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BATTERY CHARGER (T-3)

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BATTERY CHARGER (T-3)

Purpose

The Battery Charger (BC) (T-3) is used to charge ER-12-10 batteries, the power source for the Mk 4 Mod 0 bomb. It is possible to charge 8 batteries (4 clamps) in series.

The BC replaces the charge panel Mk 2 Mod 0, the McColpin-Christie rectifier and its isolation transformer, the battery load tester, and the current failure alarm system. The BC is a more efficient and usable charging device incorporating all the features contained in the battery-charging equipment listed.

The BC has a front panel and chassis mounted in a cabinet 12-1/2 x 20 x 18 inches. The front panel (Fig. 1) provides mounting space for the BATTERY CURRENT ammeter, VOLTAGE CONTROL Powerstat, CHARGING TIME timer, pilot lamps, protective fuse, switches, and connectors. The chassis (Fig. 2) provides space for the transformers, relays, potentiometers, resistors, Amperite ballast tubes, and the rectifier tube. The weight of the BC and cabinet is 70 pounds.

The power required for the BC is 115 volts a-c at 60 cps, and the capacity is 3 amperes or 345 volt-amperes.

One cable CT102 from the a-c power source to the BC and four cables CT207 from the BC to the battery clamps are supplied with the BC.

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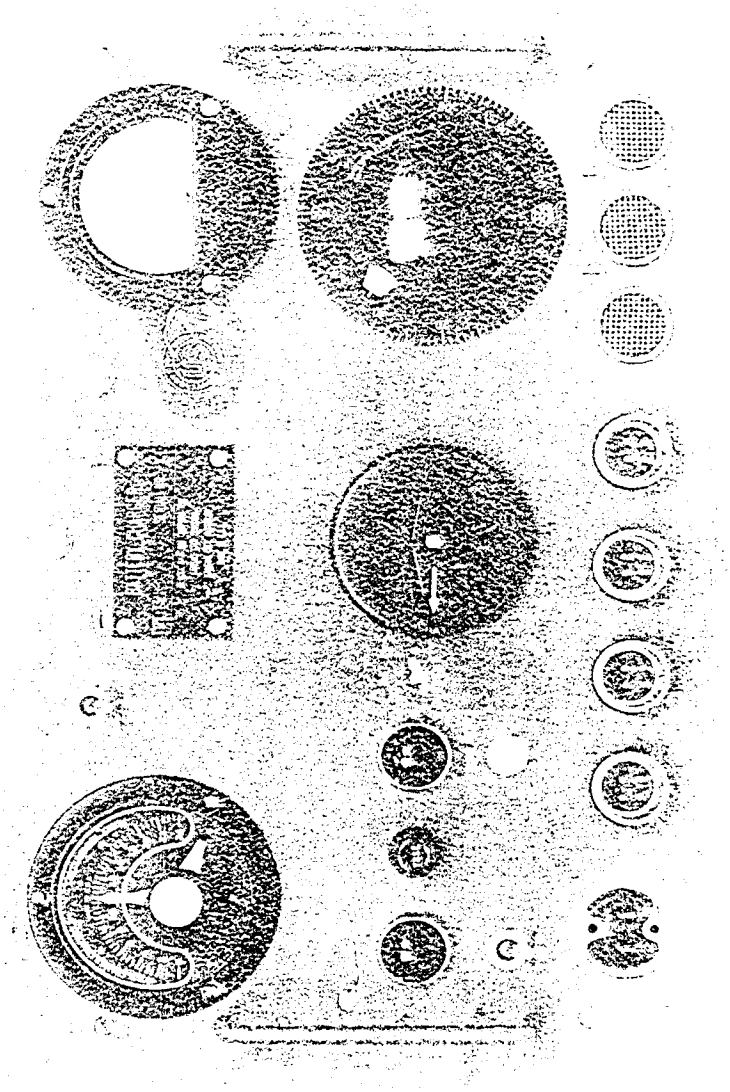

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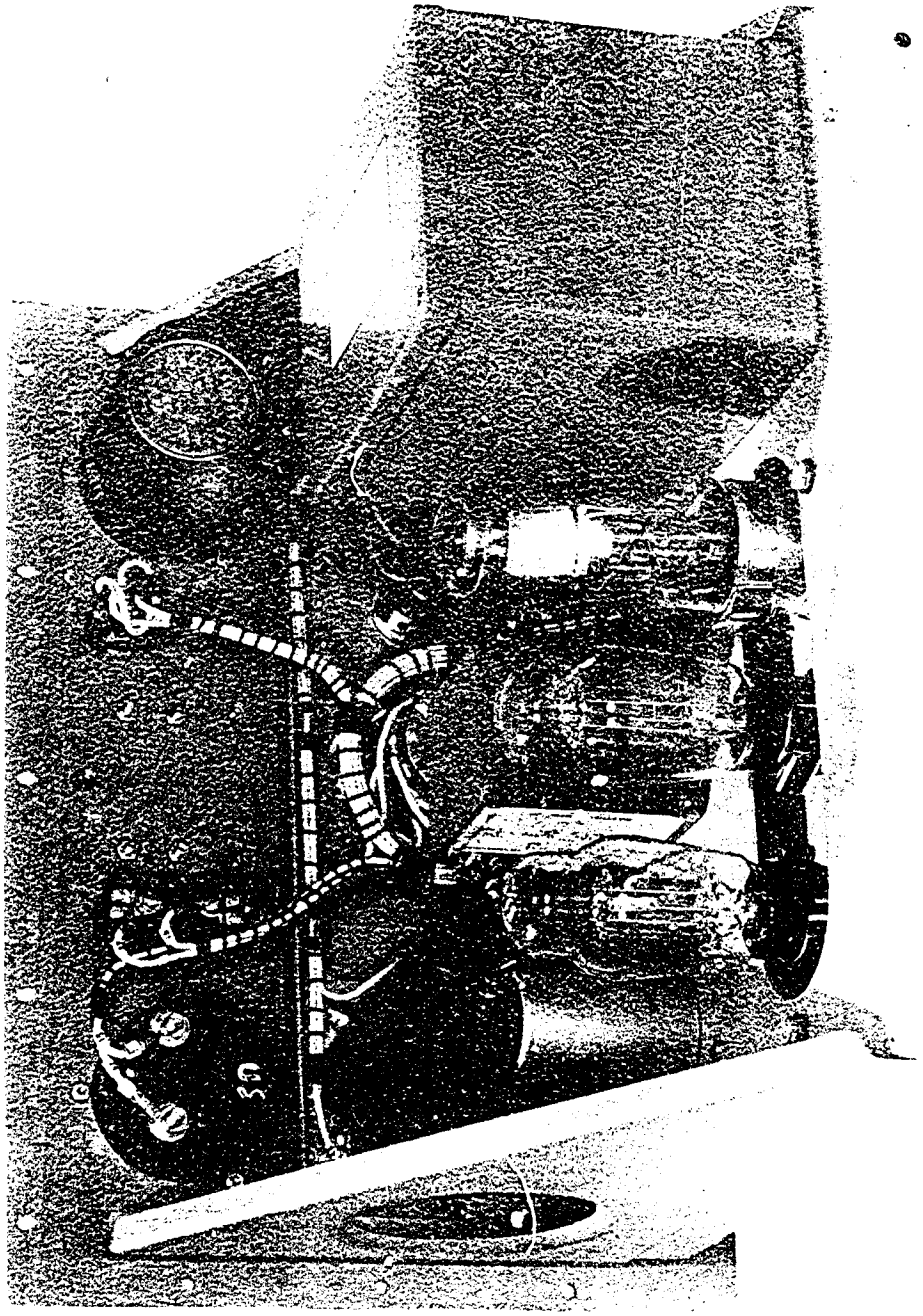

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History

Design of the BC was started in May 1949. It was to conform to the following specifications:

1. It was to be capable of charging eight ER-12-10 batteries in series using a constant current of 1.3 amperes using a rectifier having a full-wave current form.
2. The charging current was to open and an alarm to ring if the charging current fell below a definite minimum. This minimum current was to be as near one ampere as possible, the starting minimum charging current to be 1.1 amperes.
3. The charging current was to be isolated from the charger input.
4. There was to be provision for monitoring the voltage of each battery under load.

A breadboard model of the BC was constructed to test different systems of tube rectification. The following observations were made:

1. Mercury vapor rectifier tubes took too long to warm up and were not consistent in their operation.
2. Thyratron tubes did not have the desired characteristics to fit the high current and low voltage requirements of the charger. Thyratron tubes having the desired characteristics were not available.
3. Type EL3C tubes manufactured by Electrons, Inc, and RMA4B24 xenon-filled full-rectifier tubes were found to be the most satisfactory.

The Development Fabrication Department built a prototype BC conforming with the above specifications, using the EL3C tube. Some time later the alarm signal was replaced by an electrical timer to record the charging time and stop recording when the charging current was interrupted. This timer also turned off the charger at a predetermined time.

A requirement was introduced that a constant current output be maintained, regardless of the charger input voltage. After investigation it was decided to use ballast tubes in the BC output circuit. Because of the current waveform and the

widespread limits of the a-c voltage, the only ballast tubes that would furnish the required results were the Amperite type 8A10 and 9A10 tubes connected in parallel. This parallel combination of ballast tubes was then placed in series with the output circuit of the BC to regulate the charging current.

The regulation of the ballast tube arrangement can be held accurate to within ±0.15 ampere for the maximum allowable change in the a-c input voltage of the BC. This system will also compensate to some degree for the change in the voltage output of the BC in maintaining the required charging current output. However, the ballast tubes will not replace the input VOLTAGE CONTROL Powerstat.

