WHIRLWIND I
CHECKOUT PROGRESS REPORT

JANUARY 1964

Wolf

Research and Development Corporation

Baker Avenue, West Concord, Massachusetts EMerson 9-2111

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by

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P.O. Box 136; Baker Avenue, West Concord, Massachusetts EMerson 9-2111

January 17, 1964

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 describing the Whirlwind I Computer checkout from August, 1963, through the completion of checkout on January 13, 1964. In addition to describing the checkout of computer equipment during this period, the report describes routine maintenance problems and major equipment problems encountered. A description of Whirlwind utility program debugging activities is also included. Although the checkout completion date is nearly two months later than that estimated in our July, 1963 report, this time slippage is due to omission of time estimates for computer maintenance and utility program debugging rather than to any major unexpected difficulties encountered during checkout.

Please call us if you have any questions concerning this report.

Very truly yours,

William M. Wolf

William M. Wolf
President

AVS/sb

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WHIRLWIND I CHECKOUT PROGRESS REPORT

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I INTRODUCTION

This report describes the Whirlwind I computer checkout work accomplished during the period from August 1, 1963 until the successful completion of computer checkout on January 13, 1964. Although this completion date represents a slippage of nearly two months beyond the estimated completion date of November 15, 1963 presented in the July, 1963 progress report, it is due primarily to omission of time allowances for routine maintenance and utility program debugging rather than to any unforeseen complications in equipment checkout.

Section II describes the checkout of equipment since August 1, 1963.

Section III describes routine maintenance problems which have been encountered during this period. Routine marginal checking was not performed during this time due to unavailability of certain parts of the system, particularly the drums, as well as to lack of time. Considering this fact, the reliability of the machine has been very good. All of the routine maintenance problems have been forced upon us as a result of steady-state failures of the computer and it has been necessary to stop our checkout procedure and correct these malfunctions. While these problems have not been serious and would have been largely picked up by routine marginal checking in an operational system, they probably account for three to four weeks of the slippage in our schedule.

Section IV describes major problems encountered during these past five months in checking out the computer. Two of the major problem areas discussed in the July, 1963 progress report have been continuing sources of difficulty namely, wire-wound resistors and phenolic breakdowns. However, neither of these two problem areas has been as troublesome as they had been in the past. The frequency of phenolic breakdown has decreased considerably and only two of these difficulties have been encountered in the past five months. Troubles with the 400 Amp Standby Alternator slip rings, air conditioning equipment, and power failures as described in Section IV of the July, 1963 report have not recurred since that time.

Two new major problem areas have arisen, breakdown of paper tubular capacitors, and open magnetic drum head windings. The capacitor problem is not considered serious because it appears to have been limited to a particular type of paper capacitor which is used in only one place in the computer. The drum head problem could become serious if it continues and if no suitable replacement heads are available. Evidence of its occurrence at MIT and from our investigation tends to indicate that the problem is caused by mechanical flexing of the head leads as head cables are connected or disconnected. Since future connecting or disconnecting of these cables will seldom, if ever, occur no future failures are anticipated.

Section V describes the efforts involved in debugging operation of the Utility Control Program, the CSII Conversion Program, and the Post-Mortem Program.

II COMPUTER CHECKOUT

Checkout of the equipments remaining to be checked out as listed in Section III-B of the July, 1963 progress report has been completed. Table 2-1 is a revised version of Table 3-1 from the July, 1963 report. For the sake of completeness, Tables 2-2 and 2-3 are respectively revised versions of Tables 2-3 and 2-4 of the July, 1963 report to show actual completion dates of the five items in these two tables which had not been completed by the end of July. This section describes the checkout of those equipments completed since our previous report. No mention is made of checkout of equipments completed prior to the end of July, 1963. However, Section III describes maintenance problems encountered since the end of July both in equipment checked out prior to that time and in equipment checked out since then.

A. Power Equipment

1. Input/Output Equipment 400 Amp Alternator and Filament Power Distribution System

The arcing at the slip rings of the 400 Amp Filament Alternator, which was a problem at MIT, was determined to be caused by wear of the slip rings. Consequently, rather than relocating the brush boxes closer to the slip rings, it was decided to have the slip rings replaced. Unfortunately, the slip rings were not available from stock and the two week delivery period quoted was not met. Installation of the new slip rings (ME25) was not accomplished until September 30, 1963. The installation of new slip rings completely corrected the arcing problem.

Reconnection of the cables from the 400 Amp Filament Alternator (PE1) was consequently completed prior to the installation of new slip rings. This task was completed about ten days behind schedule on August 24, 1963.

Checkout of the 400 Amp Filament Alternator (PE5B) could not be started until the slip ring installation was completed. Successful checkout of the 400 Amp Filament Alternator and associated regulator and cycling system (PE5B and CO34) was completed on October 4, 1963 with only minor difficulties. These difficulties included installing three additional wires, reversing the field connections of the alternator exciter to the regulator, and replacing four or five wire-wound resistors which had opened up during the period of storage. Additional trouble with the alternator regulator and its associated power supply occurred in November due to some shorted paper tubular capacitors. These latter troubles are considered to be maintenance problems rather than checkout problems and are discussed further in Sections III and IV.

Checkout of the filament connections to the magnetic drum bays and to the individual input/output equipment racks (CO35) was accomplished by October 9 with minor difficulties. About twenty-five instances of missing or incorrect filament voltage were encountered. These were caused mainly by wiring errors and broken or missing fuses. Considering that all of the seven hundred-odd filament transformers in this area had been disconnected and reconnected during the moving and reassembly phase and that a total of about seventy-five hundred connections were involved, the wiring error rate was in the order of .3 to .5 percent.

2. DC Power Distribution System

Checking of the dc connections to the input/output equipment racks and to the magnetic drums was accomplished concurrently with checkout of the 400 Amp Filament Alternator and filament power distribution system. Checking of the connections of the dc power supplies to the input/output equipment busses (CO36) was accomplished on October 1. The only significant trouble encountered here was of an operational nature. During this checking, all circuit breakers feeding the loads from the various busses were turned off to prevent damage to the load circuits. Due to a design deficiency in a Blown Circuit Breaker Indication Panel, a twelve watt wire-wound resistor in this panel burned up when excessive voltage was applied through back contacts of breakers on the -150 volt bus and the -300 volt bus. Examination of the panel schematic revealed that simultaneous tripping of a -150 volt and a -300 volt circuit breaker would have burned up this resistor. In order to prevent future occurrence of such trouble, the twelve watt resistors on this panel were replaced with forty-seven watt resistors having the same resistance values. Checking of the dc power distribution from the bus bars to the individual racks and drum bay cabinets (CO37) was completed on October 10, 1963. Extensive resistance checks of output circuits of the dc power distribution panels were made. During this checking, a few broken wires were found and corrected. Only one serious difficulty was uncovered. This difficulty was detected as a short circuit on the output of a +200 volt line and the cause of the short circuit was found to be a video cable terminator which had fallen from a connector and had become lodged within a magnetic drum chassis in the Buffer Drum. After completion of resistance testing, dc power was applied successfully with only some operational difficulties in connection with the setting of dc circuit breakers.

B. Input/Output Equipment

1. Display Consoles

Three display consoles, in addition to the two in Test Control previously checked out, were recabled (ME26) by August 6, 1963 and checkout of these display consoles (CO31) was accomplished on August 16, 1963. The only difficulties encountered with the display scopes themselves were open wire-wound pots in the Dumont high voltage power supplies, alignment problems in the deflection amplifiers, and a few wiring errors associated with the display expand switches. Troubles with the display selection switches on these three consoles were caused by missing voltages in one computer rack and defective cathode follower tubes associated with a few display matrix mixer lines. In addition, one wiring error of display switches was found which resulted in the interchange of display categories between two adjacent switches.

