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U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Characterization of Electrical Ignition Sources Within Television Receivers

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CHARACTERIZATION OF ELECTRICAL IGNITION SOURCES WITHIN TELEVISION RECEIVERS

George J. Rogers and David D. Evans

The ignition of television receivers initiated by electrical failures in the circuitry was examined by studying four receivers. They were: two black and white portables, a color portable, and a color console receiver. Selected locations within the circuitry were stressed by introducing full or partial short circuits to simulate the failure of electronic components. The temperatures and increased power dissipation generated by short-circuited components were recorded. Although component temperatures greater than 500°C were achieved, no flaming ignition sources were generated.

For comparative purposes the energy release rate of the ignition source specified in the UL 1410 test procedure was measured. Supplemental measurements on the operating temperatures of chassis components under varying ventilation conditions were also made.

Key words: Electrical failure; fire containment; ignition; television fire.

1. INTRODUCTION

This study of television receivers was initiated at the National Bureau of Standards (NBS) to provide technical support to the U.S. Consumer Product Safety Commission (CPSC). The study was designed to provide data relevant to the containment of television receiver fires and to the existing voluntary flammability standards. The present flammability requirements are contained in the Underwriters Laboratories publication, "Standard for Television Receivers and Video Products," (UL 1410) [1][1].

The entire program of study was to be divided into two phases. In the first phase, the television receiver market would be analyzed to determine the various available construction types and sizes being sold. Then experiments were to be conducted to document the burning characteristics of the various current television receiver constructions. In phase two of the study, this information would be used to facilitate defining levels of containment, and to develop performance fire tests to assure the achievement of containment.

In June 1978, the Center for Fire Research at NBS, Gaithersburg, Maryland, and Factory Mutual Research Corporation (FMRC), Norwood, Massachusetts, began a cooperative study to supply the data requested as part of the phase-one CPSC program. The work at NBS was to continue through September 1978.

To satisfy the objectives of phase one, NBS was to study the ignition of television receiver components by simulated electrical failures in the circuitry.

[1] Numbers in brackets refer to the literature references listed at the end of this report.

FMRC was to study the fire growth and propagation from a sustained flaming ignition source in various locations on the receiver chassis. Simply, NBS would investigate means of obtaining an ignition source and FMRC would study the growth of the fire given that a flaming ignition source had been generated. Since the phase-one study was concerned with the intensity of the fire that could develop from the interior components comprising a television chassis, all the plastic television receiver enclosures would be replaced by materials that would not contribute to the fire in the FMRC tests. The NBS tests, only concerned with ignition, would be terminated at the initiation of fire spread from the ignition source.

During the studies, NBS would be responsible for determining the energy release rate of the ignition source specified in the UL 1410 test procedure [1] and obtaining operating temperature data for unventilated television receivers. In the course of the FMRC study a method for simulating television aging and dust deposits was to be developed. FMRC would also attempt to develop a classification system for television receiver chassis.

The data gathered in these phase-one studies will contribute to a better perception than existed previously of the ignition and fire spread resistance of television receivers currently being marketed. These data can also serve as the basis for the phase-two study of television receiver fire containment.

2. SELECTION OF TELEVISION RECEIVERS

Four television receivers were purchased for use in the four-month phase-one study at NBS. An effort was made to obtain receivers that would characterize the common household receivers being marketed. All the receivers purchased used solid-state circuitry and none had the "instant on" feature; each was made by a different U.S. manufacturer. As shown in the table below, two were color receivers: one large 63.5-cm (25-in) diagonal screen size console model manufactured in January 1977 and a smaller 48.3-cm (19-in) portable manufactured in March 1978. The remaining two receivers were black and white portables, one 48.3-cm (19-in) manufactured in May 1978 and the other a 30.5-cm (12-in) manufactured in December 1976. The nominal power consumption at 120 volts for the receivers was 200W, 89W, 55W, and 50W respectively. These four different popular brand name receivers were purchased from local distributors. The selection of specific brands was based on the type of circuity used, the availability of circuit diagrams, the ease of obtaining factory replacement components, and the willingness of the distributor to accept a government purchase order.

TELEVISION RECEIVERS TESTED

Type	Diagonal Screen Size	Date Manufactured	Rated Power
color	63.5-cm	January 1977	200W
color	48.3-cm	March 1979	89W
B/W	48.3-cm	May 1979	55W
B/W	30.5-cm	December 1976	50W

3. EXPERIMENTAL APPROACH

Electrical failures within the television receiver can lead to a fire condition. The cause may be a complete or partial short in a capacitor or transformer which caused increased power consumption in other circuit components, often leading to an increase in operating temperature or failure. In this testing program deliberate shorts were introduced into the television receiver circuit at capacitor and transformer connection points. During any test, only one short was introduced. Documenting the physical and electrical response of the receiver to this type of fault was the primary objective of each test in the program. No work was done to simulate arcing or glowing connection failures.

In each of the television receivers obtained for study in this program, chassis components that might serve as ignition sources needed to be located. As a first step, statistics on past television fires were reviewed to obtain data on the frequency of fires identified as starting in various sections of the television chassis. The best source of this type of data was Harwood's report, "Analysis of Subpoenaed Television Data" [2]. The data in this report were to be analyzed fully as part of the FMRC program. A cursory review of the report showed that when television fires occurred, the frequent locations identified as the source were the power supply, high voltage, and switch areas. Making use of this information, the testing in the NBS program was predominantly devoted to analysis of the power supply and high-voltage sections of the television circuitry.

Several considerations were made in determining which components to stress in the selected areas of the chassis. Components with normally high operating temperatures were identified by probing the chassis under normal operating conditions. By studying circuit diagrams, means to overload these high temperature components by simulating circuit failures were determined. In addition, consideration was also given to introducing a circuit failure that would lead to overheating components in proximity to flammable materials, such as, plastic wire tie downs, plastic terminal connectors, and wire bundles. Again study of circuit diagrams and analysis of the normal operating conditions determined the practical choices for testing.

These failures were tested in a sequence of least to most electrically destructive. After each failure mode was tested, necessary repairs were made to return the television to its normal operating condition using factory replacement parts where possible. It should be pointed out that the generation of fires within a television receiver started by electrical failures is a process that involves chance. It should also be clear from the above discussion that no attempt was made to exhaust all of the possibilities for electrical failure within the receivers.

In addition to testing circuits and components in-situ, tests of bench-top circuit mockups were performed to determine the response of components to controlled levels of electrical overload. In particular, surface temperature and deterioration measurements were made on several specific components like those overstressed in the receiver tests.

4. DOCUMENTATION

To document all the experimental work on the four television receivers, color video tapes were made of each test. The typical experimental setup is shown in figure 1. (Notice in figure 1, that for tests with the back cover of the television enclosure in place, circuitry was viewed through a polycarbonate window.) Temperature data in selected locations on the television chassis and enclosure were probed using thermocouples and monitored using a digital data acquisition system.

5. PREPARATION OF RECEIVERS

In preparation for testing, the normal operating conditions of each of the four television receivers were thoroughly studied. Each receiver was instrumented with up to 8, 0.025-cm diameter, type K thermocouples many of which were wrapped circumferentially around key resistors and secured using high temperature cement. The temperatures of transformer cases, fuse holders, wire bundles, and the television receiver cabinet were measured in some tests.

As part of the FMRC study, methods of aging components to simulate 12 years of use and methods to deposit dust and grease throughout the chassis were developed. None of the televisions tested in the NBS program were exposed to an environment designed to simulate aging. Copying the method of dust and grease deposition developed by FMRC[2], a small number of tests were run with the dust-conditioned 30.5-cm (12-in) black and white portable. These tests results were compared to identical tests conducted without dust.