Addition of the ballast tubes changed the secondary a-c output voltage requirement of the plate transformer. Procurement of this transformer delayed development, since it had to be built as a special unit.

When the problem of a constant charging current was introduced, the idea of using dry barrier-type rectification was also presented. Use of copper-oxide rectifiers was discarded because of the size and weight of the units. Use of selenium rectifiers was also investigated and found to be inadvisable unless the a-c input voltage of the BC could be held constant. The size of the selenium rectifiers was also a disadvantage, and the idea of using them was temporarily dropped.

A prototype of the BC was built at Royal in conformance with the design specifications outlined. This prototype proved satisfactory. Royal suggested that the drop-out relay be placed in parallel rather than in series with the ballast tubes, but this arrangement proved unsatisfactory.

The final schematic wiring diagram of the BC is shown in Fig. 3.

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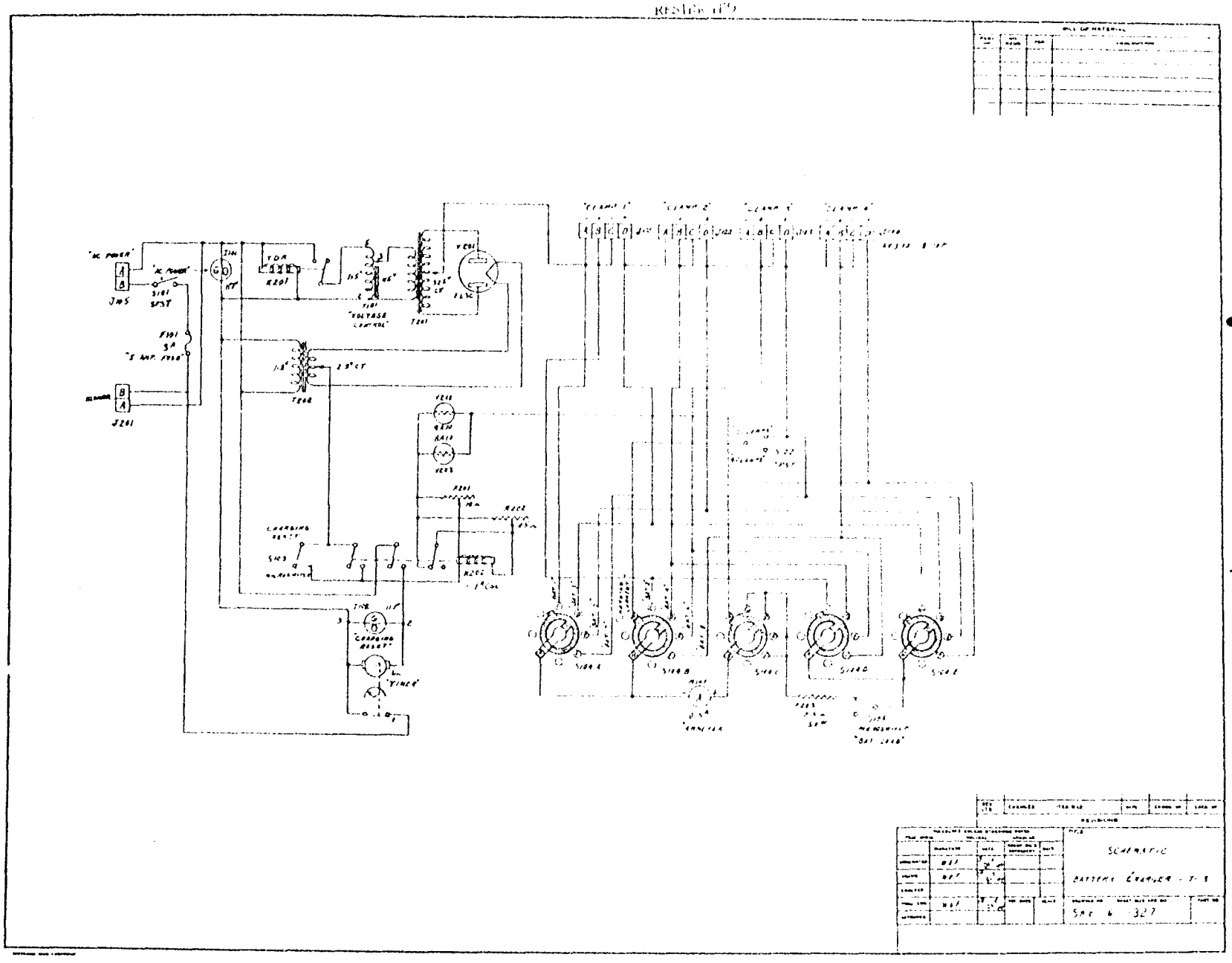

Fig. 3. -- Schematic diagram battery charger (T-3)

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Design Specifications

The BC was designed to charge eight ER-12-10 batteries in series using a constant current of 1.3 amperes. It was built to the following specifications:

1. The d-c charging current was to be produced by a full-wave rectifier and isolated from the a-c input voltage to the charger.
2. A timer was to be provided to indicate the total elapsed time and, in the event the charging current was interrupted, the remaining charging time. This timer was also to turn off the charger at the end of the charge time.
3. If the charging current fell below one ampere, the charging current was to be interrupted, the timer was to stop, and the CHARGE RESET lamp to go out. The minimum current at which the charger would start charging was set at 1.1 amperes.
4. The charging current was to be maintained at 1.3 ± 0.2 amperes and an a-c input voltage of 115 ±10 volts.
5. The charger was to be able to charge either six or eight batteries simultaneously.
6. A circuit was to be available to monitor the load voltage of each battery.
7. The meter to be used as an ammeter to measure the charging current and as a voltmeter to measure the battery-load voltages was to have an accuracy of two per cent and a range of zero to 5 amperes.

Controls and Components

The components on the BC panel (Fig. 1) are the BATTERY CURRENT ammeter, the VOLTAGE CONTROL Powerstat, the CHARGING TIME timer, and the necessary lamps, fuses, switches, and connectors.

In the upper left-hand corner of the panel is a 24-hour electrically driven timer, labeled CHARGING TIME, which indicates elapsed charging time. If the charging current is interrupted for any reason, the timer stops, indicating the remaining time necessary to charge the batteries. At the end of

the charge time it shuts off the BC. The timer does not run unless the batteries are being charged.

To the right of the timer is a switch labeled 3 CLAMPS-4 CLAMPS. As the name implies, the switch connects either three or four battery clamps (two batteries per clamp) in a series with the charging current.

In the upper right-hand corner of the panel is a ammeter labeled BATTERY CURRENT which indicated the charging rate and the condition of the batteries under load.

To the left of the BATTERY CURRENT ammeter is the BAT TEST switch. This switch, when pressed, connects a particular battery in series with the BATTERY CURRENT ammeter and a load resistor.

Below the timer on the left-hand side of the panel is a pilot lamp and a switch. This combination is labeled AC POWER. The switch applies a-c power to the BC, and the pilot lamp indicates when power is applied.

To the right of the AC POWER pilot lamp is a fuse holder for the 5-ampere fuse to protect the charger.

To the right of the fuse holder is the CHARGING RESET switch and pilot lamp. After the rectifier tube is warmed up and voltage is applied to the plates of the tube, this switch completes the charging circuit. The lamp lights when the BC is charging.

In the center of the panel is a selector switch which connects the BATTERY CURRENT ammeter in series with either the charging current or the load resistor.

To the right of the selector switch is a Powerstat, labeled VOLTAGE CONTROL. It is a variable autotransformer to adjust the charging current applied to the batteries and should be set so that the BATTERY CURRENT ammeter reads 1.3 amperes.

Below the AC POWER switch and in the lower left-hand corner of the panel is the 115-v, 60-cycle connector. This connector is used to connect the BC to a 115-v a-c source via the a-c power cable, CT102.

To the right of the 115-v, 60-cycle connector are four AN

chassis connectors, labeled CLAMP 1, CLAMP 2, CLAMP 3, and CLAMP 4. These connectors and four CT207 cables connect the d-c output of the BC to the batteries.

The BC chassis and the components mounted on it are shown in Figs. 2 and 4. The plate transformer, T201, is at the left rear side of the chassis. This transformer is used to step up the voltage of the a-c power source to operate the full-wave rectifier tube.

At the right of the plate transformer is the full-wave rectifier tube, V201, a type EL3C tube used to rectify the a-c voltage from the plate transformer.

Two ballast tubes, V202 and V203 (Amperite types 6A10 and 9A1) used to regulate the BC current output, are at the right of the rectifier tube. The rectifier ballast tubes and their sockets are mounted on a special shock-mounted support.

The time-delay relay, K201, is at the left center of the chassis. This relay delays the application of the a-c power to the plate transformer until the filament of the rectifier tube has reached its normal operating temperature.

A special under-current relay, K202, at the right of the time-delay relay, is used to open the d-c output circuit of the BC if the charging current drops below 1.1 amperes. The rectifier filament transformer, T102, at the right of the under-current relay is a step-down transformer to supply the low voltage and the current for the filament of the rectifier tube.

The cooling blower, B101, for the BC is at the right side of the chassis. The blower motor extends through the chassis, and the electrical connections are made on top of the chassis. The rotor of the blower and its housing are on the bottom of the chassis. For more efficient cooling the blower is used to circulate air past the ballast tubes and the rectifier.

Potentiometers R201 and R202, under the chassis, are used to adjust lock-in and fall-out currents of relay K202. The control shafts of these potentiometers are immediately in front of relay K202.

