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Memorandum M-332

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Project Whirlwind
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: BI-WEEKLY REPORT, PART II, APRIL 2, 1948

To: 6345 Engineers

From: Jay W. Forrester

ALFRED M. FALCIONE

6.0 MATHEMATICS

(P. Franklin)

The study of curve fitting indicates that for known functions like cosine and sine, in many cases polynomial approximations use considerably less storage and only a little more time than interpolation methods.

For the empirical aerodynamic functions, highly precise approximations used at a slower time rate will make possible numerical tests of the effect on integration of using slightly less accurate approximations to meet the time requirements of simulation.

(E. Reich)

The literature on iterative methods for the solution of systems of linear algebraic equations is being examined in order that all methods heretofore proposed can be duly appraised. The so-called Southwell method was found to have been already described by Gauss in a letter to Gerling dated December 26, 1823.

(C. Adams)

Work on coding subprograms for WWI is being continued. M-328 describing the application of the automatic subprogram orders to double-length operations and reporting the results of some coding of double-length addition, multiplication, and division is available and should be distributed to the mathematics and block diagrams sections today. Some thought has been given to the computation of conversion from binary to decimal form for output and the results will probably be submitted to R. R. Everett in memorandum form shortly.

6.0 MATHEMATICS (Continued)

(M. Daniloff)

1. Studies have shown that in simulating functions with Legendre's polynomials the arithmetic averages of the errors of estimates are not very stable even for smooth functions. They depend, in the main, upon the number of places to which the function is given and on the number of ordinates used in fitting the polynomials. Typical figures are: for a function given to three places, and with 11 ordinates being employed, the arithmetic averages of the errors of estimate varies between 0.00001 and 0.0002. This does not apply however to the arithmetic averages of the absolute values of the errors of estimate. These are, of course, larger, but very stable, and under the above conditions, fluctuate only between 0.0007 and 0.0008. As a consequence, it is suggested that WWI be made to calculate and display the latter figure as a convenient and significant index of the accuracy of simulation obtained.

2. An adequate criterion for the selection of the degree of the approximating polynomial may be either:

- a. The order of the minimum average of the absolute values of the differences of the function (care should be taken to take the absolute minimum, as relative minima or inflexions with zero slope occur quite frequently).
- b. The order "i" of the Legendre coefficient C_i ($C_i = \frac{2i+1}{2} \cdot M_i$), the absolute value of which is less than the error of estimate allowed (since the extreme values of Legendre's polynomials are ± 1).

(D. Batteau)

All time spent in calculations designed to fit a curve to data presented by J. Ely. Requirements that curve value approximate measured value to 0.25% make fitting very tedious (if at all possible). No satisfactory curves found; calculations continued.

7.0 INPUT AND OUTPUT7.1 Eastman Kodak Recorders

(H. R. Boyd)

I visited Eastman on March 30. They have assembled the complete demonstration unit including optics and are about to make tests on full-scale recording and reading. They have rebuilt some 11 digit stepping registers and will use these with a continuous film to investigate slip-page at the reading and recording point for random operation. They are again considering servos for reel control and I favor this approach. The zinc oxide coated tube is very satisfactory and simplifies the speed problem.

They are working with the Recordak people to attempt a single processing machine for both applications. The Recordak group will put in automatic threading if we can accept 2 feet/min. as a developing speed. This unit would be in production about the first of next year and could be purchased for \$2000 - \$3500. I think that for the present these slower units would be at least as acceptable as an experimental higher-speed unit. They felt that the time schedule was a good one and will try to meet it if possible.

7.4 Magnetic Recording.

(E. S. Rich)

The reading circuit for converting the double-swing output pulses into single pulses of the proper polarity was adjusted to operate satisfactorily for tape speeds from about 14 to 20 ft/sec. This circuit is described in M-317. Measurements of the resolution of recorded pulses were made and it was found that a maximum of 90 pulses per inch can be recorded on the Vicalloy tape with a playback-voltage signal-to-noise ratio of about 100, while 180 pulses per inch can be recorded if the signal-to-noise ratio is 20. These figures are for consecutive pulses of like polarity. If consecutive pulses are of opposite polarity, the maximum number of pulses that can be recorded per inch of tape is increased by a factor of 2.