In tests where the full television enclosure was used, a section of the back cover was sacrificed and replaced by a polycarbonate window through which the circuitry could be viewed. This window was molded to fit the contours of the television enclosure and perforated to allow for ventilation equal to the section it replaced. In some cases, the television receiver was tested with the back of the enclosure removed. This condition was not considered detrimental to the test results, as the maximum difference in component temperature between the entire enclosure in place, and the back removed, was 20°C (see table 3).

6. EXPERIMENTAL RESULTS

6.1 Summary

The four television receivers used in this study of ignition sources represented different types of construction. Most of the circuits of the black and white sets were mounted on a single printed circuit board placed horizontally in the 30.5-cm (12-in) set and vertically in the 48.3-cm (19-in) set. The color sets used modular construction with some of the printed circuit modules mounted horizontally and some mounted vertically in each case. In the 48.3-cm (19-in) color set, most of the modules were mounted horizontally while in the 63.5-cm (25-in) set, most were mounted vertically. The 63.5-cm (25-in) set differed from the others in that the circuits were assembled in three separate units.

These receivers used different design approaches to obtain DC voltages. Power transformers were used to furnish all DC voltages except the anode and screen voltages of the kinescope (picture tube) in the 48.3-cm (19-in) black and white set and in the 63.5-cm (25-in) color set. The 30.5-cm (12-in) black and white and 48.3-cm (19-in) color sets obtained DC voltages for most of the low-voltage circuits from one of the secondaries of the high-voltage transformer. In the 30.5-cm (12-in) set a half-wave rectifier was used to obtain DC voltages from the 110-volt supply for the horizontal circuits and audio and video output circuits. DC voltages for the remainder of the circuits were obtained from the secondary of the high-voltage transformer once the horizontal circuits were operational. The 48.3-cm (19-in) color set employed a bridge rectifier to obtain DC voltage for the horizontal driver and start-up voltages for the remainder of the horizontal circuits; after start up, all DC voltages except the collector supply to the horizontal driver were obtained from the high-voltage transformer.

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[2]Household dust is deposited on a layer of grease remaining from spraying the receiver with a mist from a mixture of 1 part lard, 1 part corn oil, and 500 parts acetone.

Kinescope heater voltage was obtained from the high-voltage transformer in the 30.5-cm (12-in) black and white and 48.3-cm (19-in) color sets, and from the power transformer in the 48.3-cm (19-in) black and white and 63.5-cm (25-in) color sets.

The number of tests that could be performed was limited by the time available. Since power supply circuits and high-voltage transformers were reported as frequent sources of fires in television receivers, testing was limited to these circuits or to circuits which would overload them. The test method chosen was to introduce short circuits into the set at locations where such faults would be likely to occur, such as across filter or decoupling capacitors, and where the resulting increase in current would stress resistors or transformers beyond their normal ratings. Thermocouples were bonded to components to record temperature changes. Direct current (DC) voltage and current measurements were made to record the electrical conditions, and were used to calculate power dissipation. Where possible, components chosen for overstressing were near connectors, wire bundles, or other flammable parts.

Because of the interaction between circuits in a television receiver, short circuits which overstressed components in one part of the set often caused a reduction of voltages and currents elsewhere. The result was that in many of the tests the overstressed component was damaged or destroyed without causing power to the set to be interrupted by a blown fuse or open circuit breaker. In all cases tested, however, there was a noticeable change in audio and/or video performance of the receiver. In those cases in which a short circuit caused one of the protective devices to interrupt power, resistive loads were introduced to simulate partial short circuits. These were chosen to produce maximum overheating without interrupting power to the circuit. In some of these cases, bench tests were made on components of the same type to determine the maximum temperature that could be reached before the component was destroyed.

By these methods, temperatures near 500°C were produced in all of the sets, and temperatures over 600°C were observed in the two black and white TV receivers. The results are summarized in table 1. A number of components were destroyed or damaged enough to require replacement. In some cases, the damage was accompanied by the emission of smoke but no flaming ignition was generated. Most of the components failed by increasing in resistance or burning out, so that the failures tended to interrupt circuit operation and did not spread to other components. Ceramic-coated resistors often showed little change while they were hot, but cracked after they cooled.

It is not possible to foresee every type of failure that might occur, or to attempt to reproduce them in limited tests of this type. The method used in these tests to produce failures tends to produce the non-spreading type of failure noted above as opposed to the over-voltage type of stress which is likely to produce a domino type of reaction in which the failure of one component leads to the successive failure of others. The short-circuited capacitor or short-circuited turn or winding is more likely to occur in power supply and high-voltage transformer circuits. In addition, it was felt that a sustained heat such as produced by these tests was more likely to lead to ignition than the momentary surge that would be produced by the over-voltage type of stress.

6.2 30.5-cm (12-in) Black and White TV Receiver

Except for the tuner assembly and picture controls, all components of the 30.5-cm (12-in) black and white TV receiver were mounted on a 15 by 33-cm printed circuit board which was mounted horizontally below the picture tube neck (fig. 2). A half-wave rectifier derived most of the DC voltages used in the set directly from the 120-volt AC supply (fig. 3). From this source, appropriate filter networks were used to obtain 140 volts for the video output and vertical control circuits, 125 volts for the horizontal output circuit, 100 volts for the horizontal driver, audio output and sync separator circuits, and 15 volts for the horizontal oscillator. A second half-wave rectifier in series with a low-voltage winding on the high-voltage transformer was a source of 35 volts for the vertical circuits, and 20 volts for the tuner assembly, IF and AGC circuits. Heater current for the kinescope (picture tube) was obtained from another low-voltage winding on the high-voltage transformer. The set was protected by a single 1.5-ampere slow-blow fuse in the 110-volt input.

6.2.1 Short Circuit in the Output of the 125-volt Supply (Test 1)

The 125-volt supply furnishes power to the horizontal output circuit through a decoupling network comprising a 56-ohm, 5-watt wirewound resistor (R4, fig. 3) and a 0.1 μF capacitor (C4). Capacitor C4 was short-circuited to simulate a short circuit in the capacitor or a short circuit to ground in the collector circuit of the output transistor. The increase in current blew the fuse and interrupted the power to the set. There was no damage to the set other than the blown fuse.

In the five seconds before power was interrupted, the temperature of R3 had increased from 147°C to 160°C, and the temperature of R4 from 125°C to 187°C. Later bench tests on resistors of the type of R4 indicated that the temperature of this resistor would have risen to over 600°C if the fuse had not blown.

6.2.2 Short Circuit in the Output of the 100-volt Supply (Tests 2 and 6)

A short circuit in the filter capacitor at the output of the 100-volt supply, C5, or a short circuit elsewhere in the circuits drawing current from this supply was simulated by short-circuiting the filter capacitor. This caused the current flowing through the 470-ohm, 3-watt wirewound decoupling resistor in this circuit (R5, fig. 3) to increase from 47 mA to 255 mA, with a resulting increase in dissipation from 1 watt to about 30 watts (test 2). Within a minute the temperature of R5 had increased from the normal 93°C to 500°C reaching a peak of 585°C 1 minute later (fig. 4). This temperature had decreased to 570°C when the test was terminated after 10 minutes. There was a slight trace of smoke for about 1 minute after the short circuit was applied. There was no raster during the test.

When the short circuit was removed after 10 minutes, the raster was restored, and no visible damage was found anywhere in the set. The resistance of R5 was measured and found to have decreased to 100 ohms. Later it was discovered that a crack had developed in R5 and that the resistance had increased to 1220 ohms.

Short-circuiting the 100-volt supply stops the signal to the high-voltage transformer and not only interrupts the high voltage but also the 20 and 35-volt supplies derived from one of the transformer windings. This results in decreases in current in other parts of the set which offset the more than five-fold increase in current in R5 so that the fuse did not open during this test. In the second test (test 6), it was found that the increase in the temperature of R5 was accompanied by decreases in the temperature of R2, R3, and R4.