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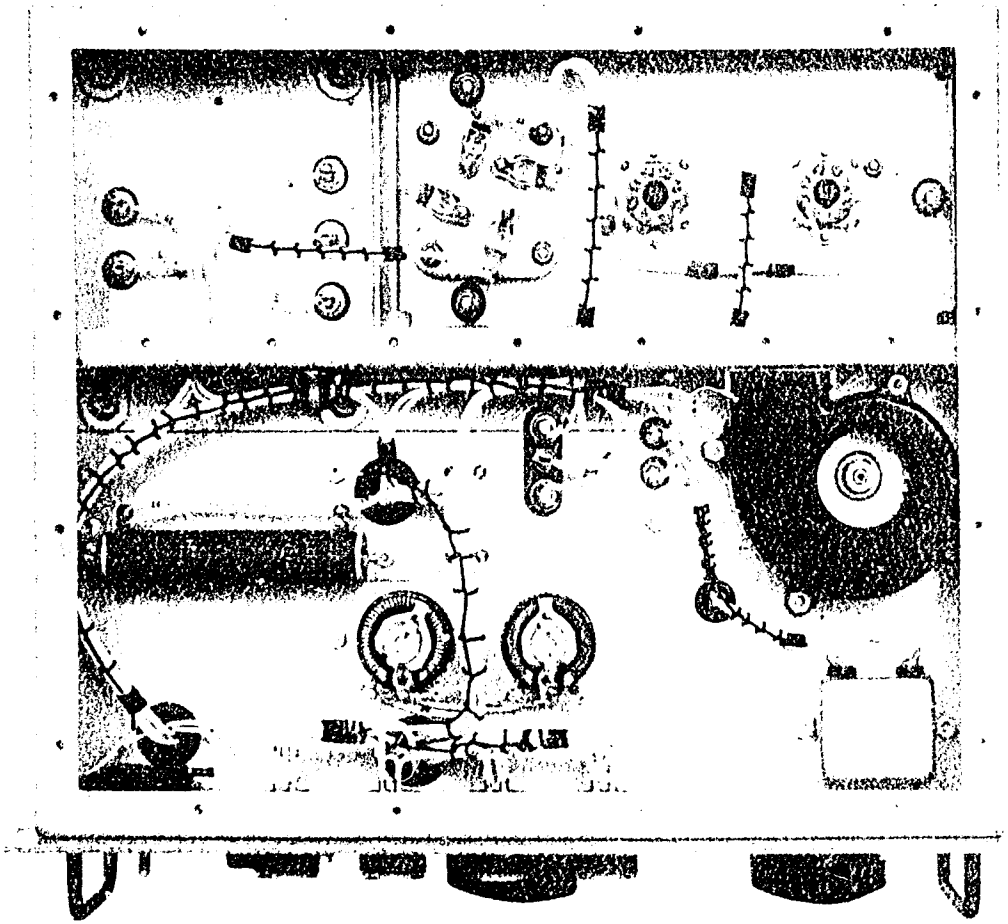

Fig. [illegible] -- Bottom of Chassis

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Theory

Reference should be made to Figs. 1, 2, and 3 for a clearer understanding of the material presented in the following paragraphs.

A. Rectification Section. -- External power of 115±10 volts, 60 cps, a-c is supplied to the BC by CR102. The power from this source is passed through the AC POWER switch and fuse. The switch labeled AC POWER is used to turn the equipment on, and the fuse is used to protect the BC and the power source from excessive currents in event of circuit trouble. The CHARGING TIME timer also contains a switch which keeps the BC turned off when the timer is set at zero. A pilot lamp labeled AC POWER lights when the BC timer is set for the desired charging interval.

The a-c power flowing from the timer is applied to filament transformer T202 and time-delay relay K202. The time-delay relay is used as a safety feature to prevent application of plate voltage to the plates of the rectifier tube until the filament has had time (30 seconds) to warm up to its normal operating temperature. After 30 seconds the contacts of the time-delay relay close, and the a-c input power is connected to the VOLTAGE CONTROL and to the primary circuit of the plate transformer. The VOLTAGE CONTROL Powerstat is used on the primary circuit of the plate transformer as a means of adjusting the primary input voltage to obtain correct secondary voltage for the plates of the rectifier tube. This adjustment determines the magnitude of the charging current. The a-c voltage from the secondary winding of the plate transformer is applied to the plates of the EL3C (or RMA 4B24) full-wave rectifier tube.

B. Current Control and Time Section. -- If the d-c output voltage of the rectifier is large enough, the under-current relay, K202, will close and lock in when the CHARGING RESET switch is held in. The charging current indicated by the BATTERY CURRENT ammeter must be at least 1.1 amperes to make the relay lock in. This lock-in current is determined by the resistance of potentiometer R201 in parallel with the relay coil. If the current falls below one ampere, the contacts of relay K202 will drop out. This drop-out current is determined by the resistance of potentiometer R202, which is connected in series with the relay coil when relay K202 is actuated.

The ballast tubes, V202 and V203, which are connected in parallel, limit the charging current to within the range of 1.3±0.2 amperes when the a-c source voltage varies between 105 and 125 volts. These tubes partially compensate for the difference in the d-c voltage required to maintain the charging current during the charging cycle. It should be remembered that this difference, if large, may be reduced by adjusting the VOLTAGE CONTROL.

The CHARGING TIME timer on the BC is an electrically driven 24-hour clock. Its indicator is so constructed that it will turn the BC input power off when the clock reaches zero. This timer is preset for a desired time interval, usually 20 hours, and runs until the interval has elapsed unless the under-current relay of the BC opens, disconnecting the a-c power source. The CHARGING RESET lamp is lighted when the timer is running and the batteries are being charged.

For monitoring purposes the BATTERY CURRENT ammeter is connected in series with the charging current when the BC selector switch is in the CHARGING CURRENT position.

A switch labeled 3 CLAMPS-4 CLAMPS is used to charge either 3 or 4 clamps at a time. It should be noted that each clamp contains two batteries.

C. Battery Load Test Section. -- When the BC selector switch is placed at any one of the BAT positions, the BATTERY CURRENT ammeter and a 2.5-ohm load resistance are connected in series by placing the BAT LOAD switch across the corresponding battery terminals. Pressing the BAT LOAD switch to close its contacts completes the circuit to the battery terminals. The BATTERY CURRENT ammeter indicates the load current of the particular battery under test.

Suggested Operating Procedure

Operating procedure of the BC should be as follows:

1. Place the AC POWER switch in the OFF position; place the BC selector switch in the CHARGING CURRENT position; place the VOLTAGE CONTROL in the fully counterclockwise position; place the 3 CLAMP-4 CLAMP switch in the desired position.

2. Connect cable CT102 between the AC POWER connector on the BC and 115-v, 60-cps, a-c power source.

3. Connect the CT207 cables between the battery clamps to be charged and the connectors on the BC, starting with CLAMP 1 and proceeding to CLAMP 4, in that order.

4. Place the AC POWER switch in the ON position.

INDICATION: The AC POWER lamp lights.

5. Place the CHARGING TIME dial at 20 hours.

6. Wait 20 seconds before proceeding further.

7. Hold the CHARGING RESET switch pressed in; turn the VOLTAGE CONTROL clockwise until the CHARGING RESET lamp lights and the BATTERY CURRENT ammeter indicates a charging current of 1.3 amperes.

INDICATION: The AC POWER and CHARGING RESET lamps light; the BATTERY CURRENT ammeter should read 1.3 amperes.

8. Readjust the VOLTAGE CONTROL periodically so that the BATTERY CURRENT ammeter continues to read 1.3 amperes.

9. At the end of the charge time the CHARGING RESET lamp will go out, and the CHARGING TIME timer and BATTERY CURRENT ammeter will read zero.

10. Place the AC POWER switch in the OFF position.

INDICATION: The AC POWER lamp will go out.

11. Place the selector switch in the BAT 1 position; press the BAT LOAD switch and read the CHARGING CURRENT ammeter.

INDICATION: The reading on the BATTERY CURRENT ammeter should exceed 4 amperes.

12. Repeat step 11 for the remaining battery positions being used.

INDICATION: Same as for step 11.

13. Return the selector switch to the CHARGING CURRENT position; remove all cables.

Operational Test Results

A. Preparations for Operational Tests.

1. The BC (P-3), Serial No. XI, made by Royal, was installed in a Royal nonshock-mounted case for the operational tests (Fig. 5).

2. The series of tests made on the BC determined the regulation of the charging current output. The temperature rise of the various components within the BC under uncontrolled ambient temperatures and a controlled high ambient temperature was measured.

The a-c input voltage of the power source used in the BC charging current regulation tests was varied from 105 to 125 volts over a time interval of 8 minutes at the beginning and end of the 20-hour charge period.

3. The ambient temperature was not controlled in the component-versus-ambient-temperature tests, except in the final high-ambient-temperature test.

A Brown potentiometer was used to make all temperature recordings from each thermocouple at 8-minute intervals.

4. Four clamps of batteries were prepared for use in the tests. These batteries were charged by the BC at a current of 1.3 amperes for a period of 20 hours. The charging current of 1.3 amperes was initally established by adjusting the voltage of the a-c power source to 115 volts.