Additional troubles with the checkout of display consoles were associated with checkout of indicator lights and audible alarms which are covered separately in Section b. below and troubles with two or three intervention switch connections.

2. Indicator Light Registers and Audible Alarms

Checkout of all Indicator Light Registers and audible alarms (CO30) was accomplished on August 16, 1963. Troubles with neon indicator lights were caused by two bad 5687 cathode follower tubes, one incorrectly connected video cable, one broken wire, and a pair of new wire-wound resistors in IOR digit 14 which had been connected incorrectly. Troubles with audible alarms, which are a part of the Indicator Light Registers system, were caused by one missing video cable, one incorrectly connected video cable, two open 8 watt wire-wound resistors, and missing voltages associated with the audible alarm panel in rack C1.

3. Light Guns

Checkout of the three Light Guns (CO29) associated with the three display consoles was also completed on August 16, 1963. Except for a few wiring errors, no difficulties were encountered.

4. Magnetic Tape Units

Checkout of the magnetic tape units (CO26) was not completed until September 16, 1963. Considerably more trouble was encountered in checking out the tape units than we had anticipated. Although none of the troubles which had to be corrected were unusual, being predominantly faulty tubes and wiring errors, the time required to uncover these troubles was somewhat greater than that required by other computer subsystems. Two basic reasons account for the longer time required to check out the magnetic tape units. First of all, some of the specialized circuits associated with the magnetic tapes are considerably more complex than the standard Whirlwind computer circuitry and information regarding the waveforms produced by this equipment is sufficiently incomplete as to permit several different interpretations of its meaning. The second factor causing this delay is that waveforms of the tape head signals were not available. The confusion caused by the incomplete information on the panels which drive the heads and the total lack of information regarding the head signals coupled with the fact that reading and recording cannot be checked independently was the ultimate cause of the extra time required to check out these units. The inability to check reading and recording functions independently is not in itself the cause of the delay as these situations were also encountered in checking out magnetic cores and the magnetic drums. However, in the case of the cores and drums, sufficient information was available to enable us to isolate malfunctions to either the reading or recording function without too much difficulty.

Troubles found in checking out the magnetic tape units included one video cable error, one defective video cable, one missing video cable, one tape head cabling error, a defective crystal, and several defective tubes.

5. IBM Card Machines

Checkout of the IBM card machines (CO24) was completed on September 9, 1963. Somewhat more difficulty than was anticipated was encountered in the checkout of the card machines. In addition, our original estimate for this task of about three days was probably overly optimistic. Troubles encountered in card machine checkout included the following: failure of a Gate Tube Buffer Amplifier plug-in unit in the synchronizing circuits of the card machine subsystem, difficulties in wiring of the IBM plug-boards due to confusing information available from MIT, some loose connections in the female IBM shoe connectors and two or three defective Diode Capacitor Gate plug-in units associated with the card machine reading function.

6. Test Control Camera

Checkout of the Test Control camera (CO27B) originally scheduled for September 4 was completed on October 31, 1963. Checkout of the camera required only about two man-days of effort but was deferred in favor of higher priority tasks which required somewhat more time than had been previously estimated. Checking of the camera wiring was accomplished during September but a quick check revealed that all the troubles had not been corrected, so further efforts on this task were suspended until October 31 when it became necessary to make the camera operational during checkout of the Drum Group 11 Utility Control Program. In making the camera operational, it was necessary to replace a broken mica capacitor, an open wire-wound resistor, four missing electrolytic capacitors, and a missing wire which supplied -150 volt dc to the camera control panel.

7. Magnetic Drums

Although the start of magnetic drum checkout was delayed three weeks due to slippage of earlier tasks such as magnetic tapes and card machines, drum checkout was accomplished in considerably less time than had been estimated. Checkout of the Auxiliary Drum (CO38) originally scheduled to be completed on October 11 was completed on October 17, 1963. Checkout of the Buffer Drum (CO39) originally scheduled to be completed on November 8 was completed on October 25, 1963, two weeks ahead of schedule. Thus, magnetic drum checkout originally estimated to require a total of three weeks for the Auxiliary Drum and four weeks for the Buffer Drum required approximately one week for each drum. Unfortunately, a recent rash of parity alarms, particularly on the Buffer Drum, have tended to offset the gain in schedule time achieved during drum checkout. Investigation of this trouble determined that intermittently open drum head windings were responsible. This trouble is discussed in more detail in Section IV.

Permanent recording of the Auxiliary Drum Group 11 Utility Control Program was found to be in perfect condition as were the timing and mark track signals on both drums.

Final checking of the condition of the drum bearings was made by turning on the drum motors, allowing them to come up to speed, and measuring the run down time from full speed to rest. Comparison of times obtained with the times specified by Sperry Rand indicate that the bearing are in excellent shape. Cold run down times for both drums were in the order of three to three and one-half minutes while run down times after the drum had been running for one hour were in the order of five to six minutes. Sperry Rand specified that the run down time from full speed to rest should not be less than two and one-half to three minutes after the drum had been running for one hour. Some seepage of oil from the inner bearing seal of the

Buffer Drum into the drum chamber was noted but the presence of a drain plug in the drum chamber indicates that this is to be expected. Some traces of congealed oil on the drum cylinder have been noted, but this must have accumulated at MIT and as yet has given no indication of trouble.

a. Auxiliary Drum

During checkout of the Auxiliary Drum, troubles were encountered with the computer synchronizing circuits, the drum parity system, drum register addressing, and several digit failures. Synchronizing problems were due to a bad Gate Tube Buffer Amplifier associated with the drum restoration synchronizer in computer rack C14, while drum parity system failures were due to a bad Gate Tube Buffer Amplifier associated with the drum input to the Read/Store Flip-Flop of the parity system. Drum register addressing trouble was due to interchange of cables connecting digits 5 and 8 of the computer In/Out Register with digits 5 and 8 of the Auxiliary Drum Storage Address Register. Digit failures were due largely to weak tubes and/or dirty contacts on pots in the reading amplifiers, while a few were due to improperly polarized connections of head cables to the drum heads.

b. Buffer Drum

Troubles encountered during checkout of the Buffer Drum included two synchronizing problems, trouble with the parity check system, and several digit failures. One synchronizing problem was evidenced by the drum stopping with the Storage Address Register containing address 3100 (octal) during execution of a program which incremented the drum address from 0 to 3777 (octal). This trouble was cleared up when it was determined that the drum monitor system chassis for the Buffer Drum was loading down the cathode followers of the Angular Position Counter causing the Angular Position Counter/Storage Address Register coincidence pulse to be lost. Removal of the monitor chassis cleared up the trouble and during checkout of the monitor system several bad crystals were found in this chassis. This trouble has not recurred since the monitor chassis was repaired and reinstalled in the Buffer Drum. The second synchronizing problem manifested itself as failure to receive a drum completion pulse which caused the computer to stop in the stop clock condition. This trouble was extremely difficult to isolate since about twenty separate but dependent pulse sources were involved. That is, failure of any unit in this chain caused failure of the entire chain and it was extremely difficult to isolate cause and effect. It was eventually determined that the trouble was due to intermittent slot pulses feeding the second gate of a flip-flop synchronizer. These intermittent pulses were always sufficient in amplitude to clear the synchronizer flip-flops upon exiting from the gate tube but were not sufficient in amplitude to drive an input amplifier in the drum control circuits consistently. The ultimate cause of the trouble was found to be a bad Pulse Standardizer plug-in unit.