6.2.3 Short Circuit in the Output of the 140-volt Supply (Tests 3 and 7)

The filter circuit of the 140-volt supply consists of a 470-ohm, 1-watt resistor (R1, fig. 3) and a 30-μF capacitor (C1). The resistor is a carbon resistor, rather than one of the wirewound types used elsewhere in the power supply circuits. It is supported by its leads about one-half centimeter above the printed circuit board on which it is mounted between R2 and R3 (fig. 5), both of which are ceramic encapsulated, wirewound types. Current through R1 is normally about 10 mA and the power dissipation less than 0.05 watt.

A short-circuited filter capacitor, C1, or short circuits to ground in the collector circuits of the video output or vertical driver stages increased the current in R1 to more than 200 mA and the power dissipation to more than 20 watts. This conditon was simulated by short-circuiting the filter capacitor with similar results in each of three tests (two tests documented in test number 3 and one in test number 7).

In the first test, the temperature of R1 had increased from the normal 50°C to 635°C within 30 to 40 seconds (fig. 6) accompanied by considerable smoke (fig. 7). Both R1 and R2, the latter, a 5-ohm fusible resistor, burned out. The fusible resistor was replaced by a wirewound resistor, and only R1 burned out in the succeeding tests. In the test number 7, the load on the 140-volt supply was increased by connecting a 500-ohm resistor across the output. The overload caused the temperature of R1 to rise to 370°C and the resistance to decrease to less than 100 ohms, but did not blow the fuse.

In each of these tests R1 was destroyed. It first charred and then cracked, opening the circuit. No other components in the vicinity of R1 were damaged. The excess current caused fusible resistor R2 to open on the first test; this would probably also have occurred on the succeeding tests if R1 had been replaced by another fusible resistor. This and the blown fuse were the only damage to the set. Operation was restored to normal after these components were replaced.

Several 470-ohm, 1-watt carbon resistors were bench tested to subject them to gradually increasing stresses. It was found that the resistors were stable when the dissipation was less than 2 watts, at which dissipation they operated at a temperature of about 125°C. Between 2 and 4 watts, the resistance tripled, and at dissipations greater than 4 watts the resistance decreased until the resistor was destroyed at dissipations between 6 and 7 watts. Maximum temperature reached in the bench tests was 420°C.

6.2.4 Short-circuited Winding in the High-voltage Transformer (Test 9)

In separate tests, the kinescope heater winding and the AGC winding of the high-voltage transformer were short-circuited to determine the effect of a short circuit in the high-voltage transformer. Power into the high-voltage transformer increased 2 to 4% and the temperature of R4 increased about 25°C, but there was no permanent damage to the set.

6.2.5 Short Circuit in the Output of the 15-volt Supply (Test 1)

Short-circuiting the output of the 15-volt supply stopped the horizontal oscillator and disrupted the operation of the set but did no permanent damage. The increase in dissipation in R6 (fig. 3) was well within the wattage rating of that resistor.

6.2.6 Effect of Dust Conditioning

Tests 6 and 7 were repetitions of tests 2 and 3 after the set had been dust-conditioned by depositing household dust on the residue of grease remaining after the interior of the set had been sprayed with a fine mist from a mixture of 1 gram lard and 1 gram corn oil dissolved in 500 ml acetone. Comparison of the results of tests 6 and 2 and of tests 7 and 3 reveals no differences that can be attributed to the presence of household dust. Test 8 in which the cabinet was sealed, and test 9 in which the heater winding of the high-voltage transformer was short-circuited were also made after the set had been dust-conditioned. The presence of dust had no effect on the results of these tests. The 30.5-cm black and white receiver was the only dust-conditioned set tested.

6.3 48.3-cm (19-in) Black and White TV Receiver

Except for the tuner and picture controls, the circuits of the 48.3-cm (19-in) black and white TV receiver are located on two chassis extending across the back and underneath the neck of the picture tube (fig. 8). Mounted on a 9 by 37-cm horizontal chassis are, from left to right when viewed from the rear of the set, the IF amplifier on a vertical printed circuit board, the power transformer, the rectifiers and filter of the 135-volt supply, and the high-voltage transformer. In figure 8 this chassis is hidden by the vertical printed circuit board on which the rest of the components are mounted. This 10 by 30-cm board is mounted in a frame which is hinged at the bottom to the horizontal chassis to permit access to the horizontal chassis and to the back of the printed circuit board. The components are mounted on the side of the board that faces the rear of the set.

The power transformer is the source of all DC voltages used by the set except the kinescope anode voltage (fig. 9). The 135-volt supply is obtained by full-wave rectification of the output of one of the transformer secondaries. A full-wave rectifier is used to obtain 32 volts from taps on the same secondary, and a half-wave rectifier is used to obtain 11 volts from another tap. The other transformer secondary furnishes heater power for the kinescope. The transformer primary is protected by a 0.6-ampere fuse which is soldered into the circuit.

6.3.1 Short Circuit at the Output of the 24-volt Supply (Tests 4 and 10)

The normal output of the 24-volt supply to the RF, IF and vertical oscillator circuits is about 110 mA. The power dissipated in the 56-ohm, 2-watt wirewound decoupling a temperature of about 80°C. A short circuit at the output of this supply (across C14) is the severest overload that could occur. This has the same effect as a short circuit in filter capacitor C14 or a short circuit to ground in one of the circuits which receives power from this source.

The short circuit increased the load on the supply to 520 mA and increased the dissipation in R14 to about 16 watts. In test 4, the temperature of R14 climbed to 560°C in 3 minutes and had stabilized at about 570°C when the test was terminated after 5 minutes (fig. 10). In test 10, the temperature climbed at about the same rate to 475°C after 1 minute 20 seconds, and thereafter decreased. At the same time resistor R14 was observed to move slightly, probably indicating that the heat conducted through the leads had loosened the solder holding the resistor to the printed circuit board. The drop in the temperature of the resistor following this occurrence probably indicates that the resistance had begun to change at this point.

Disruption of the operation of the circuits connected to the 24-volt supply, and possibly the overload on the transformer, caused currents in other parts of the set to decrease. Temperatures of R10 and R12 dropped 20°C and 30°C, respectively; temperatures of R11 and R13 dropped less than 10°C. The resistance of R14 did not change during test 4, but after test 10 had increased to 1700 ohms. There was no permanent damage to any other part of the set.

6.3.2 Further Tests on 24-volt Supply (Test 13)

The output of the 24-volt supply was again overloaded in a two-step test in which an additional 50-ohm load was connected across the output of the supply for 10 minutes followed by short-circuiting the output of the supply at C14. The 50-ohm load increased the current through R14 to 325 mA, but decreased the current to the rest of the 24-volt circuits. Power dissipated in R14 increased to about 6 watts and the temperature increased to 215°C (fig. 11). When the 24-volt supply was short-circuited completely, dissipation increased to 16 watts as before, and the temperature increased to a peak of 530°C after 4 minutes followed by a gradual decrease to about 400°C when the test was terminated at the end of 10 minutes (fig. 11).

The gradual decrease in temperature probably indicates an increase in the resistance of R14, although there was no appreciable change in resistance noted at the close of the test. The printed circuit board underneath R14 was slightly charred (R14 was mounted by its leads about 1-cm above the board). Other than that, there was no permanent damage to the set.

During the test, thermocouples on the case, fuse, transformer and neck of the picture tube each showed an increase in temperature between 1°C and 3°C. Temperature of components in the 32 and 135-volt supplies decreased 20°C to 25°C.

6.3.3 Short Circuit in the 26-volt Supply to the Low-power Horizontal Circuits (Test 5)

The 26-volt supply furnishes about 30 mA to the horizontal oscillator and driver circuits through a 150-ohm, 1/2-watt film resistor (R13, fig. 9). A short-circuit in capacitor C13, or a short circuit to ground in the collector circuit of the horizontal oscillator or driver would draw maximum current from this source.