7.6 Output Printers.

(F. A. Foss)

The primary register which provides for the energizing of the relay selector circuits has been completed. Another register which will contain the second digit to be printed

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7.6 Output Printers (Continued)

is now under construction. The pulsing of these circuits will be synchronized by means of a transmitter distributor.

A Western Union transmitter distributor has been borrowed from the Electrical Engineering Machinery Laboratories for the purpose of testing the operational characteristics of the electronic printing circuits.

8.0 STORAGE TUBES

8.1 Tube Construction and Testing

8.11 Tube Construction and Processing

(J.H.McCusker, T.F.Clough and P.Youts)

The first five-inch storage tube has been constructed and processed. It is now ready to be tested. Holding gun current is below normal and a very small part of the storage surface was damaged during construction. All previous tubes of similar volume which we attempted to process last summer would not pump below 1×10^{-6} mm of Hg. However this tube pumped satisfactorily.

Envelopes for three more five-inch storage tubes have been constructed. Complete components for another five-inch tube are ready for assembly.

The hydrogen-firing ovens of RLE are being serviced during the next fortnight. This will delay a few of our projects.

Several tubes were constructed for the secondary emission life tests.

A tube to study a new type of holding gun was processed and ready for testing.

Through cooperation of C. S. Pearsall of RLE we set up facilities to clean and polish electrolytically the nickel stem leads. This facilitates welding and gives clean leads for inside the vacuum tubes.

(R.Shaw)

One five-inch signal plate assembly has been completed and installed in tube no. ST25. The chief mechanical difficulty encountered in this assembly was distortion of the screen. The following corrective measures are being taken:

- 1) A new two-way stretching fixture is being made.
- 2) New, more rigid electrodes are being made for the spot-welding machine.

8.11 Tube Construction and Processing (cont.)

- 3) A supporting fixture is being sketched which will hold the screen at a fixed height relative to the lower electrode of the welder. This, together with the new electrodes, should prevent the imposition of irregular stresses on the screen during welding.
- 4) Care is being taken to avoid distortion of the support ring, such as may be caused by poorly-fitting holding fixtures.
- 5) The screen will be held between flat stainless steel plates during preliminary stress relieving.
- 6) The possibility of using a nickel-gold brazing alloy is being investigated as a possible substitute for spot-welding.

A signal plate assembly for ST26 is in process. This is similar to the previous one with only minor modifications.

Parts for signal plate assemblies for ST27 and ST28 are partly finished. These were designed to be as light as possible and are necessarily fragile, consequently some difficulty has been experienced in machining. As a temporary expedient some parts have been made heavier; however, a study is being made of the possibility of making tools and fixtures to produce the parts as designed.

The sketches and notes from which all the above parts were made are being put into more permanent form by the Drafting Department.

(F.H.Caswell)

Elements for the first large five-inch storage tube were given final assembly, mounted on a stem and photographed for our files. The second five-inch tube is now ready for final assembly with several mechanical improvements over the previous structure.

Elements were fabricated for three research tubes

8.11 Tube Construction and Processing (cont.)

and one evaporation tube, including several new electron gun modifications.

Experiments continue to improve calcium tungstate settling on Al_2O_3 surfaces.

8.12 Tube Testing

(S.H.Dodd)

Mod 18B (calcium tungstate storage surface) was tested. Results indicate operation similar to Mod 18 as reported in M-311 except that best holding beam accelerating potential was found to be -310 volts. Also adjustment of this voltage was very critical. Higher writing beam current decreased writing time to 15 to 20 μ seconds.

Mod 18A was also tested but surface SE was very poor. Operation of this tube indicated a varying SE over the surface with poorest values in the center.

8.13 Storage Tube Demonstration

(W.J.Nolan)

Construction on the demonstrator has been completed and the circuits are working satisfactorily.

(J.S.Rochefort)

A report on the E.S.T. Demonstrator is being prepared. The drawings which will be incorporated in the report have been compiled and revisions are being processed by the Drafting Department.

8.2 Storage Tube Research

8.21 Surface Material Characteristics

(W.J.Nolan)

Equipment for life testing of 931-A multiplier phototubes has been constructed and some preliminary runs are being made to determine if the proposed test procedure will be satisfactory.

8.21 Surface Material Characteristics (cont.)

(H.L.Heydt)

The secondary emission test set-up has been completely revised to accommodate the new type research tubes described in a previous bi-weekly report. It is now possible to make secondary emission measurements on a particular surface in a matter of minutes.