The parity system trouble was due to an open video cable while the digit troubles were due to faulty video cables, faulty video tee connectors and a few head cables which had been reconnected incorrectly. Two causes for digit 6 failure were uncovered: one was a defective tee connector on the input to the Drum Recording Register for the Buffer Drum which prevented the writing of 1's in this digit, while the other trouble was a defective cable from the digit 6 read out amplifier to digit 6 of the computer In-Out Register.

8. Anelex Alphanumeric Printer

Completion of the task of recabling the Anelex printer (ME24) was delayed due to additional time which had to be spent on other higher priority tasks. This recabling task was completed on October 4, 1963. Checkout of the Anelex equipment (CO25) was completed on December 18, 1963. Troubles encountered with the Anelex system included several missing video cable terminators, a few incorrectly connected cables and wires, two defective tubes which were causing failure of synchronization of the Anelex with the computer, a broken thyratron plate lead in the Anelex print hammer driver panels which were causing trouble with columns 13, 93, and 116, and four defective tubes which were causing format alarms.

9. Teletype Input and Output

Checkout of the teletype input and output subsystems has just been completed. Due to the unavailability of the associated teletype equipment, it has only been possible to check the electronics portions of these two subsystems. In forming a closed loop teletype system through the computer, the output of the teletype output system was tied to the input of the teletype input system. It was found necessary to construct a stepping switch device to simulate the operation of a teletype transmitter distributor to provide teletype start and stop signals. The need to construct this device is partially responsible for the additional time required to check out these teletype systems. Most of the troubles encountered in checking out these systems have been of an operational nature, particularly in connection with the stepping switch simulator. Other troubles have included two defective plug-in units, two missing tubes, one defective video cable and two missing wires.

TABLE 2-1

CHECKOUT (CO)

Event No.	Description	Date Completed or Scheduled	Revised Date Completed or Scheduled
CO1	Standby Alternator Cycling to Computer Bus	December 19, 1962	December 19, 1962
CO2	AC to Computer Racks	December 19, 1962	December 19, 1962
CO3	DC Supplies to Computer Busses	January 21, 1963	January 21, 1963
CO4	DC to Computer Racks	February 28, 1963	February 28, 1963
CO5	Marginal Checking System	April 30, 1963	April 30, 1963
CO6	Pulse Generator, Frequency Divider, and Restorer Pulse Generator	February 28, 1963	February 28, 1963
CO7	Clock Pulse Control	February 28, 1963	February 28, 1963
CO8	Time Pulse Distributor	February 28, 1963	February 28, 1963
CO9	Test Control Synchronizers	February 28, 1963	February 28, 1963
CO10	Alarm System	May 10, 1963	May 10, 1963
CO11	Control Switch	March 15, 1963	March 15, 1963
CO12	Operation Matrix	March 15, 1963	March 15, 1963
CO13	Control Pulse Output Units	March 15, 1963	March 15, 1963
CO14	Program Counter	April 23, 1963	April 23, 1963
CO15	Toggle Switch Storage and Parity Register	April 22, 1963	April 22, 1963
CO16	Flip Flop Storage	May 16, 1963	May 16, 1963
CO17A	Initial Check Arithmetic Element	May 16, 1963	May 16, 1963
CO17B	Final Check Arithmetic Element	July 30, 1963	July 30, 1963
CO18A	Initial Check Core Memory	June 4, 1963	June 4, 1963
CO18B	Final Check Core Memory	July 3, 1963	July 3, 1963
CO19	In-Out Element	June 5, 1963	June 5, 1963
CO20	Check Register	May 10, 1963	May 10, 1963

TABLE 2-1

Checkout (CO) (Cont'd)

Event No.	Description	Date Completed or Scheduled	Revised Date Completed or Scheduled
CO21	Start I/O Equipment Check	June 5, 1963	June 5, 1963
CO22	Flexowriter Keyboard Input, Punch, Reader and Printer	June 5, 1963	June 5, 1963
CO23	Photoelectric Tape Reader	June 5, 1963	June 5, 1963
CO24	IBM Card Machines	August 15, 1963	September 9, 1963
CO25	Anelex Printer	August 30, 1963	December 18, 1963
CO26	Magnetic Tape Units	August 12, 1963	September 16, 1963
CO27A	Test Control Displays	June 19, 1963	June 19, 1963
CO27B	Test Control Camera	September 4, 1963	October 31, 1963
CO28	Intervention and Activate Registers	June 19, 1963	June 19, 1963
CO29	Light Guns	August 7, 1963	August 16, 1963
CO30	Indicator Light Registers	August 7, 1963	August 16, 1963
CO31	Display Consoles (3)	August 7, 1963	August 16, 1963
CO32	Real Time Clock	June 13, 1963	June 13, 1963
CO33	Teletype Output	September 13, 1963	January 13, 1964
CO34	400A Alternator Cycling to Bus	August 23, 1963	October 4, 1963
CO35	AC to I/O Racks	August 30, 1963	October 9, 1963
CO36	DC Supplies to I/O Busses	September 6, 1963	October 1, 1963
CO37	DC Supplies to I/O Racks	September 20, 1963	October 10, 1963
CO38	Auxiliary Drum	October 11, 1963	October 17, 1963
CO39	Buffer Drum	November 8, 1963	October 25, 1963
CO40	Teletype Input	November 15, 1963	January 13, 1964

TABLE 2-2

Power Equipment (PE)

Event No.	Description	Date Completed or Scheduled	Revised Date Completed or Scheduled
PE1	400A Alternator Wired	August 14, 1963	August 24, 1963
PE2	400A Standby Alternator Wired	June 22, 1962	June 22, 1962
PE3A	Power Control Racks Set Up	April 6, 1962	April 6, 1962
PE3B	Power Control Racks Wired	October 15, 1962	October 15, 1962
PE4	Filament Contactors Wired to Busses	October 26, 1962	October 26, 1962
PE5A	Standby Alternator Checked Out	December 13, 1962	December 13, 1962
PE5B	400A Alternator Checked Out	August 20, 1963	October 4, 1963
PE6A	DC Supplies Installed in Racks	June 9, 1962	June 9, 1962
PE6B	DC Supplies Wired	October 12, 1962	October 12, 1962
PE7	AC Inputs to DC Supplies Wired	October 12, 1962	October 12, 1962
PE8	DC Supplies Checked Out	January 17, 1963	January 17, 1963
PE9	DC Supplies Wired to Busses	August 17, 1962	August 17, 1962
PE10	Lab. DC Supplies Wired and Checked Out	June 29, 1962	June 29, 1962
PE11	Lab. DC Distribution Completed	October 16, 1962	October 16, 1962

TABLE 2-3

Mechanical and Electrical Reassembly (ME)