When the circuit was short-circuited to ground at the junction of R13 and C13, the current in R13 increased to 200 mA and the power dissipation to about 6 watts (from a normal 0.15 watt). The temperature of R13 rose to 645°C in the first 2 minutes then declined gradually to about 610°C after 5 minutes when the test was terminated (fig. 12). Temperatures in other parts of the set decreased as much as 50°C because the short circuit disabled the signal from the horizontal oscillator and shut down the high-voltage supply.

6.3.4 Short Circuit in the 24-volt Supply to the Vertical Amplifiers (Test 11)

The collector voltage of the vertical amplifiers is supplied through a decoupling network consisting of a 30-ohm, 5-watt wirewound resistor (R12, fig. 9) and a 470 μF capacitor (C12). A short circuit in this capacitor or a short circuit to ground in one of the collector circuits of the vertical amplifiers, which was simulated by placing a short circuit across capacitor C12, caused the current through the resistor to increase from 200 to 900 mA and the power dissipation to increase from 1.5 watts to 24 watts.

Within 3 minutes, the temperature of R12 had reached about 450°C (fig. 13). This was followed by a more gradual increase to 485°C at the end of the 10-minute test. Temperatures in other parts of the set changed less than $\pm$ 10°C except the temperature of R13 which increased from 86°C to 163°C in the first 5 minutes and for the remainder of the test remained near that temperature.

During the test the raster was reduced to a single horizontal line, indicating that the horizontal circuits and high-voltage supply were still operating. The set recovered with no permanent damage after the short circuit was removed.

6.3.5 Short-circuited Winding in High-voltage Transformer (Test 14)

The AFC winding of the high-voltage transformer was short-circuited to observe the effect on the circuits associated with the transformer. The short circuit resulted in a 40% increase in power to the transformer and an increase in current to the horizontal driver from about 150 mA to 500 mA. Power dissipation in each of the decoupling resistors (R10 and R11, fig. 9) in the 135-volt supply to the horizontal driver increased from 1.5 to 23 watts.

In the first test, the short circuit was removed after 2 minutes. The temperature of decoupling resistor R11 increased from about 130°C to nearly 500°C, and that of R10 increased from about 100°C to about 320°C (fig. 14). The second test terminated when the 0.6-ampere fuse blew at the end of 3-1/2 minutes. At that time, the temperature of R10 had leveled off at 320°C, but the temperature of R11 was over 540°C and still rising.

Each time the circuit was interrupted, the temperature rate of rise increased momentarily before decreasing, probably caused by interference from the horizontal output stage. Temperatures in other parts of the set rose 30°C or less. Other than the blown fuse there was no permanent damage to the set.

6.4 48.3-cm (19-in) Color TV Receiver

Except for the tuner, picture controls, and convergence assembly, the circuits of the 48.3-cm (19-in) color set were mounted on a U-shaped chassis frame to the rear of and parallel with the bottom of the picture tube. The tuner and picture controls were mounted on the front panel of the set, and the convergence assembly was mounted on the neck of the picture tube. The IF and sound modules were mounted vertically on the left upright of the chassis frame (when viewed from the rear as in figure 15). Five modules -- chroma, luminance/sync, video drive, horizontal oscillator, and vertical drive -- were mounted horizontally on the base of the chassis frame, and the horizontal output, high-voltage transformer and deflection circuits were mounted on the right upright.

Except for the 150-volt supply to the collector of the horizontal output transistor, all DC supply voltages are obtained from the high-voltage transformer (fig. 16). A bridge rectifier is used to obtain 150 volts DC from the 110-volt AC input and also to provide a 27-volt start-up supply to furnish power to the horizontal oscillator and driver.

Basic protection for the circuit is provided by a 7-ampere fuse in the AC line; a 3-ampere fuse is used to protect the kinescope heaters. Two over-voltage protection circuits guard against excessive high voltage and over-voltage in the 27-volt supply by disabling the horizontal oscillator if such over-voltages occur. R21 is a 3.9-ohm fusible resistor in the input of the bridge rectifiers.

6.4.1 Short Circuit in Decoupling Network to Horizontal Driver (Tests 15 and 19)

Because of the multiplicity of protection circuits, tests on the 48.3-cm (19-in) color set did not always have the expected results. The filter capacitor, C22, in the decoupling network in the 27-volt supply to the horizontal driver was short-circuited with the intention of overloading the associated resistor, R22. The short circuit was accompanied by a momentary surge of current in R22, but the temperature rise was less than 5°C during the 5-minute test.

Within 30 seconds, however, the temperature of the decoupling resistor in the 27-volt supply to the sound module, R23, had reached a peak of 470°C before dropping to 260°C at the conclusion of the test (fig. 17). At the same time the resistance of R23 increased tenfold, so that it had to be replaced after the test. Temperature increase in other components was less than 10°C.

Later the test was repeated by connecting a 100-ohm resistor across C22 to increase the current through R22 from the normal 70 mA to 180 mA. Power dissipated in R22 increased from about 1/3 watt to 2 watts with a resulting temperature increase from 65°C to 230°C (fig. 18). During this test the temperature of R21 increased 20°C; all other temperature changes were less than 10°C.

6.4.2 Short Circuit in Decoupling Network to Sound Module (Test 18)

In test 18, the load on the 27-volt supply was increased in three steps by connecting additional resistances across the output of the decoupling network to the sound module, i.e., across C23 in figure 16. After test 15, the original 27-ohm, 1/2-watt film resistor R23 had been replaced by a 27-ohm, 1-watt film resistor.

Additional loads of 100, 71 and 50 ohms across C23 increased the current through R23 to 220, 280 and 360 mA, respectively, with corresponding increases in dissipation to 1.3, 2.1 and 3.3 watts. The normal current in R23 was 30 mA and the normal dissipation about 1/40 watt. Maximum temperatures recorded for R23 were 140°C, 160°C and 170°C for the three loads, as indicated in figure 19. Since the original resistor had a 1/2-watt rating, higher temperatures would have been expected if the original resistor or an exact replacement had been used.

6.4.3 Short-circuited Zener Diode in the X-ray Protection Circuit (Test 16)

A voltage obtained from a low-voltage winding on the high-voltage transformer is compared with a reference voltage in the x-ray protection circuit and used to interrupt the high-voltage supply if the high voltage exceeds safe limits. The zener diode in the x-ray protection circuit was short-circuited to overload resistors R28 and R29 in the input to that circuit. One of these, R29, was located on the deflection circuit board and the other, R28, in the horizontal drive module. Both were in close proximity to other components. The increased dissipation was well within the dissipation rating of both resistors, and no temperature increases greater than 10°C were recorded.

6.4.4 Short Circuit at the Output of the 11.2-volt Regulator (Test 17)

The output of the 11.2-volt regulator in the chroma module was short-circuited by shorting capacitor C25, thereby increasing the load on R24 and R25 (fig. 16). The increase was insufficient to overstress the resistors. The temperature of R24 increased 26°C but no other temperature increases greater than 5°C were recorded.

6.4.5 Overloaded Resistor in 40-volt Supply (Tests 20 and 21)

The decoupling network in the 40-volt supply to the vertical drive module was overloaded by connecting a resistor in parallel with C26, and then short-circuiting C27 when the temperature of R26 had stabilized. Capacitor C26 was paralleled by a 100-ohm resistor in test 20, and by a 50-ohm resistor in test 21.

Normal dissipation in R26, a 4.7-ohm, 2-watt wirewound resistor, is about 0.1 watt. When a 100-ohm resistor was connected across C26 in test 20, the dissipation in R26 increased to about 1/3 watt and the temperature leveled off at 77°C (fig. 20). When C27 was short-circuited, dissipation in R26 increased to 6 watts and the temperature stabilized at 405°C. During the test, the temperature of R27 increased from 44°C to 137°C, and of R21 from 105°C to 211°C. No other significant temperature changes were recorded.