B. Testing Procedures.

1. The ability of the BC to regulate the charging current for various input voltages from the a-c power source was checked at the beginning of the first charge by varying the voltage of the a-c power source from 105 to 125 volts, in 5-volt steps, over a time interval of 8 minutes. Graphs 1 and 2 (Fig. 6)

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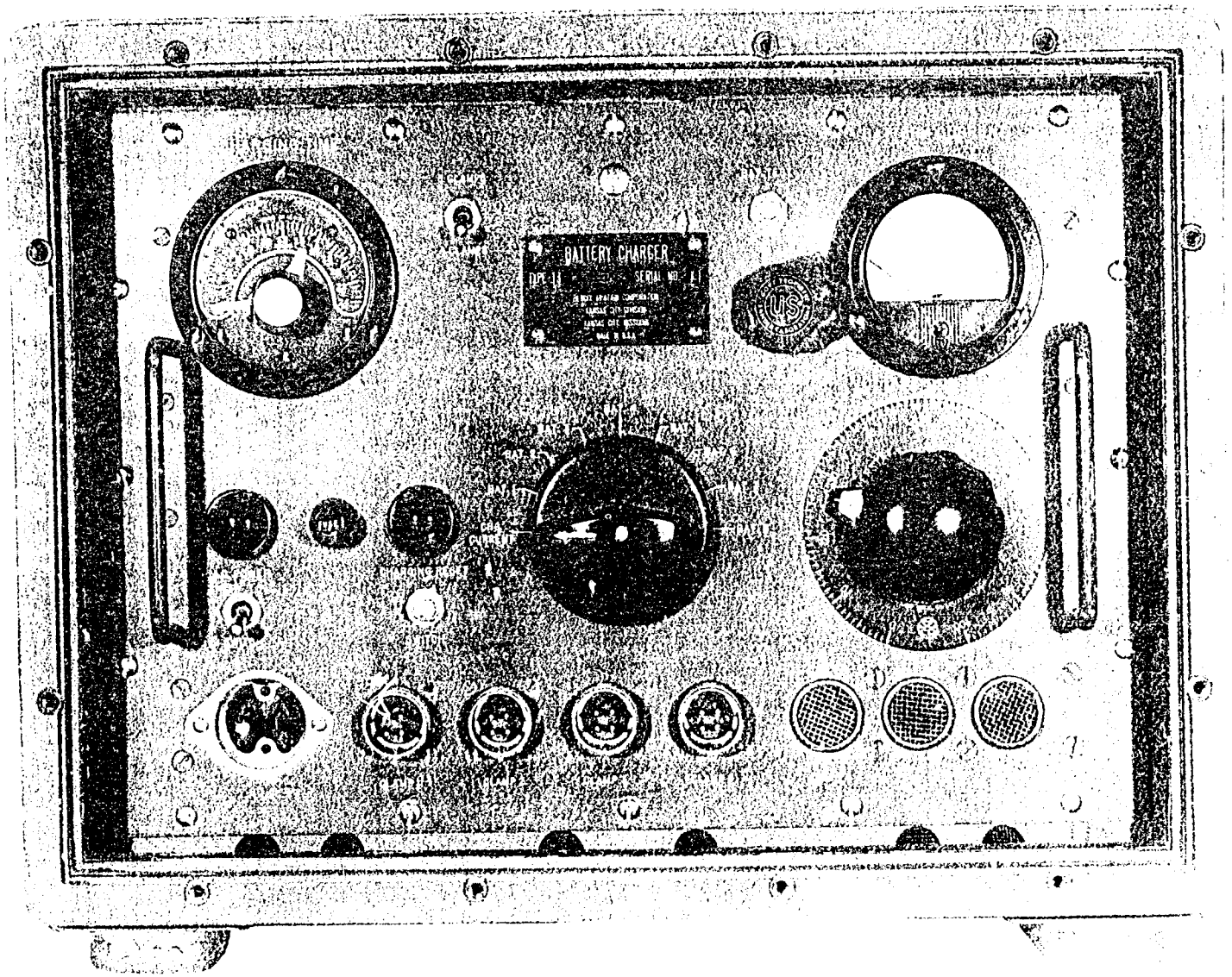

Fig. [illegible]. -- BC in Royal case

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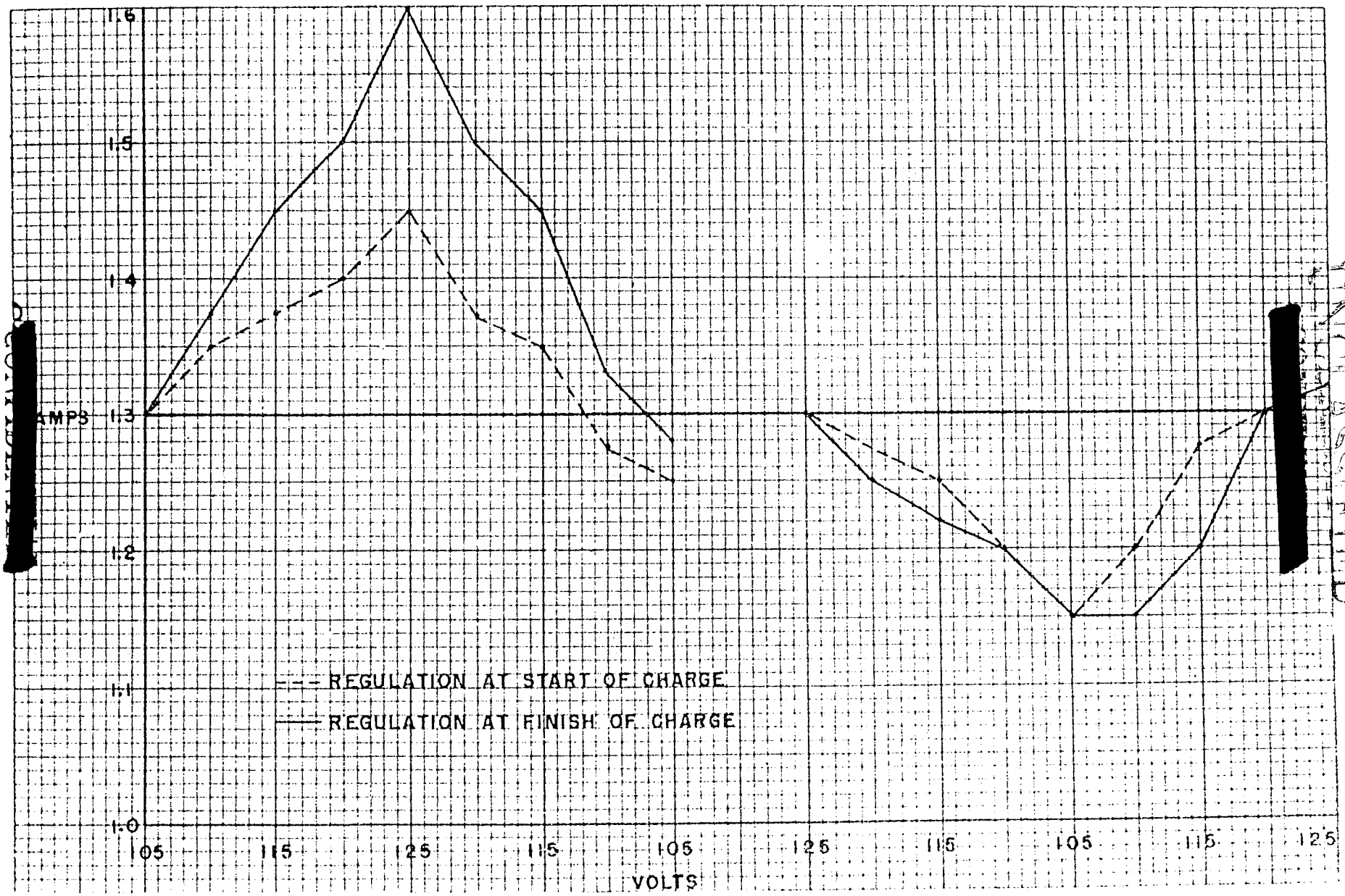

Fig. 6. -- Current regulation capability of BC

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show the regulation capability of the BC at the beginning and end of the 20-hour charge period.

2. It can be seen from these graphs that the maximum charging current recorded during the initial part of the charge interval was 1.45 amperes; the minimum current recorded was 1.15 amperes.

3. The maximum and minimum charging currents recorded at the end of the charge period were 1.6 and 1.15 amperes, respectively. These excursions in the BC charging current are within the limits of 1.0 to 1.6 amperes set for BC charging current.

4. During the charging current regulation check, temperatures at 16 points in the BC were recorded. These temperatures are shown in Fig. 7. The greatest temperature rise was found on the surface of the insulation of the BC ceiling that passed between potentiometers R201 and R202. The maximum temperature rise was from the ambient temperature of 28°F to 125°F.

5. At the end of the charging period the maximum temperature recorded was again found at the same point between the potentiometers. The temperature rose to a maximum of 130°F from an ambient temperature of 70°F. This change in temperature was found to follow the rise and fall of the charging current.

6. The graphs of temperature-versus-time are shown in Fig. 8 for thermocouples located in the air above the BC rectifier and regulator tubes, for the surface insulation of the cable between potentiometers R201 and R202 under the rectifier and regulator tube sockets, and for the ambient temperature. These graphs reveal that

a. The temperature of the surface insulation for the cable under the chassis between the potentiometers rose 50°.

b. The changes in temperatures at the three points within the BC closely followed the change in ambient temperature.