Event No.	Description	Date Completed or Scheduled	Revised Date Completed or Scheduled
ME1	Floor Marked for Computer Racks	April 6, 1962	April 6, 1962
ME2	Floor Marked for TC Racks	April 2, 1962	April 2, 1962
ME3	Floor Marked for I/O Racks	April 10, 1962	April 10, 1962
ME4	Junction Box Mount Completed	April 18, 1962	April 18, 1962
ME5	Computer Wireway and Ground Bus Installed	April 26, 1962	April 26, 1962
ME6A	Start Test Control Wireways	April 16, 1962	April 16, 1962
ME6B	Test Control Wireways Installed	April 27, 1962	April 27, 1962
ME7	I/O Wireways and Ground Bus Installed	April 27, 1962	April 27, 1962
ME8	Removed Panels Replaced	July 26, 1962	July 26, 1962
ME9A	Transformer Panels Replaced	April 20, 1962	April 20, 1962
ME9B	Transformer Panels Rewired	August 10, 1962	August 10, 1962
ME9C	Filter Panels Replaced	November 15, 1962	November 15, 1962
ME10	Bus Bars Installed	July 18, 1962	July 18, 1962
ME11	Computer Cut Wires Reconnected	September 26, 1962	September 26, 1962
ME12	I/O Cut Wires Reconnected	September 27, 1962	September 27, 1962
ME13A	Start Reconnection of Wires and Cables	April 30, 1962	April 30, 1962
ME13B	Reconnection of Cables Completed	October 29, 1962	October 29, 1962
ME14	Reconnection of Cables Checked Out	Deleted	Deleted
ME15	Intercom Reconnected and Checked Out	September 14, 1962	September 14, 1962
ME16	Transformers in Banks A and B Replaced	October 25, 1962	October 25, 1962
ME17	Core Stacks A, B and C Installed	October 29, 1962	October 29, 1962
ME18	Drum Bearings Checked and Replaced if Required	September 24, 1962	September 24, 1962

TABLE 2-3

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

Event No.	Description	Date Completed or Scheduled	Revised Date Completed or Scheduled
ME19	Drums Installed	September 28, 1962	September 28, 1962
ME20	AC and DC Power for TC Installed	October 3, 1962	October 3, 1962
ME21	Junction Boxed Repositioned	October 5, 1962	October 5, 1962
ME22	Test Bench for Drum Chassis Installed	September 24, 1962	September 24, 1962
ME23	Construct Anelex Transition Panel	April 11, 1963	April 11, 1963
ME24	Install Anelex Cabling	August 9, 1963	October 4, 1963
ME25	Repair Brush Boxes on 400A Alternator	August 9, 1963	September 30, 1963
ME26	Recable 3 Display Consoles	August 2, 1963	August 6, 1963

III ROUTINE MAINTENANCE PROBLEMS

During equipment checkout in the period from August 1st to the present, it has not been possible to devote any significant amount of time to routine marginal checking and preventive maintenance. During this time equipment failures have occurred and have been detected and corrected as required. This procedure has been necessitated by limitations of time and equipments previously checked out. Despite the inefficiencies of such unscheduled routine maintenance, we feel that the reliability of the computer has been reasonably good and experience during this period indicates that the high reliability attained at M.I.T. by this machine can be approached using sound preventive maintenance procedures. The detection of such failures as have occurred has often been more time consuming than it would have been had scheduled maintenance been performed. The necessity for correcting such troubles as they occur has contributed in large part to the time slippage of the schedule presented in our July, 1963 progress report.

This section describes the routine maintenance problems encountered in each of the major subsections of the computer during this period while Section IV discusses some of the major maintenance problems encountered during this period.

A. Air Conditioning Equipment

Operation of the air conditioning equipment during the period from August 1, 1963 to the present has been excellent. The only equipment failure was a broken fan belt on a cooling tower fan. On two or three occasions we detected indications that the Freon level of the system may still be somewhat low, probably due to incomplete recharging of the system following complete loss of Freon during the latter part of May. Since this low Freon level indication on a hot day did not adversely affect computer operation, it was decided not to add more Freon for the present. This decision was made so that the Freon level could be observed over a longer period of time to determine whether additional losses were occurring or whether this was just a failure to completely recharge the system in June.

B. Power Equipment

In general, operation of the power equipment has been excellent during the period of August 1, 1963 to the present or from its date of checkout until the present in the case of the in-out equipment associated with the drums.

1. Filament Alternators and Filament Power Distribution System

Four troubles have occurred in the operation of this equipment. On October 30 a failure in the regulator of the 400 Amp Standby Filament Alternator caused the machine to cycle down to the off condition. A check of the alternator regulator and its associated power supply revealed a faulty 6X5 tube as the cause of failure. This tube was replaced and no trouble has been encountered since that time. On November 1 trouble was encountered with the reading of all 1's from the Intervention Registers and failure of the magnetic core clear system. These two troubles were traced to a loose connection from a filament transformer to a panel of plug-in units. The loose connection resulted in overheating and burning of the wire feeding the filaments of the tubes in this panel. Replacement of the lug on the end of the wire and the tightening down of this screw connection cleared up the trouble and none has been encountered since due to this cause. Around the middle of November, slightly more than a month after the 400 Amp Filament Alternator supplying filament power to the drums and associated equipment racks had been checked out, the drum filament system was suddenly cycled down. Investigation of this trouble revealed a shorted .01 microfarad paper tubular capacitor in the 400 Amp Filament Alternator Regulator. Replacement of this capacitor cured the trouble but two days later a similar difficulty occurred. This second trouble was traced to the shorting of a similar capacitor in the power supply associated with the 400 Amp Filament Alternator Regulator. Since the power supply contained two of these capacitors, they were both replaced as a preventive measure, although the second one had not broken down.

2. DC Power Supplies

Operation of the dc power supplies has been very good with only three failures occurring in a four month period and only one of these caused the computer to fail to operate. On October 9, the regulator for the -30 volt power supply failed due to a faulty 6AC7 tube. This prevented the computer from being turned on properly. On October 28, a plate fuse in the -450 volt power supply was replaced when it was noticed that two thyratrons were not operating, and on October 29th, a thyratron in the +150 volt power supply was replaced when it was noticed that its filament was open.

3. DC Power Distribution Systems

Operation of the dc power distribution systems has been excellent during this period and no troubles have been encountered which could be traced to failures of either the computer dc power distribution system or the input-output equipment dc power distribution system.

4. Marginal Checking System

The marginal checking system has not been used extensively during this period. However, its operation has generally been trouble-free when it has been used. One difficulty did occur during November with the failure of the units digit of the marginal checking line selection system. This trouble which resulted in the units digit 3 being selected whenever the digit 2 or 8 was specified was traced to a faulty 2D21 thyratron tube. A trouble which occurred during this time resulted in the computer being taken to standby, (i.e., dc being turned off) when a margin was placed on a line associated with the magnetic core memory. It is presumed that faulty selection of the marginal checking line units digit may have caused the shorting of two dc voltages and the resultant turning off of computer dc power.

C. Control Element

The Control Element of the computer, most of which has been operational since the middle of March, has been one of the most reliable parts of the machine. During the period from August 1st to the present only four difficulties have been encountered and one of these was due to accidental damage during installation of cabling for the Anelex printer.

On October 1st trouble was encountered during the execution of the in-out instruction which selects the photoelectric tape reader. This instruction which is an si 213 was being interpreted as an si 0 causing the computer to stop. The trouble was traced to a broken terminator on the Time Pulse 7 line which drives the lower half of the Control Pulse Output units. This terminator is one of several special ones which do not have a metal case as do the standard video cable terminators and one of its leads had become broken presumably due to accidental damage in installing another cable associated with the Anelex equipment. To prevent further such occurrences, a new set of terminators with metal shields was constructed and installed and no further difficulties have been encountered with these terminators.

On November 6th, check alarms were generated due to failure of digit 13 of the Check Register. This trouble was cured by replacing the flip-flop tubes in this panel. Two recent troubles have been encountered; the first being manifested by Time Pulse 7 transfer check alarms on the bo instruction; the second being Time Pulse 7 transfer check alarms on the bi instruction. The trouble with the bo transfer check was traced to an unsoldered diode on the control matrix associated with Time Pulse 7 of the bo instruction. The trouble with the bi instruction is presumed to be similar since it cleared up when a scope probe was placed on the crystal associated with Time Pulse 7 of the bi instruction.