When a 50-ohm resistor was connected in parallel with C26 (test 21) and then C27 short-circuited, dissipation in R26 increased to 8 watts. The temperature of R26 increased from 53°C at the beginning of the test to 115°C after 5 minutes with 50 ohms paralleling C26, and then increased to 440°C when C27 was short-circuited. The resistor opened a little more than 2 minutes after the short circuit was applied.

Temperatures in other parts of the set were similar to those recorded in test 20. The circuit board near R26 was discolored slightly, but no permanent damage was done and circuit operation was restored after R26 was replaced.

6.4.6 Short-circuited X-ray Protection Winding (Test 22)

To determine the effect of a short-circuited winding on the high-voltage transformer, the low-voltage winding which furnishes input to the x-ray protection circuit was short-circuited. The transformer began smoking and the set became inoperative within 30 seconds. The x-ray protection winding of the transformer was damaged, and the high-voltage winding opened. The horizontal output transformer was destroyed, and possibly the regulator module and silicon controlled rectifier were damaged. During the 30 seconds before the circuit opened, the temperature of R21 increased from 104°C to 148°C. Temperatures in other parts of the set decreased.

6.5 63.5-cm (25-in) Color TV Receiver

The circuits of the 63.5-cm (25-in) set were mounted in four groups which were well separated from each other and which were connected together by detachable cables. The tuner and picture controls were mounted on the front panel of the set to the left of the picture tube when viewed from the rear of the set (fig. 21). An assembly containing the power transformer and the power supply circuits was mounted at the left rear. The low-voltage assembly was mounted between this chassis and the neck of the picture tube. This assembly consisted of a vertical interconnect board into which were connected the IF/audio chroma video, audio output, horizontal oscillator, and RGB drive modules. The printed circuit chassis of these modules were mounted vertically, three on one side of the vertical support and two on the other. The high-voltage assembly was located to the right of the neck of the picture tube. It contained horizontal drive and output circuits, the high-voltage transformer, vertical drive and sweep interconnect modules mounted vertically, and the convergence module mounted horizontally at the top of the unit.

The power transformer and associated rectifier circuits furnished DC power to all circuits of the set except anode and focusing voltages for the kinescope, which were obtained from the high-voltage transformer (fig. 22). The primary of the power transformer was protected by a 2.5-ampere slow-blow fuse. A circuit breaker in the primary lead of the power transformer opened the 143-volt supply when tripped, and a 1-ampere fuse protected the 30, 26 and 23-volt supplies which were obtained from the same transformer winding. A 6.3-volt winding on the power transformer furnished heater current to the kinescope.

Possible heat sources chosen for study in this set were decoupling resistors in the high-voltage assembly, audio output and IF/audio modules, and four decoupling resistors in the power supply assembly. The temperature of each of these resistors (R31, R32, R33, R34, R35, R36 and R37, fig. 22) was monitored by means of thermocouples. In addition, the temperature of the wood composition cabinet was monitored near the power transformer.

6.5.1 Short-circuited Decoupling Network in Horizontal Driver Circuit (Test 23)

The 143-volt supply furnishes power to the vertical oscillator, horizontal driver and output circuits and the picture tube yoke. Current to the horizontal driver circuit is supplied through a decoupling network consisting of a 1300-ohm, 10-watt wirewound resistor (R31, fig. 22) and a 0.1-μF capacitor, (C31). The resistor is mounted below the pincushion transformer and near several plastic connectors used to connect leads from the high-voltage transformer to the rest of the circuit.

When decoupling capacitor C31 was short-circuited, the current through the decoupling resistor, R31, increased from 60 mA to 110 mA, and the power dissipated in the resistor increased from the normal 4.6 watts to 16 watts. The temperature of R31, which was 157°C under normal operating conditons, stabilized at 350°C after about 8 minutes (fig. 23). Temperatures in other parts of the set increased no more than 1°C to 5°C. During the test, the raster disappeared, but sound remained normal.

When the short circuit was removed after 10 minutes, operation of the set returned to normal. The resistance of R31 had changed from 1307 to 1320 ohms, but the resistor was not damaged. There was no visible damage to the set.

6.5.2 Short-circuited Network in Audio Output Module (Test 24)

The 26-volt supply is obtained from the 30-volt winding of the power transformer through a 40-ohm, 3-watt, film decoupling resistor in the power supply circuit (R32, fig. 22). It furnishes power to the audio output module only. Current enters the audio output module through a decoupling network consisting of an 18-ohm, 2-watt resistor (R33, fig. 22) and a 470 μF capacitor (C33). The module is mounted at the top of the left side of the low-voltage assembly and the decoupling resistor is at the top rear corner of the module near one of the cables interconnecting the modules. The 40-ohm resistor is under the power transformer near some of the transformer leads.

Normal current in this circuit is about 13 mA. Power dissipation in the filter and decoupling resistors, R32 and R33, is normally less than 10 mW; the resistors normally operate at a temperature of 35°C to 40°C.

When decoupling capacitor C33 was short-circuited, current in this circuit jumped to 0.5 ampere. Under these conditions the power dissipated in R32 was 10 watts and in R33 was 4.5 watts. After about 5 minutes, the temperature stabilized at about 370°C for R32 and about 220°C for R33 (fig. 24). Temperatures registered by the other thermocouples increased 2°C to 10°C. During the test, the picture was undisturbed, but sound was completely silenced.

After the short circuit was removed, sound was restored. There was no visible damage to the set or to the wires or other components near the overheated resistors. The resistances did not change.

6.5.3 Overloaded 26-volt Supply (Test 25)

The decoupling resistor in the 26-volt supply (R32, fig. 22) was further stressed by adding an extra 10-ohm load to the output of the supply (point A, fig. 22). Such an overload could be caused by a defect in the audio output module or a partial short circuit in the cabling connecting the module and the power supply. The 550 mA increase in current caused a 2-volt reduction in the output voltages of the 26 and 23-volt supplies and increased the current through the 1-ampere fuse to 0.9 ampere. Power dissipated in R32 increased to more than 13 watts causing an increase in its temperature to 435°C after about 5 minutes (fig. 25). The reduction in the output of the 23-volt supply resulted in a reduction of 7°C and 1°C in the temperatures of R34 and R35, respectively. Other thermocouples registered changes in temperature between -2.5°C and +2.5°C. Sound volume was reduced.

When the short circuit was removed after 10 minutes, operation of the set returned to normal. There was no visible damage to resistor R42, the transformer wires, or other components near R32.

6.5.4 Short-circuited Decoupling Network in IF/audio Module (Test 26)

The 23-volt supply furnishes power to the IF/audio module through several decoupling networks located on the module. The network which filters current to the IF/AGC integrated circuit consists of a 360-ohm, 1/2-watt carbon resistor (R35, fig. 22) and a 447 μF capacitor (C35) and is located near the bottom of the vertically mounted, printed circuit chassis.

When capacitor C35 was short-circuited, the current through R35 increased from the normal 30 mA to 70 mA and the power dissipated in the resistor increased from 0.25 to 1.6 watts. The temperature of the resistor increased from 55°C to 140°C in about 3 minutes and remained stable for the duration of the test (fig. 26). The short circuit eliminated both picture and sound.

The increase in current produced a slight increase in the dissipation of the decoupling resistor in the 23-volt supply (R34, fig. 22) whose temperature increased from 138°C to 152°C during the test. The temperature of the decoupling network in the horizontal driver circuit (R31) increased about 7°C; other temperatures increased less than 2°C.

When the short circuit was removed after 5 minutes, operation of the set returned to normal. The resistance of R35 did not change, and there was no visible damage to the chassis or other components mounted on the module.

6.5.5 Overloaded 23-volt Power Supply (Test 27)

The 23-volt supply is the principal source of low-voltage power for the set. Defects in any of the circuits which receive power from this supply may increase the current that it is required to deliver, and therefore increase the dissipation in the associated 20-ohm, 5-watt wirewound decoupling resistor (R34, fig. 22). Resistor R34 is located on the printed circuit board at the rear of the power supply assembly, and is within 2.6-cm of the fiberboard back of the set.