C. Ambient Temperature and Component Temperature. -- At the end of the charging period a series of component temperature tests was made at ambient temperatures of 65°, 75°, and 85°F, with thermocouples located in the free air under the rectifier and regulator tubes, on the Powerstat winding, on the

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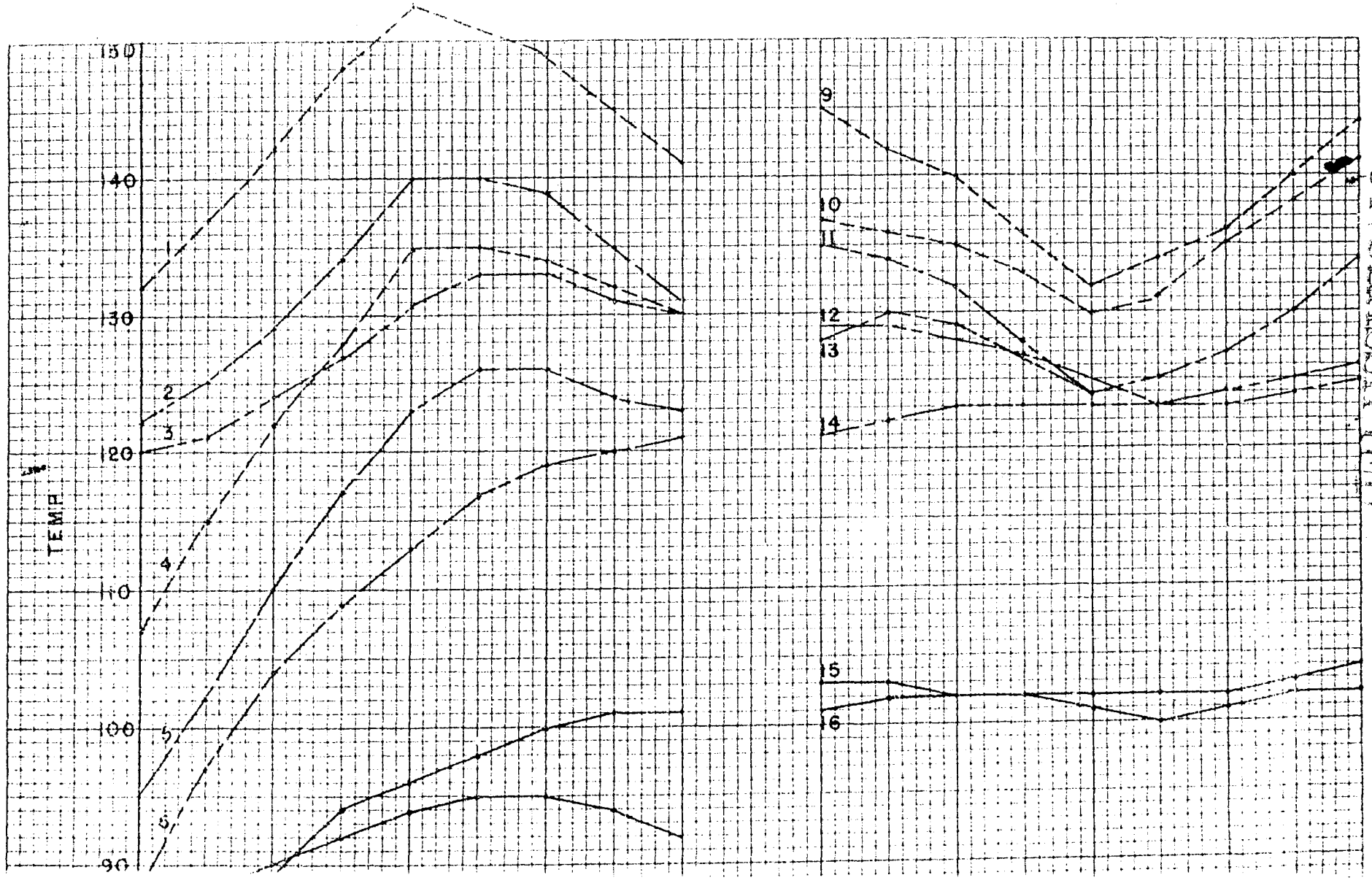

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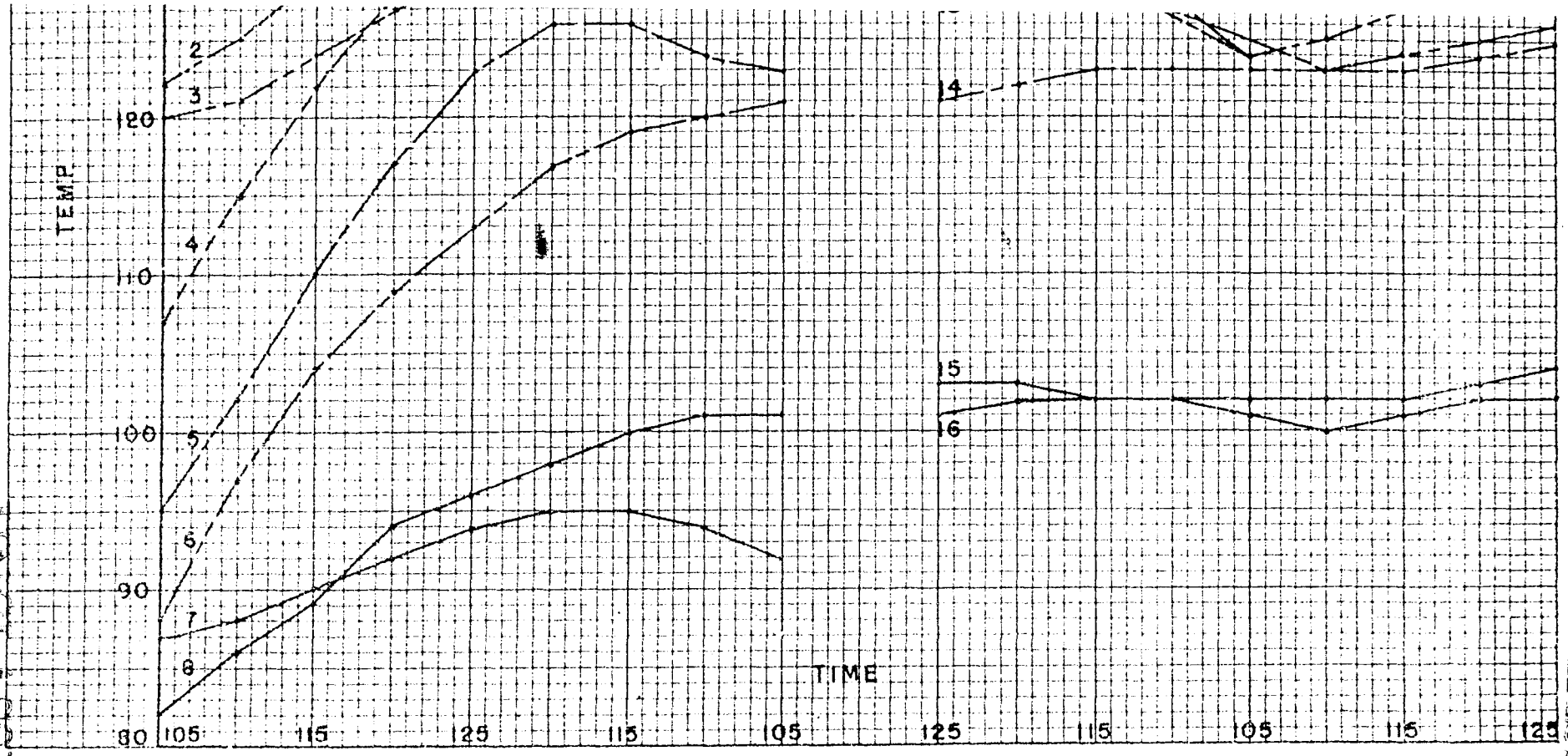

1. Air above tubes - finish of charge
2. Blower motor - finish of charge
3. Between potentiometers - finish of charge
4. Air above tubes - start of charge
5. Blower motor-start of charge
6. Between potentiometers - start of charge
7. Under tubes - finish of charge
8. Under tubes - start of charge
9. Air above tubes - start of charge
10. Air above tubes - finish of charge
11. Blower motor - finish of charge
12. Between potentiometers - finish of charge
13. Blower motor - start of charge
14. Between potentiometers - start of charge
15. Under tubes - finish of charge
16. Under tubes - start of charge