Research tube RT8 has been studied in the new test set-up. This tube has a storage surface of beryllium on Al_2O_3 . Because of certain defects, the tube has been opened and re-pumped several times, so that it is probable that the beryllium surface is considerably oxidized. Since the beam current in RT8 is very small, measurements are not too accurate and it is doubtful if any life-testing can be performed on the tube. Measurements do indicate, however, that the surface has very desirable secondary emission properties. The first crossover potential is near 40 volts, while the secondary emission ratio at 1500 volts exceeds 2.5. Whether such properties will exist after continued usage is another matter which will be studied in similar beryllium tubes now being prepared.

8.23 Output System Circuits

(C.H.R.Campling)

The gate amplifiers which were constructed for test purposes have been completed and are being used. Rise times are good enough for this particular work. Amplitudes are variable from zero to about 350 volts for the high-power unit, and from zero to about 200 volts for the low-power unit. The gate amplitudes are dependent upon p.r.f. except at maximum amplitude.

Some difficulty was encountered in obtaining an oscilloscope with a good amplifier. Since all the TS-239 'scopes were being used, and since it was possible to obtain one only by borrowing it for short periods of time from the storage tube lab, some other substitute had to be found. A TS-34 'scope was procured, and it is being used at present. It has been calibrated in voltage and in time, and has proved useful for most purposes although it lacks many of the conveniences which are incorporated in the TS-239.

8.23 Output System Circuits (cont.)

Clamp circuits, both d-c and a-c coupled, have been investigated. The performance of the former is about what was expected and the circuit gives results comparable to those obtained by Steve Dodd. The use of back-to-back Germanium crystals on the output of this circuit shows promise of providing a usable output signal. A few tests with these crystals using a simulated signal pulse seem to indicate that such an arrangement would pass the signal pulse and clip the spurious signals to comparable amplitude. However, it is difficult to make predictions about this matter without making tests with an actual storage tube.

The operation of the a-c coupled clamp-circuit depends so much upon the duty-cycle that it virtually has been dropped after a number of unsuccessful attempts to overcome the difficulty.

Preliminary tests have been made on the three pulse-transformers which were constructed for the delay-line circuit. Despite their large physical size, these transformers will pass with a reasonable amount of distortion a 350-volt signal-plate switching-gate from a source with 1000 ohms internal impedance. For a 50-microsecond gate the decay is less than 10% for each transformer, and the rise time for the two transformers with single-layer windings is not much more than one microsecond. The outputs from the centre-tapped secondary show objectionable ringing in each case. Further tests were made with the secondary loaded with an RC network designed to cancel the switching gate at the input to an amplifier. It is not difficult to obtain exact cancellation for the flat portion of the gate, but differences in the oscillatory transients at opposite ends of the centre-tapped winding have made it impossible so far to cancel these transients completely.

8.3 Unclassified

(M.I.Florencourt)

Information on the significant components of the following tubes has been outlined and is now available

8.3 Unclassified (cont.)

in Room 220:

Storage Tubes: 7, 8A, 9, 10, 11A, 12, 13, 14A,
14B, 15A, 15B, 16, 17, 18, 18A,
18B, 19, 20, 20A, 20B, 21, 22,
23A, 24, 25.

Research Tubes: 1, 2, 3A, 4B, 5, 6, 7, 8, 9,
10, 11, 12, 12A, 13, 14, 15, 16, 17.

Evaporation Tubes: 1 -- 28.

A summary of the test results for each tube will be available shortly.

8.4 Deflection Circuits

(L.J.Nardone)

Matching of the 100K increment resistors for the deflection voltage generator has been completed. Each resistor was measured on the Per Cent Limit Bridge. The resistors were grouped such that those of slightly higher resistance were designated as the 1's increment resistors, to those of slightly lower resistance which were designated as the 16's increment resistors.

Matching of the IN38 switching crystals for the deflection voltage generator was also completed. These crystals were grouped such that the crystals with the higher forward and back resistances were designated for the 1's increment crystals, to those of lower forward resistance which were designated as the 16's increment crystals.

Several breadboards were constructed to be used with the 256-B A/R scope to permit single sequence of control pulses for test purposes.

Voltage testing on the single increment deflection voltage generator has been started.

During the next two weeks, voltage tests on the single increment generator will continue and tests on the main panel may start.