The load on the 23-volt supply was increased in three steps by connecting 40, 20 and 10-ohm resistors across its output at point B, figure 22, at 10-minute intervals and observing the effect on the set. The 40-ohm resistor increased the current through R34 from the normal 370 mA to 650 mA and increased the dissipation from 2.8 to 8.8 watts. The temperature of R34 increased from 137°C to 295°C in about 6 minutes and remained there until the load was changed (fig. 27). After 10 minutes, the load was changed to 20 ohms causing a further increase in current to 800 mA and an increase in dissipation to 13.5 watts. After 5 minutes at this current, the temperature of R34 had increased to 380°C where it remained. After a total elapsed time of 20 minutes, the load was changed to 10 ohms. Current in R34 increased to 965 mA and the power dissipation to 20 watts. The temperature had reached 470°C when the fuse blew after a total time of 28.5 minutes (about 7 minutes after increasing the current to 965 mA).

During these tests there was no picture or sound except for a pronounced 120 Hz hum. Maximum temperature increase in the other circuits was about 4°C. The temperatures registered by the thermocouples not associated with the 23 or 26-volt supplies decreased between 7°C and 40°C.

Except for the blown fuse, there was no damage to resistor R34 or to other parts of the set. Operation of the set returned to normal after the fuse was replaced.

7. REDUCED VENTILATION TESTS

Supplemental to the basic ignition source measurements made in this program, measurements of the increase in operating temperature for the four solid-state (except for the picture tube) television receivers were made with all of the ventilation ports blocked. These data were requested by the CPSC to aid them in present discussions of design changes associated with fire containment.

Experimentally, the operating temperatures of selected components were measured under normal conditions and with all ventilation openings in the cabinet sealed with 0.3-mm thick duct tape (fig. 28). The data are summarized and tabulated in tables 2 and 3. The temperature increase caused by restricted ventilation was higher in the smaller, more compact sets, but in all cases was less than 20°C. It should be noted that although the cabinet openings were sealed in the blocked ventilation tests, circulation of air around the cabinets themselves was not restricted. Air flow about the receiver may have been enhanced by the ventilation of the hood under which all tests were performed.

8. VOLUNTARY STANDARD UL 1410

The UL 1410 Standard for Television Receivers and Video Products covers the fire performance requirements for materials used in enclosures or parts of enclosures, barriers, and other applications. Of particular interest for this study are the requirements for the polymeric enclosure materials. Depending on the location, size, and intended service of the enclosure, a flammability classification of 94V-0 or 94V-1 is required. For a major component such as the polymeric television receiver cabinet, the more stringent 94V-0 rating is required.

8.1 UL 94 Test

The 94V-0 rating is assigned to materials based on the results of the UL 94 Tests for Flammability of Plastic Materials for Parts in Devices and Appliances [3]. Briefly, the UL 94 vertical burning tests are run on five specimens in a draft-free chamber. In most cases, these specimens are flat-stock bar samples 13.7-cm long by 1.27-cm wide. The test allows for thicknesses up to 1.27-cm to be tested. For the test each specimen is supported from the upper 0.63-cm with the longitudinal axis vertical so that the lower edge is at the mid-height of the 1.9-cm high blue ignition flame on top of the burner tube and 30.5-cm above a 0.64-cm thick horizontal layer of dry absorbent surgical cotton. Each specimen is exposed to the flame for 10 seconds. Then the flame is withdrawn. The duration of flaming of the specimen is recorded. When flaming ceases the test flame is immediately placed under the specimen for a final 10 seconds exposure and then withdrawn. The duration of flaming and glowing is recorded.

To achieve a 94V-0 rating, section 3.2 of the standard states that the five test specimens shall:

a. Not have any specimen which burns with flaming combustion for more than 10 seconds after each application of the test flame.

b. Not have a total flaming combustion time exceeding 50 seconds for the 10 flame applications for each set of five specimens.

c. Not have any specimen which burns with flaming or glowing combustion up to the holding clamp.

d. Not have any specimen which drips flaming particles that ignite the dry absorbent surgical cotton located 30.5-cm (12-in) below the test specimen.

e. Not have any specimens with glowing combustion which persists beyond 30 seconds after the second removal of the test flame.

8.2 Measurement of Ignition Source

For comparison purposes with the measurements of energy release rates from ignition sources within the television receiver, it was of interest to determine the energy release rate of the test flame specified in the UL 94 test procedure.

The ignition source specified in section 3.2 of the UL 94 standard [3], is a 1.9-cm high blue flame produced by burning technical grade methane gas with a Tirrill burner having a tube length of 10.16-cm and an inside diameter of 0.95-cm. The burner is not equipped with an end attachment or stabilizer. The flame is produced by adjusting the gas supply and the air parts of the burner until a 1.9-cm yellow-tipped blue flame is produced and then increasing the air supply until the yellow tip disappears. Following this procedure the test flame shown in figure 29 was produced on the burner (shown fully in figure 30) built to comply with the specifications of the test procedure.

To evaluate the energy release rate in the flame, the methane gas flow rate was measured using a piston gas flow rate meter, shown in figure 30. The flow rate of gas to the burner was adjusted with an in-line needle valve. After a 1.9-cm high blue flame had been established by following the recommended procedure, the gas flow was diverted from the burner and the flow rate measured with the piston meter. Using the measured gas flow rate and the lower heat of combustion for methane, at 25°C (802 kJ/g-mole), the rate of energy release in the flame was calculated assuming complete combustion for each of the 18 trials. From these measurements the energy release rate from the burner was determined with 95% confidence to be in the interval of 60 $\pm$8 watts.

In the UL 94 test, the tip of a bar-shaped plastic sample is placed in the center of the test flame cone. For completeness sake, tests were run to determine the percentage of energy release in the flame that is transferred to a sample. An approximate, but adequate, way to determine this quantity is to measure the rate of temperature rise for a copper slug of known mass shaped like a test sample and placed in the flame as shown in figure 31. Measurements were made on two copper samples, one a 2.5 x 1.27 x 0.63-cm rod and the other a 6.1 x 1.27 x 0.63-cm rod, each mounted on a rigid plastic support to bring the overall dimensions to 12.7 x 1.27 x 0.63-cm. The two measurements were in good agreement with each other, and showed that 40% to 50% of the energy released in the flame could be expected to be transferred to the UL 94 test sample.

8.3 Comparison of Television and UL 1410 Ignition Sources

A primary goal of this program of study was to collect sufficient data to compare the energy release rate of the ignition sources that could be generated within a television receiver with the ignition source specified in the UL 1410 standard. Comparison of these ignition sources was complicated by the fact that the UL 1410 ignition source was a small flame and all of the ignition sources generated in the television receivers were non-flaming hot spots.

As reported in the previous sections the energy release rate from the burner specified in the UL 1410 standard is approximately 60 watts. The temperature in the flame, although not measured, should be in the neighborhood of 1900°C. For comparison, maximum component temperatures and power dissipation recorded in the television tests are tabulated in table 1.

Generally speaking, ignition sources with the same order of magnitude of energy release as the flame were generated during the test. The temperatures of the stressed components were of course lower than the methane-air burner flame specified in the UL 1410 standard. The combination of highest temperature and highest power dissipation occurred in test 3 in which resistor R1 reached 635°C dissipating 40 watts. In test 3, this condition lasted for only a brief time (see fig. 6). The worst case recorded was test 2 on the 12-in black and white portable where the receiver operated continuously with resistor R5 dissipating 30 watts at temperatures in excess of 550°C (see fig. 4).

From the measurements made it has been verified that the ignition source specified in the UL 1410 standard has an energy release rate the same order of magnitude as ignition sources that can be generated by electric failures in the television receiver. This, of course, is not sufficient evidence to verify that the UL 1410 ignition source or test procedure is a good simulation of the television ignition problem, because of the difference in the character of the sources. In the UL 1410 (UL 94) test procedure, a combustible is exposed to a flame for 10 seconds. In the television receiver the same material may be exposed continuously to a hot spot at temperatures in excess of 500°C.