D. Arithmetic Element

Operation of the Arithmetic Element during this period, while not quite as reliable as that of the Control Element, has been extremely good. Here again, only four troubles have been encountered. On August 2nd, failure of digit 3 of the A-Register was traced to an open 2000 ohm 12 watt wire-wound resistor. All of the 12 watt wire-wound resistors in this panel were replaced as a precautionary measure since they had been changed at M.I.T. and were thus subject to the storage conditions at South Boston. On September 16, erratic operation of digit 12 of the B-Register was cured by replacing the matched flip-flop tubes in the panel. On November 6th, readout from digit 1 of the B-Register to the Accumulator was failing on the ab instruction and this was cured by replacing a faulty 7AK7 readout gate tube. During the same week the cause of intermittent check alarms, which had been occurring, was located and corrected. The cause of the trouble was traced to faulty operation of the overflow flip-flop and it was necessary to replace the 1600 ohm 10 watt wire-wound resistors in this flip-flop with 1600 ohm 12 watt resistors. Replacement of these resistors increased the operating margins of the flip-flop from virtually zero to a margin in the order of ± 30 volts.

E. Storage Element

Operation of the various components of the Storage Element has generally been much less reliable than that of the Control and Arithmetic Elements during this period. In particular, operation of the Flip-Flop Storage section and the core memory has been relatively poor. Troubles with Flip-Flop Storage are due primarily to marginal flip-flops caused by 1000 ohm 10 watt wire-wound resistors and the worst troubles have been cleared up while the remaining 1000 ohm resistors will be replaced as time permits. Troubles with core memory, on the other hand, have been due largely to failures in the electronics associated with the core stacks.

1. Toggle Switch Storage and Parity Register

Only two difficulties have been encountered in connection with the operation of the Toggle Switch Storage system and the Parity Register. During the last week of November, readout of Flip-Flop Storage Register 6, which is controlled by Toggle Switch Storage, failed due to a video cable which had become open. On November 1st a bad 6BL7 cathode follower tube in digit 3 of the Parity Register was found to be the cause of digit 3 parity alarms which had been occurring for about ten days during the first hour of computer operation, but which had cleared up thereafter. This Parity Register trouble was not found sooner due to its intermittent nature and to time spent in checking the core memory equipment since the relative reliability of the Parity Register and the core memory led us to look for the trouble in core memory first.

2. Flip-Flop Storage

Troubles with Flip-Flop Storage, as mentioned previously, are due primarily to the 1000 ohm 10 watt resistors which were installed during the Summer of 1962. During checkout of Flip-Flop Storage, the bulk of the problems was corrected by replacing the 2000 ohm 10 watt wire-wound resistors with 12 watt resistors of the same value. It was not until early November, when we started debugging the operation of the Utility Control Program, that these other difficulties in Flip-Flop Storage became apparent. Subsequent to completion of Flip-Flop Storage checkout on May 16th up until about the first week of November, two or three troubles with Flip-Flop Storage had been encountered and these were cured by replacing matched flip-flop tubes. However, the operation of the Utility Control Program, which subjected the Flip-Flop Storage Registers to more severe operating conditions, pointed up troubles which could not be cleared up by tube replacement. These troubles led to a detailed investigation of Flip-Flop Storage Register operation and the results of about one man-week of bench testing three or four of these panels proved conclusively that the poor operation was due to the 1000 ohm 10 watt resistors. Consequently, the resistors were replaced in about four of the most troublesome panels in Flip-Flop Storage Registers 2 and 3. Since the Utility Control Program uses only Flip-Flop Storage Registers 2 and 3, no effort was made to replace resistors in flip-flops of the other three registers at this time, but this will be done as time permits now that computer checkout has been completed.

3. Core Memory

Operation of the core memory during the period from August 8th to October 8th was fairly good, but somewhat poorer than would be expected. However, since October 8th, only one trouble has occurred which could be associated with the core memory and this was finally traced to a Parity Register trouble on November 1st as pointed out in Section 1 above. During the period from about the middle of August to the last week in November, Core Memory Banks A and B were not turned on in order to avoid overloading the 400 Amp Standby Filament Alternator. The reason for turning off these core banks was that it was necessary to connect the display consoles to the standby alternator in order to check them out prior to checkout of the input-output equipment filament alternator. During the last week in November, the display consoles were transferred from the standby alternator to the input-output alternator and Core Memory Banks A and B were again turned on. As noted in our July, 1963 progress report, several troubles had been encountered with Banks A and B due to open non-inductive wire-wound resistors. Prior to turning these banks on again, each of these resistors was checked and the resistors in the eight spare units were replaced. When these core banks were turned on, parity alarms occurred on three digits of Bank A and four digits of Bank B. One of the troubles with Bank A was due to failure to replace a plug-in unit while one was due to a burned out tube and a third to a gassy tube. Troubles with Bank B were all due to open filaments of tubes in the digit plane drivers. Little use of these two core banks has been made since the last week of November, therefore, no information is available regarding their reliability.

On August 8th, investigation of a blown +250 volt fuse associated with Core Memory Banks A and B revealed a shorted pulse transformer in the Memory Address Register Readout Gate and Gate Driver Panel which was cured by replacing the pulse transformer. M.I.T. records revealed considerable difficulty with the type of pulse transformer which had become shorted and the replacement pulse transformer was of a newer type used by M.I.T. Also, on August 8th trouble was encountered when the computer became hung up during a core memory cycle. This trouble was traced to a failure of the Core Memory Start Pulse due to a bad Dual Buffer Amplifier plug-in unit in Core Memory Control. On August 12th and 13th investigation of a fuse blowing problem associated with Core Memory Bank C revealed four type 5998 tubes in the Read-Write Gate Generator which had intermittent tap shorts.

On August 14th Core Memory Start Pulse failure was again encountered. This time the cause was traced to an intermittently open pulse transformer in a Delay Line Amplifier in Core Memory Control. No further troubles with core memory occurred until September 16th when trouble was encountered with incorrect reading of instructions from core memory during the program timing portion of the machine cycle. This trouble was a rather difficult one to isolate since it was intermittent in nature. More often than not, the correct instruction was read from memory and the trouble appeared to be very sensitive to the frequency of memory reference. Investigation of Bank C of core memory revealed that a one-half amplitude pulse was appearing at all times on the Y14 selection plane and this was caused by an open 15,000 ohm 12 watt wire-wound resistor. Here again, is another instance of a 12 watt wire-wound resistor installed at M.I.T. and subject to storage conditions which had opened up after several hundred hours of operation following checkout. On October 3rd, trouble was encountered with some fuses which had been accidentally damaged which prevented proper operation of Bank C; and on October 8th, Bank C digit 3 was failing due to an open filament in a tube in the Sense Amplifier for that digit.

F. Input-Output Element

Operation of the Input-Output Element has been extremely good except for recent troubles with the Buffer Drum. Considering the electro-mechanical nature of most of the input-output devices, we feel that the reliability of these devices has been better than expected.

1. Control

Operation of the control section of the Input-Output Element has been excellent. Only one instance of failure in this section is known to have occurred. This trouble, failure to complete the bo instruction, was due to a loose wire which failed to transmit a pulse.