8.4 Deflection Circuits (cont.)

(J.O.Ely)

Construction of the first 32-position deflection-voltage generator is approximately $3/4$ completed. Original estimates of the time required by the electronics shop to construct this unit were considerably too optimistic. Construction schedule for the second unit has been extended by two weeks, although the starting date has not been changed.

Tests of the single increment-switch subpanel have been delayed by lack of suitable test equipment. The testing which has been done, however, indicates a switching time for the eight-increment of about $1/2 \mu$ second when connected in the completed deflection-voltage generator. No obvious design defects have been noted up to date.

Preparation of the report on preliminary phases of this work is proceeding. It has been decided to make this an R-series report, so that date of issue will be determined to a great extent by the time required to prepare illustrations.

Some difficulties in making measurements have been caused by line-voltage transient fluctuations. Some temporary expedient for overcoming this difficulty must be worked out to permit tests on the deflection-voltage generator to be made in the time between the date on which it is completed and the date on which line-voltage regulation is installed.

9.0 SERVOS AND SIMULATION

9.1 Cockpit

9.11 Cockpit Structure

(E.S.Prohaska)

The hydraulic cylinders for loading the controls are ready to be detailed and should be ready for manufacture within two weeks, if personnel is available for detailing.

In order to meet the present schedule, it will be necessary to have a detailer available full time between April 15 and June 6.

9.13 Control Force Loading

(C.G.Eaton)

The differential pressure regulator has been tested qualitatively with the servo loop closed using the Control Force Demonstrator equipment. Overall performance seems good, although some trouble with the torque motor has been experienced. The torque motor difficulty is being investigated.

9.2 Sampling Servo Stability Study

(W.K.Livill)

The Hurewicz system functions are quite complicated since the impulse response of the feed-forward section of the servo is the sum of a set of exponentials. Simplification of the system functions seems possible if the impulse response can be approximated by some other functions. Since the system operates on intermittent data and since Hurewicz's analysis attempts to describe the output only at discrete values of time (at the instant of switching), it seems permissible to approximate the impulse response.

A study is being made to determine the system functions which result from simplified impulse-response functions.

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10.0 TRAINING

10.1 Seminar Series

(R. P. Mayer)

Lecture I, Introduction, may be available for
distribution in a few days.

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11.0 FACILITIES AND CENTRAL SERVICE

11.1 Publications

(J. N. Ulman, Jr.) The following material has been received in the Library, Room 217, and is available to 6345 personnel.

6345 Reports

R-120	Deflection Circuits for Electrostatic Storage Tubes.	J. O. Ely
R-122	Low Power Pulse Transformers	T. F. Wimett
E-107	Consolidation of Operation Matrix and Program Timing Matrix	J. A. O'Brien
M-293	Meeting of Electronic Group, March 5, 1948	C. C. Sumner
M-305	Design Problems of Arithmetic Element Control Progress Report: A Trouble Location Scheme for a Digital Electronic Computer	(G. Hoberg (E. Blumenthal
M-306	Overloading of Neon Indicator Lamps in Basic Circuit IND-I	J. Hunt
M-307	Sylvania Prints to M. I. T.	A. Falcione
M-309	Flip-Flop Storage Layout	H. Fahnestock
M-310	Bi-Weekly Report, Part I, March 19, 1948	J. Forrester
M-311	Bi-Weekly Report, Part II, March 19, 1948	J. Forrester
M-312	Power Cabling, Proposal No. I	H. S. Lee
M-313	Proposed Elevating Test Truck for WWI	R. E. Hunt
M-314	Connections and Changes on Basic Circuits RA-1 and GG-1	J. A. O'Brien
M-315	Bus Driver Panel Layout	H. Fahnestock
M-316	A-Register Prototype Drawing Approval	H. Fahnestock
M-317	Progress Report: High Speed Pulse Recording on Magnetic Tape	E. S. Rich
M-318	Progress Report: Investigation of Electronic Computer Output Circuits	F. Foss
M-319	Arithmetic Control and AC-0 Preliminary Notice of Work Load	H. Fahnestock
M-320	Pulse Transformer Test Unit	R. Everett
M-321	Meeting of the Electronics Group, March 12 and 19, 1948	J. J. O'Brien
M-322	Additional Voltage Requirements for WWI	C. W. Watt
M-324	Filament Transformers, WWI	(J. Forrester (H. Fahnestock
M-325	Underwriters Approval	W. S. Rogers
M-326	WWI Rack Door Material	R. E. Hunt
M-327	Arithmetic Control Time Schedules	H. Fahnestock