9. CONCLUSIONS

In the four television receivers studied in this program, no flaming ignition sources were generated by introducing electrical failures in the circuitry. It was possible to generate hot spots having temperatures in excess of 500°C. Dust contamination applied artificially to one black and white receiver was shown to have negligible effect in the tests. The effect of material aging or long term deterioration was not examined. Although every possible failure mode could not be examined, the resistance of the receivers to ignition from electrical overload failure was found to be good in the tests conducted. No work was done to simulate arcing failures or glowing connections.

The energy release rate from the gas burner ignition source specified in the UL 1410 standard was estimated to be 60 ± 8 watts. This is the same order of magnitude as the energy dissipated from stressed components in a television receiver with an electrical fault present. However, this is not offered as justification that the UL 1410 ignition source or test procedure is a good simulation of the television ignition problem.

Supplementary tests were conducted to measure the increase in operating temperature for these television receivers with the enclosure vents blocked. These tests showed that an increase of less than 20°C occurred in the operating temperature of electronic components in the sealed enclosures.

10. REFERENCES

[1] UL 1410 Standard for Television Receivers and Video Products, 13th edition, revised June 13, 1978, Underwriters Laboratories Inc, Northbrook, Ill.

[2] Harwood, Beatrice, Analysis of Subpoenaed Television Data, HIA Special Report, U.S. Consumer Product Safety Commission, March 1978.

[3] UL 94 Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, 2nd edition, revised July 30, 1976, Underwriters Laboratories Inc, Northbrook, Ill.

Table 1. Summary of tests

Test	TV Set	Component* Number	Component* Resistance ohms	Component* Type	Power Dissipation Watts Rated	Power Dissipation Watts Normal	Power Dissipation Watts Maximum Recorded	Maximum Temperature Degrees - C	Figure	
1	30.5cm	R4	56	W	5	2.1	33	187		C4 short-circuited for 5 s
		R5	470	W	3	1	30	258		C5 short-circuited for 5 s
		R6	8.2K	W	3	1.4	3	123		C6 short-circuited for 5 s
		R7	180	W	3	0.1	7	206		C7 short-circuited for 5 s
2	30.5cm	R5	470	W	3	1	31	585	4	C5 short-circuited for 10 min; temperature peaked in 1 min 30 s; R5 damaged
3	30.5cm	R1	470	C	1	0.05	40	635	6	C1 short-circuited for 5 min; temperature peaked in 30 s; both R1 and R2 destroyed
4	48.3cm B & W	R14	56	W	2	0.8	16	570	10	C14 short-circuited for 5 min
5	48.3cm B & W	R13	150	F	0.5	0.15	6	645	12	C13 short-circuited for 5 min; temperature peaked in 1 min 30 s
6	30.5cm	R5	470	W	3	1	15	540		Dust conditioned. C5 short-circuited for 6 min; R5 had been damaged in previous test; replaced
7	30.5cm	R1	470	C	1	0.05	10	370		Dust conditioned. C1 shunted by 500 ohms for 5 min; temperature peaked in 2 min; resistance of R1 decreased and blew fuse
8	30.5cm	R7	180	W	3	0.1		157		Dust conditioned. Ventilation blocked
9	30.5cm	R4	56	W	5	2.1	2	135		Dust conditioned. Heater winding of high-voltage transformer short-circuited
10	48.3cm B & W	R14	56	W	2	0.8	17	475	10	C14 short-circuited for 10 min; temperature peaked in 1 min 20 s; R14 damaged
11	48.3cm B & W	R12	30	W	5	1.4	24	485	13	C12 short-circuited for 10 min; temperature stabilized after 5 min

*Components with numbers between 1 and 9 are identified in figure 3; with numbers between 10 and 19 in figure 9. Type: C-Carbon, F-Film, W-Wirewound

Table 1 (continued)

Test	TV Set	Component* Number	Component* Resistance ohms	Component* Type	Power Dissipation Watts Rated	Power Dissipation Watts Normal	Power Dissipation Watts Maximum Recorded	Maximum Temperature Degrees - C	Figure	
12	48.3cm B & W	R10	68	W	3	1.8	23	452		AFC winding of high-voltage transformer short circuited. Fuse blew after 3 1/2 min. Power transformer overheated
13	48.3cm B & W	R14	56	W	2	0.8	16	530	11	C14 short-circuited for 20 min
14	48.3cm B & W	R11	68	W	5	1.5	23	545	14	AFC winding of high-voltage transformer short-circuited. Fuse blew after 3 1/2 min
15	48.3cm color	R23	27	F	0.5	0.05	--	470	17	C22 short-circuited. Temperature of R23 peaked in 30 s; resistance of R23 increased tenfold, R23 replaced
16	48.3cm color									Short-circuiting C28 for 1 min had little effect on component temperatures
17	48.3cm color									Short-circuiting C25 for 5 min had little effect on component temperatures
18	48.3cm color	R23	27	F	0.5	0.05	3.3	170	19	C23 shunted by a 50-ohm resistor for 5 min
19	48.3cm color	R22	68	F	2	0.3	2	230	18	C22 shunted by a 100-ohm resistor; C27 short circuited
20	48.3cm color	R26	4.7	W	2	0.1	6	405	20	C26 shunted by 100-ohm resistor; C27 short-circuited
21	48.3cm color	R26	4.7	W	2	---	8	440	20	C26 shunted by 50-ohm resistor; C27 short-circuited R26 opened after 2 min

*Components with numbers between 10 and 19 are identified in figure 9; with numbers between 21 and 29 in figure 16. Type: F-Film, W-Wirewound, C-Carbon

Table 1 (continued)

Test	TV Set	Component* Number	Component* Resistance ohms	Component* Type	Power Dissipation Watts Rated	Power Dissipation Watts Normal	Power Dissipation Watts Maximum Recorded	Maximum Temperature Degrees - C	Figure	
22	24.8cm color	R21	3.9	Fusible	10	--	--	150		X-ray protection winding of high-voltage transformer short-circuited. High voltage winding burned out and X-ray protection winding damaged within 1 min
23	63.5cm	R31	1.3K	W	10	4.6	16	350	23	C31 short-circuited for 10 min
24	63.5cm	R32	40	F	3	0.01	10	370	25	C33 short-circuited for 10 min
25	63.5cm	R32	40	F	3	0.01	13	435	26	C32 short-circuited for 10 min
26	63.5cm	R35	360	C	0.5	0.25	1.6	140	27	C35 short-circuited for 10 min
27	63.5cm	R34	20	W	5	2.8	20	470	27	C34 shunted by 10-ohm resistor

*Components with numbers between 21 and 29 are identified in figure 16; with numbers between 30 and 39 in figure 22. Type: C-Carbon, F-Film, W-Wirewound.

Table 2. Range of component operating temperatures

Set	Normal operation	Cabinet sealed
30.5-cm B&W	60 to 144°C	76 to 157°C
48.3-cm B&W	55 to 128	60 to 139
48.3-cm color	44 to 122	*
63.5-cm color	39 to 163	48 to 166

*Extensive damage to the receiver in test 22 did not permit these measurements to be made.