Fig. 7. -- Temperatures recorded at 16 positions in BC

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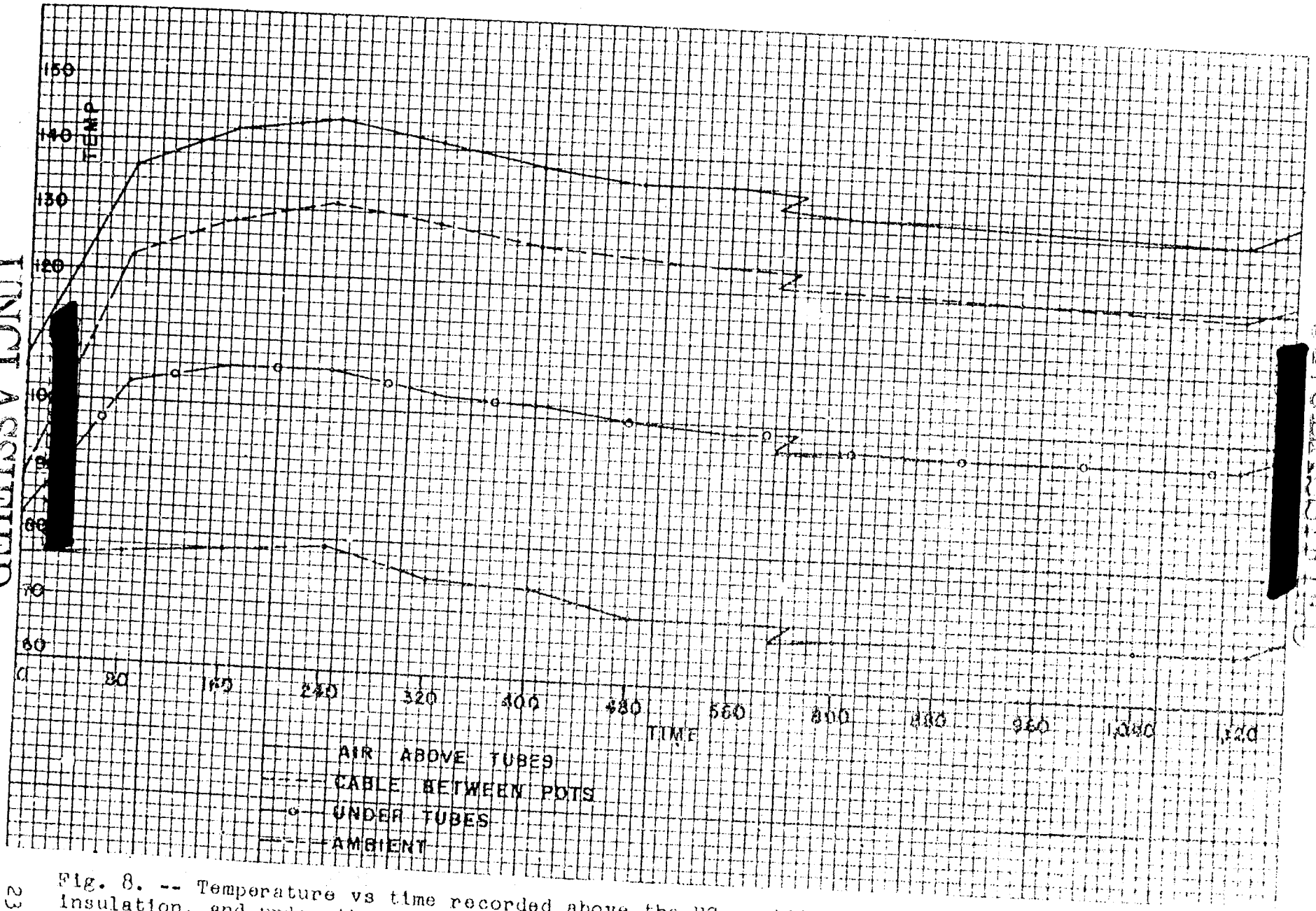

Fig. 8. -- Temperature vs time recorded above the BC rectifier, ballast tubes, cable surface insulation, and under the rectifier ballast tube sockets, with normal BC cooling arrangement

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surface of the BC plate transformer, T201, and finally, in the free air above the regulator and rectifier tubes. The temperatures recorded at these points are shown in Figs. 9, 10, 11, 12, and 13. The amount of temperature rise in each test was almost the same for each value of ambient temperature.

D. More Efficient Component Cooling Method. -- It was decided, in the light of the results presented in paragraph C, that there should be a more efficient method of cooling the BC components. Two methods of cooling were tried, as outlined below:

1. A hole was cut in the bottom plate of the BC chassis directly below the blower intake. The components above the chassis were thus cooled more efficiently. However, the components mounted below the chassis were cooled less efficiently. This method of cooling was abandoned, and the cooling method described in the following paragraph was tried.

2. The three air-intake holes on the BC front panel were covered. The three connectors at the far left of the panel were removed to allow the air to pass completely across the bottom of the chassis as it was sucked in by the blower. This airflow arrangement resulted in more efficient cooling of the BC components.

To test the efficiency of the second method of cooling the BC components, it was decided to charge a set of batteries for a 20-hour period, using an a-c voltage of 115 volts and a charging current of 1.3 amperes.

The results of this test are plotted in Fig. 14. It can be seen that the average temperature rise was about 35°F, or 15° less than that of the original BC cooling arrangement.

To test the efficiency of this cooling method more fully, the BC was operated at a controlled ambient temperature of 120°F. The results of this test are shown in the graphs in Fig. 15. It can be seen that at this ambient temperature the average temperature rise was 40°F, only 5° greater than the temperatures found in the test described in the preceding paragraph.

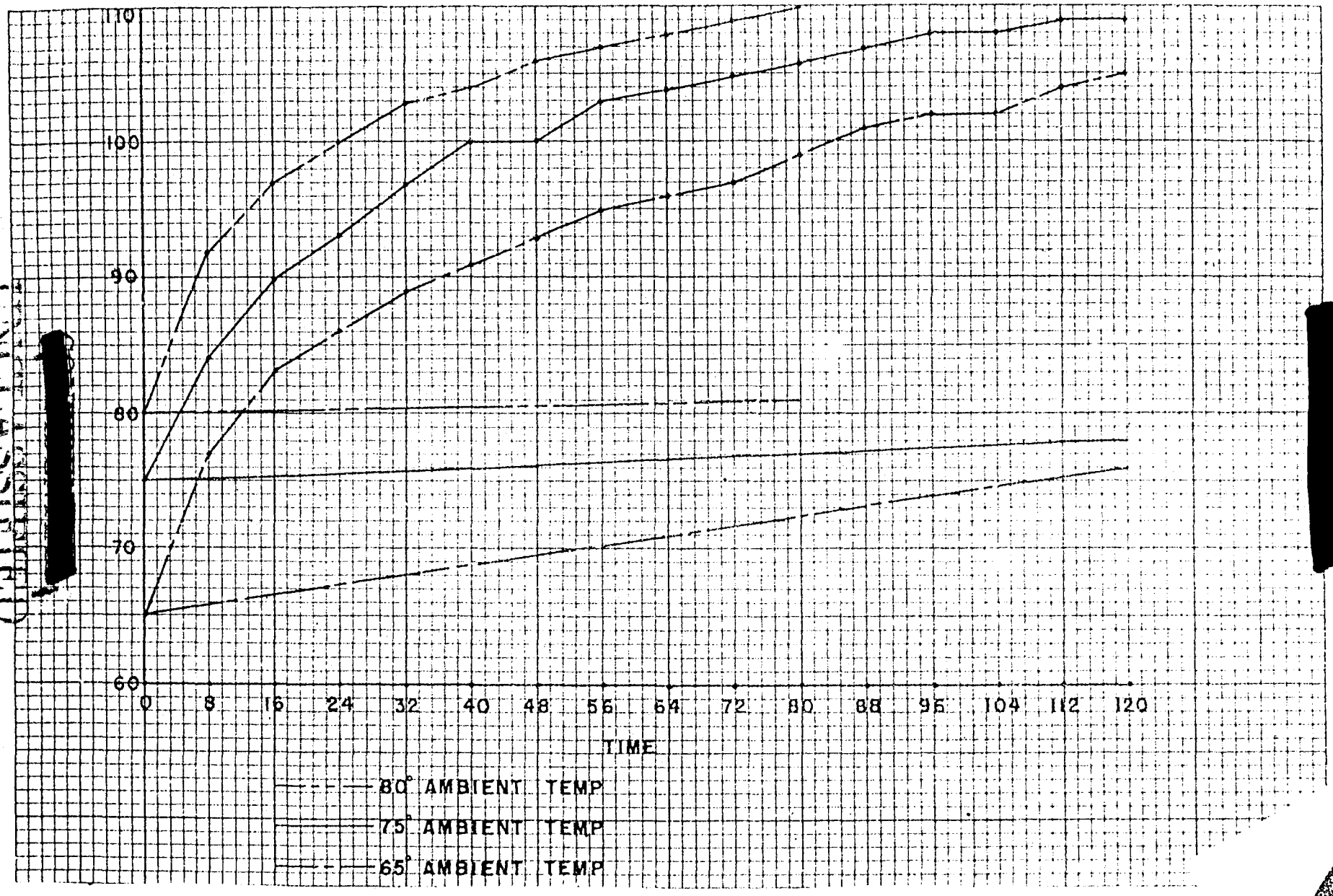

Fig. 9. -- Free air below tubes at ambient temperatures of 65°, 75°, and 80°F vs ti