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11.1 Publications (Continued)

M-330 WWI Control: Time Schedules
M-333 Progress Report: Investigation of
Electronic Computer Output Circuits

H. Fahnestock
F. Foss

Library Files

.004 European Scientific Notes, March 1, 1948

Material on Loan from ONR

G 350-15 Interim Engineering Report on
Development of Shock and Vibration
Isolators for Airborne Electronic
Equipment

L. N. Barry Co.,
Inc.

G-352-13 Report on Pulse Transformer Research

University of
California

R-352-28 High Voltage Connectors, Inserts, and
Cables

Bell Telephone
Laboratories, Inc.

2032 A Fast Coincidence Circuit With Pulse
Height Selection

Clinton
Laboratories

11.2 Standards Committee

(W. S. Rogers)

A method of impregnating our radio frequency chokes was checked and an improved product was submitted by Cambridge Thermionic using three coats of modified "Tuff On" followed by a light baking.

A pulse transformer was given three special coats without the baking. This sample is to receive light bake to see if this will completely "set" the coating.

(S. Abbott)

The following specifications (M.I.T.) have been approved and distributed since the last report:

Class P6.199	Transformers (Non-standard)
Class P6.115	Solder - Lead and Tin Alloy.

A survey of tube requirements for all Test Equipment is being made and will be issued as a supplement to the present standard tube list.

A number of standard sheets have been revised by the Drafting Room to conform with their standard practice procedures.

11.2 Standards Committee (Cont.)

(C. W. Watt)

Power Connectors: Discussions were held during this period with representatives of the Waltham Horological Company and the Industrial Products Company, and proposal drawings on a power connector for WWI were obtained from each. A sample showing contact arrangement was obtained from Waltham and seemed fairly satisfactory. A similar sample from Industrial Products will take about three weeks to obtain, and it appears likely that in order to obtain connectors in time we must decide on a supplier and a design sooner than that. Some details of the Waltham connectors were obtained from Mr. Webster, the Waltham engineer. The sample connector contains eight 10 amp and twenty-one 5 amp contacts. The current carrying capacity of the male contact was calculated on a basis of 1500 circular mills of cross section per amp, while the area of the female contact was about 20% greater than this. The actual area of contact between the male and female pins is about 25% greater than the cross section area of the male pin for perfectly aligned contact. Mr. Webster states that the production quantity of these contacts will be more uniform than those in the samples submitted. The male pins of these connectors are made of brass, the female of beryllium copper, heat treated at 600° for two hours, and cooled slowly for seven to eight hours. The female contact is split four ways and the split end is pushed together in a die before heat treatment and takes a permanent set during the heat treatment which can be expected to remain for the life of the connector. This contact design has been used before in the production connectors and according to Mr. Webster has proved very satisfactory.

WWI Standards Committee

WWI Standards Committee acted upon the following specifications which are now ready for approval by Fahnestock and Stevens.

- P7.018 Channel-Dural
- P7.074 Slotted Machine Screws - Machine Screw Nuts - Hex Washers - Flat Metal Lock Washers - Shake Proof
- P7.097 Lamps Neon Indicator
- P7.115 Solder Lead and Tin Alloy
- P7.024 Capacitors - Paper - Dielectric - Bath Tub
Capacitors - Paper - Dielectric - Tubular

The specifications mentioned in the last bi-weekly report have been approved by Fahnestock and Stevens and are now part of the WWI Standards Book.

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11.3 Purchasing - Stock

(H. B. Morley)

Some new information has been added to the catalog file, consisting of literature brought back from the I.R.E. convention by representatives who attended.

In accordance with the time schedule received from Sylvania, orders are being placed for pulse transformers to meet this schedule.

Sample filament transformers for WWI are being ordered from four transformer manufacturers for comparison and test.

Cinch Manufacturing Company has promised samples of a loktal tube socket that will meet the WWI requirements.

Waltham Horological Company has indicated that they will consider making a high-quality loktal and octal tube socket to meet our requirements.

More quantity orders are being placed for fast-moving stock items - especially in view of recent instances of slow delivery on such items.

The volume of requisitions being processed by this office has nearly doubled since the first of the year. Estimated costs have approximately tripled in the same period.