2. Peripheral Equipment

a. Flexowriter

Considering its electromechanical nature, the Flexowriter has operated very reliably. Only two troubles have occurred with this equipment; one in October, the other during the first week of December. The first trouble was a mechanical jamming of the keyboard, while the second was the failure of the Flexowriter to receive a start pulse from its control panel. This latter trouble cleared itself while it was being investigated, therefore the exact cause is unknown. However, no troubles have been encountered since.

b. Photoelectric Tape Reader

The only difficulties encountered with the Ferranti photoelectric tape reader have been due to misadjustment of the clutch and brake. Misadjustment of the brake caused the reader to skip over one character during conversion of a fairly long program where the photoreader had to be stopped until the previous block of information read had been recorded on magnetic tape. During the period from August to the present it has been necessary to adjust the clutch and brake settings on two occasions. Lack of information as to the proper gap settings on the clutch and brake caused the first adjustment to be inadequate. The second adjustment was made to the manufacturer's specifications after receiving a maintenance manual from Ferranti. No failures have been encountered in the electronics circuitry associated with the photoelectric tape reader.

c. Real-Time Clock

While extensive use has not been made of the Real-Time Clock, its operation has been observed during the execution of the Utility Control Program which reads the clock and logs the time on the direct Flexowriter. At no time have any failures of the clock been observed.

d. Display Consoles

Operation of the display consoles since their checkout has been generally good. Investigation of fuse blowing problems in the Conference Room display console revealed the cause to be two shorted output amplifier tubes and two defective voltage regulator tubes. Fuse blowing problems with the camera scope in Test Control also were caused by shorted output amplifier tubes. In addition, tripping of a +250 volt circuit breaker has been found to be due to overloading. This situation will be corrected by redistributing scope loads.

e. Intervention and Activate Registers

Three failures have been encountered in the operation of the Intervention Registers, but none have been encountered in connection with the Activate Registers. Troubles with the Intervention Registers have included a bad diode which was causing a digit readout failure, and two instances of In-Out Switch Driver plug-in unit failure. Failures of the latter type are extremely inconvenient since they cause one of the Intervention Registers to be selected continuously and this results in reading of minus zero to the In-Out Register on Time Pulse 7 of all si instructions.

f. Indicator Light Registers and Audible Alarms

Only one instance of failure of the Indicator Light Registers has been encountered. As in the case of the Intervention Registers, this failure was traced to a faulty In-Out Switch Driver plug-in unit.

g. Light Guns

Two Light Gun failures have occurred since these units were checked out. One Light Gun in Test Control became inoperative and the trouble was corrected by replacing it with another unit. The second trouble affected all Light Guns and was found to be caused by a tube with a burned out filament in the Light Gun control panel.

h. Magnetic Tape Units

Operation of the magnetic tape units since their checkout has been excellent. Considering the age of these units, their electromechanical nature, and the difficulties in checking them out initially, their excellent operating experience has been surprising. Only one serious trouble has been encountered. Investigation of this trouble, intermittent arcing within the drive circuits of Magnetic Tape Unit #0, revealed a metal mounting band on a 50 watt wire-wound resistor which had come loose and was intermittently shorting one of the resistor terminals to ground. Another possible trouble has been observed with Magnetic Tape Unit #1 on a few occasions when it apparently failed to find recorded information following a block mark during a conversion run. Since this trouble appeared to occur in certain sections of the tape, the tape was changed but similar effects have been noted after changing the tape. Further investigation of this problem has not been made since successful conversion is obtained about 90% of the time. Operation of Magnetic Tape Unit #0 has been excellent and the utility program information recorded on this tape unit has been read successfully many times with no evidence of failure.

i. IBM Card Machines

No information is available regarding the reliability of the IBM card machines since their checkout. These machines were added to Whirlwind in early 1959 and apparently very little programming use was made of them. Consequently, their use has not been required in operating the Whirlwind utility programs. No serious difficulties are expected to have occurred with this equipment however.

j. Test Control Camera

No difficulties have been experienced with the Test Control camera since its checkout at the end of October. While no photographs have been taken, due partially to the troubles with the camera display scope, no failures of camera indexing have been observed during operation of the Utility Control Program which generates a scope display of the tape number and records this on the camera each time a binary tape is read in by this program.

k. Magnetic Drums

Operation of the magnetic drums since their checkout has been somewhat less reliable than had been expected, particularly in the case of the auxiliary section of the Buffer Drum. After completion of the Buffer Drum checkout, efforts to operate the Auxiliary Drum in conjunction with the Utility Control Program, which is permanently recorded on Group 11 of the Auxiliary Drum, made evident three troubles which had developed in the Auxiliary Drum since it had been checked out a week before. These troubles included readout failures of two digits and a low mark pulse, which was failing to clear the Angular Position Counter reliably and thus causing intermittent drum interlace alarms. The low mark pulse problem was corrected by replacing the mark pulse amplifier chassis while the digit readout problems were cured by replacing a dead read amplifier tube in one case and a loose writing amplifier tube in the other. About two days later, drum interlace alarms again occurred and the trouble was thought to be due to low mark pulses again. However, the trouble was traced to a blown fuse for which no cause could be found. It is assumed that the fuse was defective since replacing it cured the trouble and no difficulty from this source has occurred since. Also, while checking Auxiliary Drum operation with the Utility Control Program, trouble was encountered with the end carry pulse from the Angular Position Counter adding one to the Group Selection Register. This caused reading of register 0 of Drum Group 1 rather than register 0 register 0 of Drum Group 0 following the reading of register 3777 of Drum Group 0. The cause of this trouble was found to be a 5965 tube with one-half of its filament openin an In-Out Switch Driver plug-in unit. This defective tube was holding open a gate which is normally open only when an si instruction having an address greater than 1700 is being used with the drum. This trouble also existed in the Buffer Drum but was detected and corrected in connection with operation of the Auxiliary Drum.

Since the end of October, operation of the Auxiliary Drum has been quite good, but intermittent parity alarms have been encountered in connection with the use of the Buffer Drum by the Conversion Program. The most persistent digit failure in the Buffer Drum has been the parity digit for Group 5 and since it was a parity digit, which was not vital to program operation, it was often more convenient to suppress this than to investigate the cause of the trouble, particularly where it was intermittent. Investigation into the Group 5 parity digit trouble during the first week of December and subsequent investigation of other parity problems on the Buffer Drum have led to the conclusion that some of the heads on the Buffer Drum are intermittently open. This problem of drum heads is known to have occurred at Cambridge but could be more serious now due to possible unavailability of replacement heads. This head replacement problem is discussed in more detail in Section IV.

l. Anelex Printer

Operation of the Anelex printer since completion of checkout on December 18, 1963 has encountered no difficulties.

m. Teletype Input and Output

Since checkout of these teletype subsystem has recently occurred, no significant operating experience has been accumulated.

IV MAJOR PROBLEMS ENCOUNTERED

In our July, 1963 report, we described four major problem areas which had been encountered up until that time, namely wire-wound resistors, 400 Amp Standby Filament Alternator slip rings, air conditioning equipment trouble, and phenolic breakdowns. During the period since August 1st, defective wire-wound resistors and phenolic breakdowns have been a continuing problem, although their severity has decreased considerably, while the other two trouble areas encountered earlier have not been a source of difficulty. Two new major problem areas have been encountered, however. The first of these is breakdown of tubular paper capacitors and the other is intermittently open magnetic drum heads. The first of these new troubles is not considered too serious since the number of paper capacitors of this type appears to be limited to the circuits in which we have already encountered difficulty. It is considered worthy of mention here only because it points up one additional case of component failure not previously encountered. The other new problem area, that of open drum heads, is new to us but M.I.T. records show that this problem was encountered in the early days following delivery of the drums from the ERA division of UNIVAC. This is potentially a more serious problem now than it was nine to ten years ago because of the possibility that replacement heads may not be obtainable.

