the present. Also presented are our plans for completing the checkout of the computer by November 15, 1963. PERT networks showing the events of the moving and reassembly phase and the checkout phase, their interrelationships and completion dates are presented and described.

To date this project has encountered several major problems, some of which were expected while others were unexpected. These problems have been described as have their solutions. Solutions to all problems have been effected with the exception of that for the phenolic breakdown problem and this will be effected when and as required. No further major problems are anticipated but if new ones should occur, they are not expected to be insurmountable. Thus, we feel that successful completion of checkout will be accomplished on November 15, 1963.