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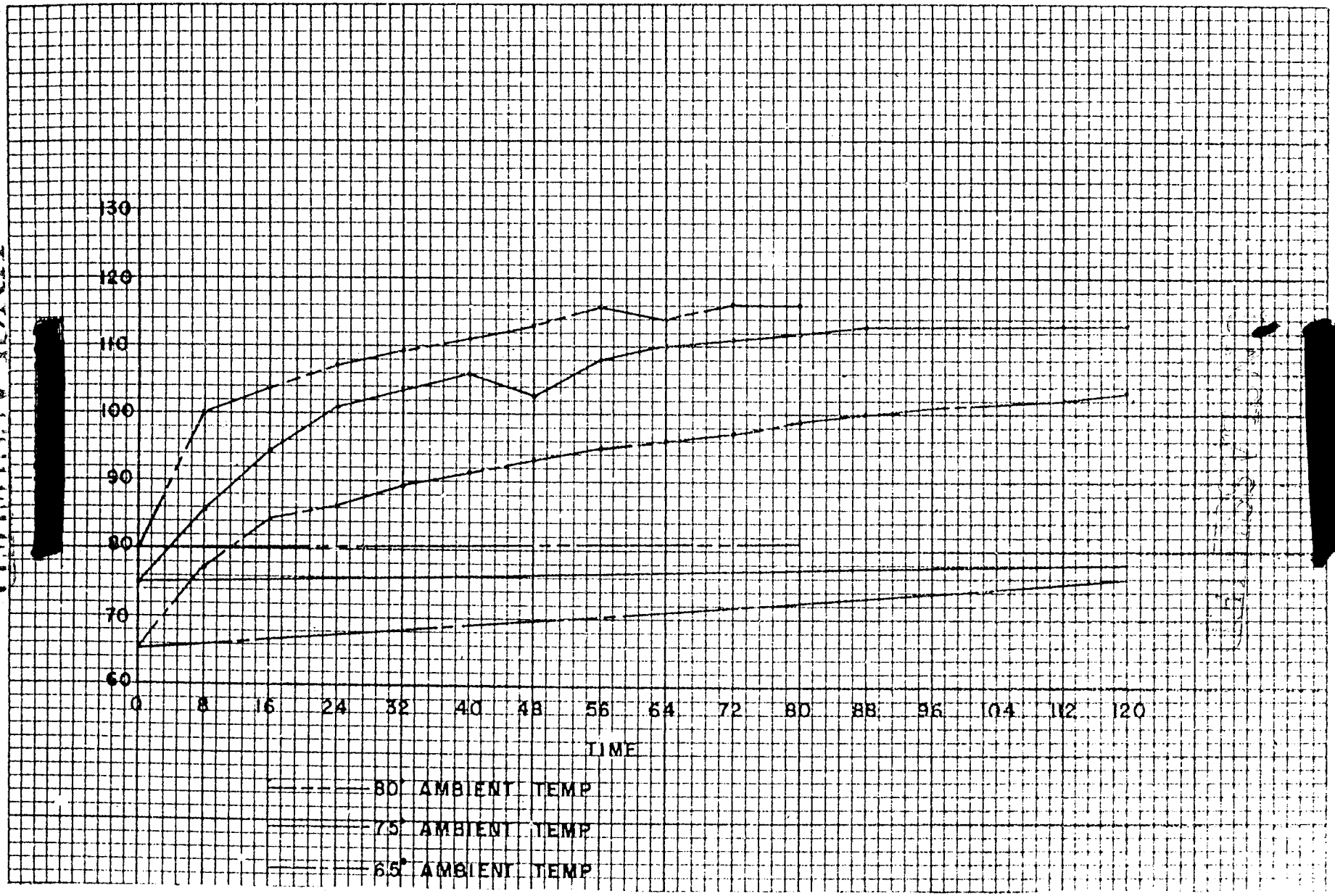

Fig. 11. -- Cable insulation surface temperature rise (cable between potentiometers R201 and R202) at ambient temperatures of 65°, 75°, and 80°F vs time

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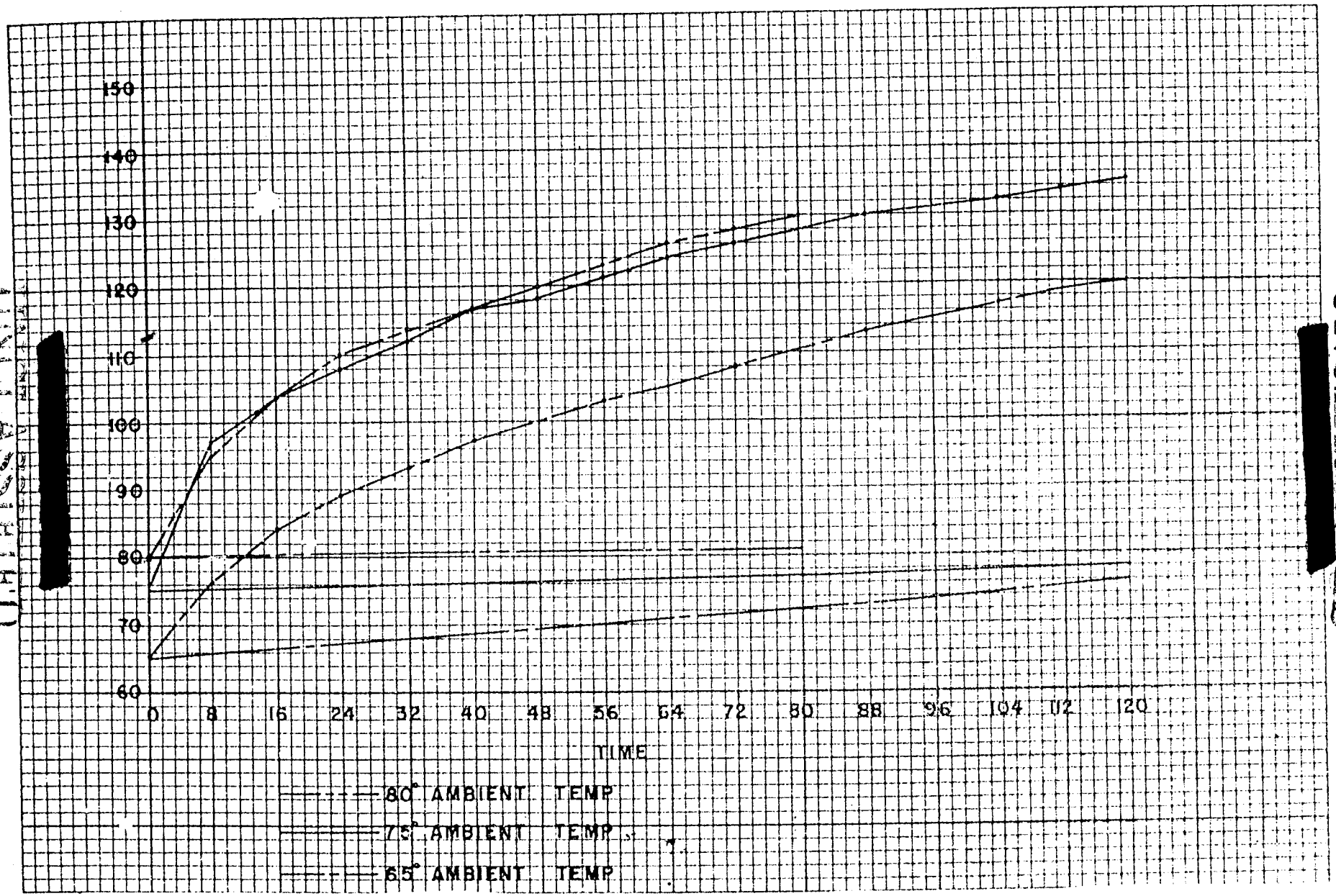

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Fig. 12. -- Plate transformer T201 temperature rise at ambient temperatures of 65°, 75°, and 80°F vs time

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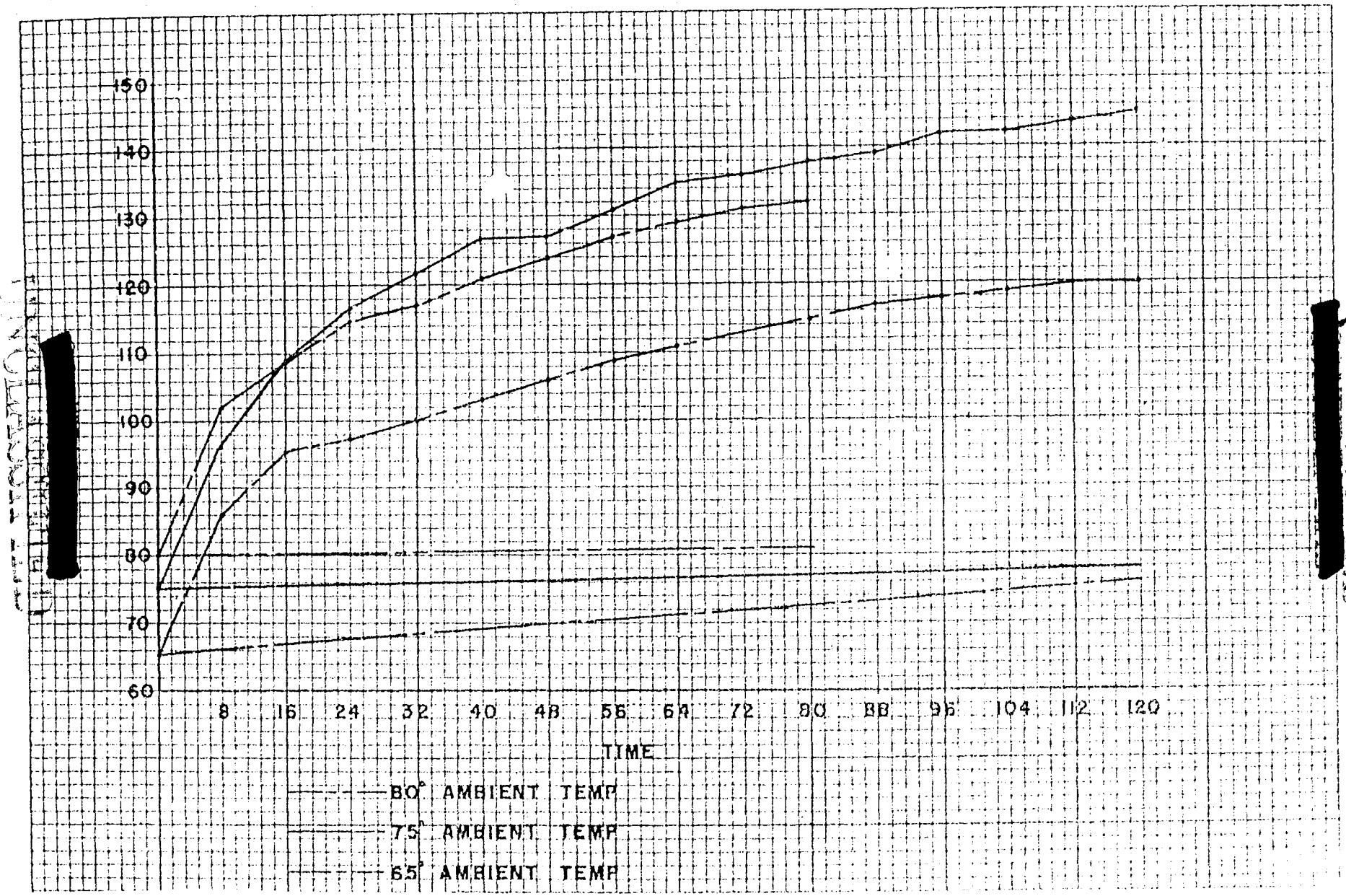