Two aspects of the wire-wound resistor problem have continued to be a source of difficulty. A few instances of open wire-wound resistors have been encountered in additional equipment checked out during this period and further difficulties with flip-flop instability due to the new ten watt wire-wound resistors installed during the Summer of 1962 have developed. A new aspect of the wire-wound resistor problem also developed during this period when a few instances of open wire-wound resistors were encountered with resistors which had successfully survived the storage period and opened up subsequent to checkout. However, the frequency of wire-wound resistor troubles has decreased and is expected to decrease further in the ensuing months, particularly when time permits replacement of wire-wound resistors of the 10 watt size known to be causing flip-flop instability in the Flip-Flop Storage section and the Arithmetic Element. Similarly, the occurrence of only two phenolic breakdowns during the period since the first of August indicates that the outbreak of a large number of phenolic breakdowns during the past Summer was not indicative of a sudden deterioration of all computer panels. In the two instances which have occurred, the simple procedure of cutting an air gap between the affected lugs was used successfully. Except for the wire-wound resistor problems, and the recently encountered difficulties with paper tubular capacitors and drum heads, failure rates of other electronic components have continued at low rates as reported in our July report. Rates of vacuum tube failure and crystal diode failure have continued at the same levels encountered prior to the end of July. Relay operation has continued to be excellent with no relay failures encountered during this period.

A. Wire-Wound Resistors

Checkout of additional equipment during this period of time revealed open wire-wound resistors to be a factor contributing to the malfunction of the 400 Amp Filament Alternator Regulator for the drums and associated input-output equipment, the Test Control camera, and the audible alarm panels. In addition, one instance of failure of a wire-wound resistor which had satisfactorily survived the storage period was encountered in a Selection Plane Driver for Core Memory Bank C. Additional instances of poor flip-flop operation due to the new ten watt wire-wound resistors were also encountered during this period, particularly in the Flip-Flop Storage Registers and the Accumulator Overflow Flip-Flop. As mentioned in the July, 1963 report, most of the flip-flop instability troubles had been cured by replacing only the 2000 ohm 10 watt resistors with 2000 ohm 12 watt resistors, but that it had also been necessary to change the 1600 ohm resistors in the Accumulator Partial Sum Flip-Flops and the B-Register Flip-Flops to obtain reliable shifting operations. Troubles with Flip-Flop Storage Registers during this period indicate that it will eventually be desirable to replace all of the 1000 ohm 10 watt plate load resistors in these flip-flops with 1000 ohm 12 watt resistors to obtain greater operating margins. Five or six of the worst cases in Flip-Flop Storage Registers No. 2 and No. 3 were corrected by replacing the 1000 ohm resistors. As time permits over the next few months, all such resistors will be replaced to improve the reliability of Flip-Flop Storage. Since checkout has been completed, it is felt that most of the open wire-wound resistors have been found and replaced and that the only troubles to be encountered from this source in the future will result from the opening up of a few resistors in the core memory Selection Plane Driver panels and four or five of the A-Register panels, which are the only locations of 12 watt wire-wound resistors which had been installed at M.I.T. and thus were subjected to the environmental conditions of the storage period. All of the non-inductive 10 watt wire-wound resistors in the Digit Plane Drivers of Core Memory Banks A and B have been checked and replaced where open. No instances of further failure of these resistors were encountered during this period but this may be due to the fact that these two core memory banks were not operated during about half of the time. Thus, these Digit Plane Drivers may be an additional source of trouble from open wire-wound resistors.

B. Phenolic Breakdowns

During this period only two phenolic breakdowns were encountered. This record of two breakdowns in a period of slightly more than five months compares very favorably with the record of six or seven breakdowns during the previous five months. This decrease in the frequency of breakdowns is encouraging because it fairly definitely shows that the occurrence of six phenolic breakdowns during a two week period in July was not an indication of a sudden increase in the frequency of such breakdowns. Repair of both of these breakdowns was accomplished with a minimum of time using the procedure of cutting a small air gap in the phenolic board between the affected terminals. This procedure has proven very effective. A possible contributing factor to the first of these breakdowns is the fact that the outside air damper was inadvertently left open the night before the breakdown occurred. Since this was a rainy night, the absorption of damp outside air may have hastened the onset of this particular breakdown.

C. Tubular Paper Capacitors

Shortly after the checkout of the 400 Amp Filament Alternator for the magnetic drums and associated input-output equipment, two failures of the Filament Alternator Regulator were encountered, the first being encountered in the regulator itself and the second in the power supply for the regulator. Both of these troubles were caused by faulty paper tubular capacitors. These capacitors had somehow broken down and had developed a resistance characteristic. One of these capacitors measured 600 ohms while the other had a resistance value in the order of 100 ohms. One of these capacitors was dissected and it appeared that the kraft paper used in insulating the metal foil had dried out in places and had become brittle, permitting a conduction path between layers of the foil. These are the only instances of such capacitor breakdown and it is not felt to be a serious problem since these are the only known capacitors of this type used in the computer. It is worthy of mention here only because it represents another area of computer component failure.

D. Magnetic Drum Heads

During the first week of December, more detailed investigation into intermittent parity alarms from the Buffer Drum revealed two heads on this drum whose windings are intermittently open. The cause of opening of these drum head windings is not known but it is felt to be mechanical rather than environmental. Three reasons for this assumption are:

1. The drums were moved with greater caution than was the rest of the computer and were stored in our Boston office rather than at South Boston.

2. M.I.T. records indicate that considerable trouble was encountered with open head windings shortly after the two drum systems were delivered.

3. Dissection of a defective head revealed a possible weakness in the design which permits flexing of the extremely small wires from the head assembly to the connector pins.

We are awaiting information from UNIVAC regarding the procedure for installing and aligning new heads and the availability of new heads. We presently have two good spare heads and four or five spare tracks on the drum with good heads. The digit troubles investigated during the first week of December have been corrected temporarily by switching head cables to spare drum tracks and when alignment information becomes available, we can install the two spare heads.

Initial information regarding availability of new heads is slightly discouraging, however, since UNIVAC has changed its drum head design within the past few years. It may be possible though, if heads are not available from stock, to obtain some spare heads from UNIVAC drums turned in with some of their earlier computers or alternatively, they may possibly have facilities for reworking the defective heads. Another alternative might be a modification to their present head design if these are electrically equivalent to the existing heads. This open head winding problem will become a major one only if some type of replacement head is not available, and if additional heads become open. No information is available regarding the rate of head failure, however, M.I.T. records reveal that 26 spare heads were purchased at one time and apparently all but two had been used.

Since M.I.T. records of head failure after about 1954 are not available, and since this is a mechanical problem, it is hoped that the rate of head failure decreased considerably after the initial shakedown of the equipment. Since available evidence indicates the cause of head failure is mechanical, due to twisting of the head leads when connectors are inserted and removed, these present troubles may have been caused during the disconnecting and reconnecting of head cables. If this is indeed the case, then head failure will not be a major problem, but if additional head failures occur and no suitable replacements are available, then the problem may become serious. In the latter eventuality, the only solution will be to reduce the number of working groups of drum storage by one and to utilize the remaining good tracks in the discontinued group as spares for the other working groups.