(C. W. Watt)

Watt, Boyd, and Morley spent two days at the Institute of Radio Engineers Radio Show in the Grand Central Palace in New York. Careful attention was given to components on display and a considerable amount of interesting information was picked up. Tube sockets, rotary switches, and wire were specially studied and methods of construction used by different equipment manufacturers were investigated. Requests were left with a number of company representatives for specialized literature, and drawings of a large console that might be usable in WWI were requested from the Karp representative.

11.4 Electronic Construction

(F. H. Caswell)

All air, gas and oxygen lines have been installed on new glass bench and connected to supply sources.

A test circuit was constructed to enable life tests of 931-A tubes. Construction of a deflection circuit for use with 5-inch storage tubes and modification of one Mod 5 Synchroscope to enable use of 5 RP2 CRT is now in progress.

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11.4 Electronic Construction (Cont.)

A "Marinite" platform for use in the annealing oven was constructed to replace "Transite" (platform) which broke up under heat.

(A. J. Taylor)

Vacuum tube life test panels are now under construction. If fuse holders are received on the date promised, 50 units will be completed May 5, 1948.

(Robert H. March)

The following jobs and units are in the Electronic Laboratory for construction.

1. 4 d-c Bench outlet Boxes
These units are being held until a relay is available, so that a control for +500 volts can be added to them.
2. Modifications to Single Pulse Synchronizers
This job is being held until it is approved by Test Equipment Committee.
3. 25 adapter sockets
13 of these have been completed. The balance will be completed April 7, with substitute material.
4. 10 a-c Circuit Breaker Boxes
These have been completed except for installation of pilot light sockets which are out of stock.
5. Deflection Voltage Generator
This unit is under construction and will be completed in about a week.
6. Accumulator Prototype
This unit is under construction and will be completed by April 17.
7. Restorer and Push Button Pulse Generator
Construction will start on this next week.
8. 3 Whiffle Tree Electronic Switches
These units are under construction.
9. Bus Driver Breadboard BA-1
Completed except for pulse transformer which has to be wound.

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11.4 Electronic Construction (Cont.)

10. Restorer Pulse Generator Breadboard
Under construction.
11. Rock Power Control Unit Prototype
Machine work on chassis has been completed and
wiring will start next week.
12. 7 Digit Parallel Binary-Coder Breadboard
This will be completed April 3.
13. Pulse Generator Breadboard
This will be completed about April 7.
14. Flip-Flop and Gate tube breadboard
This will be completed about April 8.
15. Installation of d-c Circuit Breaker
Box in Basement for tube life test racks.
This job will start about April 6.

The above jobs represent about 2 weeks work for the group. In addition to the above jobs, construction of the Arithmetic Control Unit for WWI and the Second Deflection Voltage Generator Panel will require 2 men full time and 1 man part time from April 19 to August 7.

11.5 Drafting

(A. M. Falcione)

1. Sylvania Prints to M. I. T.

Memorandum M-307 dated March 19, 1948 has been issued on this subject for information of all concerned.

2. Work Load Status

The work load on the Drafting Department is now on the increase. Additional draftsmen have been requisitioned to compensate for the additional work load. The labor market on draftsmen is very tight at the present time. We have had requisitions in for 2 draftsmen for some time but have had no candidates. It is hoped that this condition will change in the near future.

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11.6 Unclassified

(A. J. Taylor)

About 50% of available machine shop time is devoted to storage tube parts. The remaining time is being absorbed in the manufacture of electronic equipment hardware. The backlog is about 3 man-weeks of work.

A power hack saw, and a 5 ton, 10 in. throat punch press have been received.

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12.0 GENERAL

(H. Fahnestock)

Change title of Section 2.13 from Bus Driver to Drivers. Subject matter should include bus drivers, register drivers, and line drivers.

(H. R. Boyd)

New Personnel:

Edward Holmes - is a technician working with Bob Murch. He recently transferred from the Instrumentation Laboratory. He formerly worked at National and Submarine Signal.

Dwight Batteau - is working with Professor Franklin on a part-time basis. He will join the staff on a full-time basis in June when he completes his degree at Harvard. He was a radio station engineer for six years. Served four years in the Army and left as a first lieutenant. During this period he taught radar and did technical writing and editing.

Lawrence Martin - is a new carpenter working with Bill Wiercinski. He lives in Needham and was formerly at the Sawyer Company in Needham.