Fig. 13. -- Air temperature above rectifier tube and ballast tubes at ambient temperatures of 65°, 75°, and 80°F vs time

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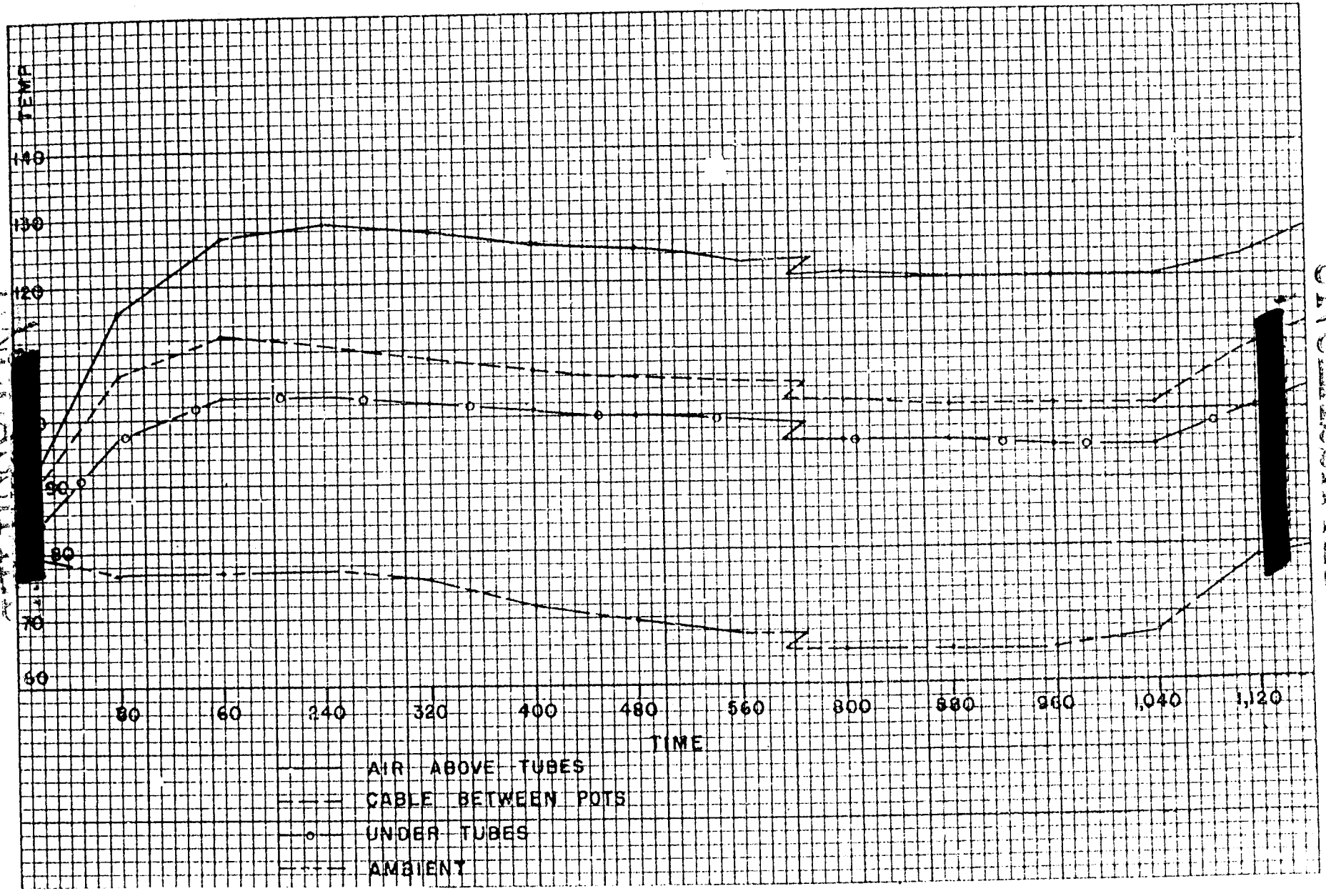

Fig. 14. -- Temperature vs time with modified cooling

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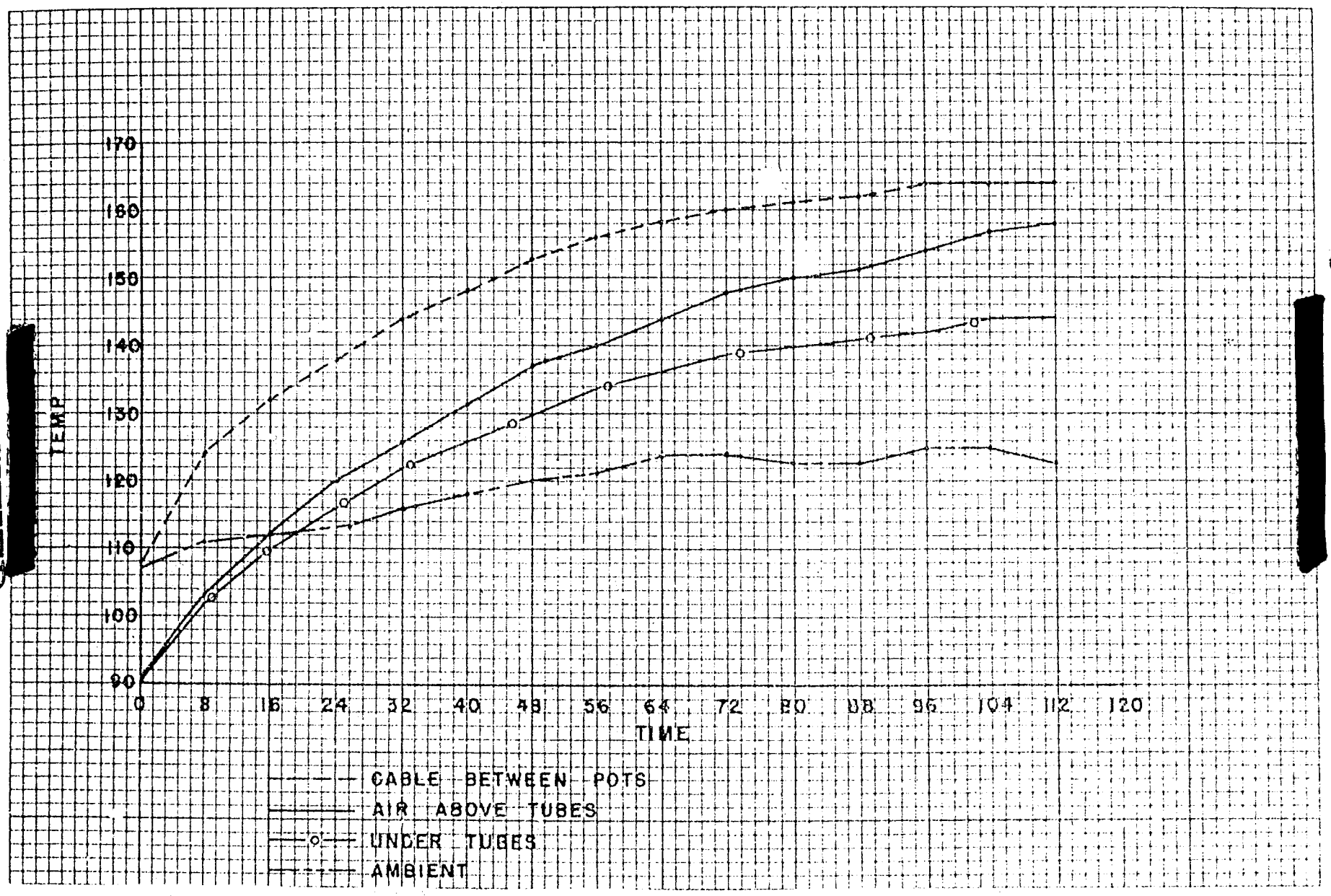

Fig. 15. -- Temperature vs time for a high controlled ambient temperature of 120°F

E. Conclusions and Recommendations. -- To assure efficient and safe operation of the BC, it is concluded that

1. A more efficient method of cooling is needed.

2. Wire having high-temperature insulation and suitable fungicidal properties should be used.

The foregoing conclusions led to the following recommendations:

1. The cooling vents should be moved from their present position on the BC panel to the opposite side. By moving these vents cooling will be more efficient. This change in cooling method will allow the cables passing between potentiometers R201 and R202 to be moved to another location, resulting in cooler cable insulation.

2. The wire used in the BC should have high-temperature insulation which includes suitable fungicidal properties. The wire insulation should be capable of withstanding temperatures greater than 140°F.

The wire in the cable under the BC chassis should be rerun to obviate the high-temperature points found around potentiometers R201 and R202. Rearranging the ventilating holes on the BC panel will allow this to be done.