V UTILITY PROGRAM DEBUGGING

After completion of checkout of the magnetic tapes and the two magnetic drums, the computer was sufficiently operational to permit operation of M.I.T.'s utility system which handles such functions as the read-in of binary tapes, the read-in and conversion of Flexowriter coded (alphanumeric) tapes to binary, and the reocrding of post-mortem (memory dump) printouts of selected core memory and/or drum register contents. These utility programs are permanently recorded on either Group 11 of the Auxiliary Drum or Magnetic Tape Unit No. 0. We were indeed fortunate to find both the Drum Group 11 programs and the Tape Unit 0 programs had been preserved without a single flaw on the magnetic drum surface and one of the magnetic tapes for Tape Unit No. 0 during the four and one-half year period that the computer had been out of operation. Work in making these programs operational has uncovered a few additional machine malfunctions which had not been found during equipment checkout. The time which has been spent in debugging the operation of these programs has been one of the major factors contributing to the schedule slippage since no estimates were made in the original schedule for such checking. The fact that the programs were preserved on tape and drums was extremely fortuitous since these programs had been operational before and failures encountered during the execution of these programs could be definitely stated to be machine errors rather than programming errors. Had it been necessary to rerecord any of these programs, then the debugging of their operation would have become much more time consuming since it would have not been immediately apparent that errors were due to machine malfunction during program operation rather than machine malfunction during the recording of the programs.

A. Utility Control Program

The Utility Control Program which is commonly known as the Drum Group 11 program performs the functions of binary tape read-in and logging, Flexowriter coded (alphanumeric) tape title block read-in, logging and subsequent read-in of the CSII Conversion Program from Tape Unit No. 0 to the auxiliary section of the Buffer Drum, and interpretation of post-mortem requests and read-in of the CSII Post-Mortem Program. Some work on checking the Utility Control Program was done during the checkout of the Auxiliary Drum system to evaluate the status of the Utility Control Program recording. Such checking was very helpful in proving that there was an addressing error associated with the Auxiliary Drum.

Once the Auxiliary Drum addressing error was corrected and the Buffer Drum had been checked out, attempts were again made to operate the Drum Group 11 program. At this time, activation of the "Read-in" button caused the contents of core memory to be recorded in the Auxiliary Drum Group 0 and the contents of Drum Group 11 to be brought into core memory, following which control was transferred to the Drum Group 11 program. The Group 11 program then read a title block from tape and logged the tape title and time on the Flexowriter as well as the tape title on the monitor display scope in Test Control, but thereafter stopped when selecting the si instruction to index the camera. At this point, action was taken to correct the malfunction of the camera following which operation of the Drum Group 11 program was again attempted. At this point, successful read-in of binary tapes could be accomplished about one out of every three tries with the failures resulting in a transfer of control to location 0. At this time, attempts were also made to use the Utility Control Program to produce a post-mortem request on the direct Flexowriter and on the camera scope. Each time the Utility Control Program successfully searched Magnetic Tape Unit No. 0 for the Post-Mortem Program but we were only able to get occasional scope post-mortems.

Similarly, attempts to have the Utility Control Program initiate read-in of a Flexo tape and call in the conversion program generally failed after successfully finding the conversion program on Tape Unit No. 0 and storing it on the auxiliary section of the Buffer drum. Failures of attempted conversions soon led to the discovery of instability in Flip-Flop Storage Registers 2 and 3, which were corrected by replacing 1000 ohm 10 watt wire-wound resistors in the more marginal digits of these registers.

Following correction of the troubles with Flip-Flop Storage, intermittent arithmetic check alarms during attempted conversions led to the discovery of instability in the Overflow Flip-Flop of the Accumulator. After correcting troubles with the Overflow Flip-Flop by replacing the 1600 ohm 10 watt resistors with 12 watt resistors, operation of the Utility Control Program has been error free and most of the troubles with the CSII Post-Mortem Program and the CSII Conversion Program were cleared up. Since this time, no read-in, conversion, or post-mortem operation errors have occurred which are due to failure to read the Utility Control Program properly from Drum Group 11.

B. <u>CSII Conversion Program</u>

As mentioned in Section A above, initial attempts to operate the CSII Conversion Program were unsuccessful due to instability of flip-flops in the Flip-Flop Storage Registers 2 and 3 and the Accumulator Overflow Flip-Flop. Once these troubles had been corrected, conversion of an existing Flexo-coded tape, which had been converted at M.I.T., were generally successful except on occasions where intermittent parity alarms from the Buffer drum were encountered. However, attempts at converting a rather long Flexo-coded test tape which we had prepared pointed up two other troubles beside Buffer drum parity alarms which were occurring during a conversion period. One of these troubles was found to be due to misadjustment of the brake on the photoelectric tape reader which permitted the first character of a block to be skipped over when the photoreader was stopped during read-in of the Flexo tape. Adjustment of the gap on the clutch and brake of the photoelectric reader have cleared up this problem.

The other problem, which was also thought initially to be caused by slippage of the tape reader brake, results in incorrect interpretation of clear and add (ca) instructions whose address is specified as some floating address minus a constant. Since the M.I.T. information on coding for the CSII Conversion Program is not as explicit as it might be, it was thought at first that this was possibly a coding error. However, examples were found where such an address coding sequence was properly converted with a different instruction code, therefore it is felt to be a machine malfunction. At present, the cause of this trouble is being investigated, but as yet no conclusive results have been obtained. Troubles with conversion failures due to intermittent parity alarms from the Buffer Drum were essentially eliminated during the first week of December when investigation of these troubles revealed some intermittently open head windings on the Buffer Drum and the trouble was corrected temporarily by switching the head cables to spare tracks.

C. CSII Post-Mortem Program

Initial attempts to operate the CSII Post-Mortem Program which is called in from Magnetic Tape Unit No. 0 or the auxiliary section of the Buffer Drum by the Utility Control Program were successful only in generating scope post-mortems. Since troubles with Flip-Flop Storage and the Accumulator Overflow Flip-Flop have been corrected, consistently good operation of the Post-Mortem Program has been obtained. No difficulty with Buffer Drum parity alarms has been encountered with the Post-Mortem Program probably because this program occupies Drum Groups 6 and 7 and most of the parity alarms have occurred in Drum Groups 3 and 5 which are occupied by the Conversion Program.

VI SUMMARY

This progress report describes the work accomplished and troubles encountered during the checkout phase of the Whirlwind I computer from August 1, 1963 to the completion of checkout on January 13, 1964. It is essentially a supplement to our progress report of July, 1963 which describes the effort since that time. Also presented are revised versions of the tables listing the events of which the PERT network for Whirlwind I Computer Checkout (Figure 3-1 of the July progress report) is comprised. The scheduled date for checkout completion presented in the July, 1963 report was November 15, 1963. This scheduled date has slipped approximately two months due primarily to three factors which were either underestimated or not considered in preparing the schedule of the July report. These factors are:

1. Overly optimistic estimates of the time required to check out the magnetic tape units and the IBM card machines.
2. Failure to allow for time required in correcting malfunctions in computer equipment checked out prior to the end of July.
3. Failure to include time required to check out operation of the Utility Control Program, the CSII Conversion Program, and the CSII Post-Mortem Program.

In addition to describing the effort involved in checking out the remaining equipment, this report also presents a description of routine maintenance problems encountered with equipment previously checked out, a description of major problems encountered, and a description of the effort involved in checking out the operation of the existing Whirlwind I utility programs.

Considering the fact that routine maintenance has not been performed on a scheduled basis during this period, the reliability of the computer has been extremely good.

As for major problems encountered, only two of the four described in the July report have continued, namely trouble with wire-wound resistors and phenolic breakdowns. The end of the wire-wound resistor problem is in sight and the phenolic breakdown frequency has diminished by a factor of at least three which has allayed our fears, expressed in July, that this might become a serious problem. Two new major problems which have occurred during this period are also described: breakdown of paper tubular capacitors and the occurrence of open drum head windings. The paper capacitor problem is not considered to be a serious one since both of the breakdowns encountered occurred in a particular type of paper capacitor which is not used elsewhere in the computer. The problem of open drum head windings is known to have occurred at MIT shortly after delivery of the drums and is potentially serious only if suitable replacement heads are not readily available.