Table 3. Effect of ventilation on temperatures of selected components

A. Black and White Receivers

Receiver size	Thermocouple location	Cabinet open Degrees C	Cabinet closed (Normal operation) Degrees C	Cabinet sealed Degrees C
30.5-cm	cabinet		38	49
	wire bundle to CRT socket	43	50	59
	R1(a)	52	60	76
	R2	92	108	120
	R5	98	106	115
	R4	112	121	136
	R3	126	139	151
	R7	142	144	157
48.3-cm	cabinet		36	42
	fuse	56	55	60
	power transformer	59	63	74
	CRT neck	56	69	78
	R13(b)	75	79	88
	R14	68	79	91
	R10	98	96	106
	R12	113	117	126
	R11	125	128	139

B. Color Receivers

Receiver size	Thermocouple location	Cabinet open Degrees C	Cabinet closed (Normal operation) Degrees C	Cabinet sealed Degrees C
48.3-cm	R28(c)	40	44	(e)
	R27	41	44	
	R26	52	54	
	R22	51	62	
	R24	75	75	
	R29	85	94	
	R21	103	122	
63.5-cm	cabinet		34	34
	R32(d)	33	39	48
	R33	34	41	43
	R35	55	58	62
	R36	96	102	107
	R37	119	122	125
	R34	140	149	150
	R31	155	163	166

(a) Components identified in figure 3
(b) Components identified in figure 9
(c) Components identified in figure 16
(d) Components identified in figure 22
(e) Extensive damage to the receiver in test 22 did not permit these measurements to be made.

Figure 1. Equipment for television receiver tests

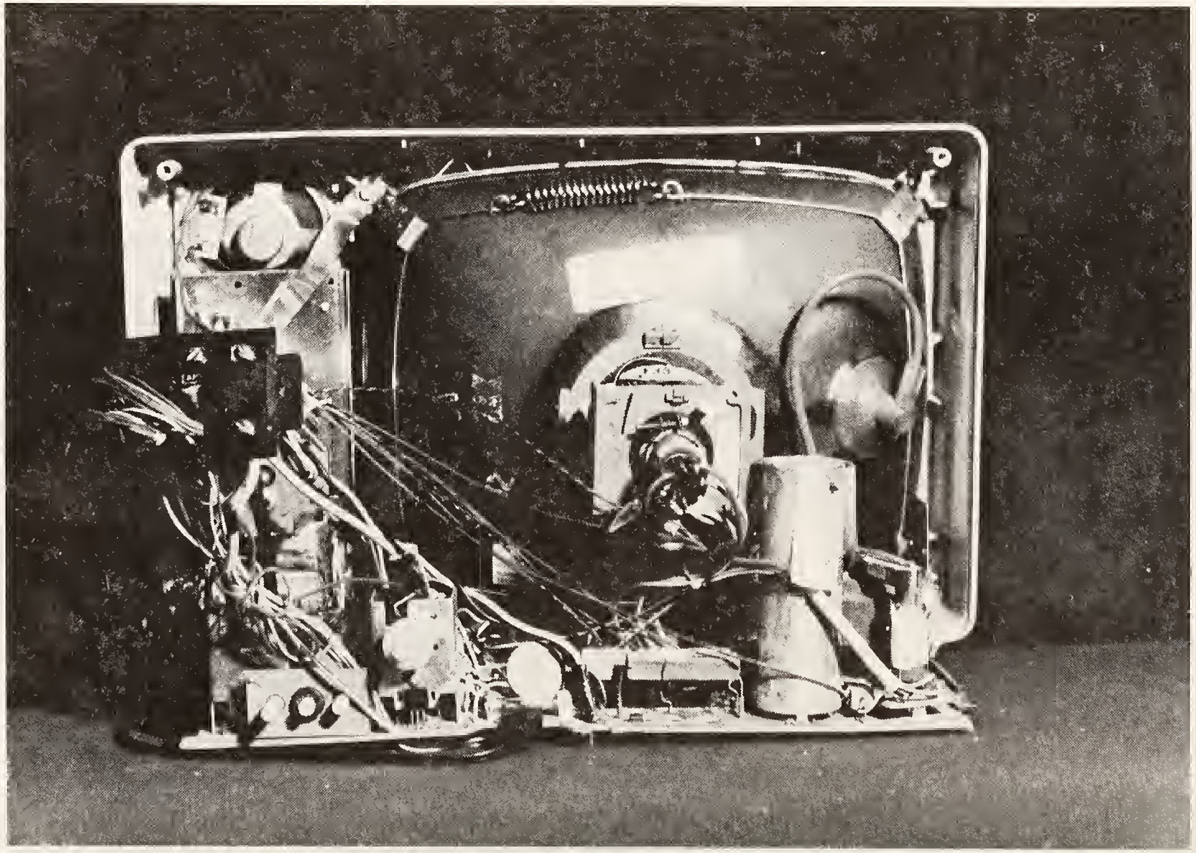

Figure 2. 30.5-cm black and white receiver, back cover removed

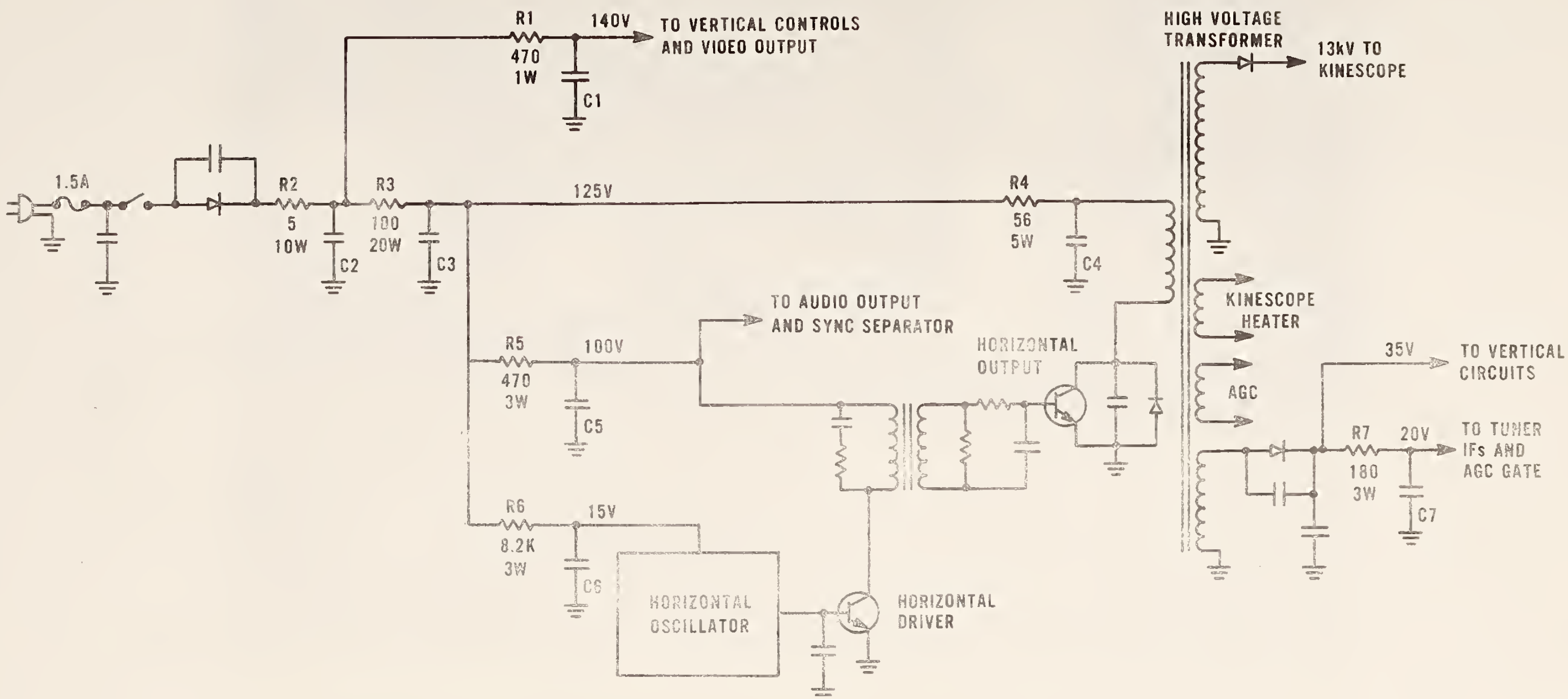

Figure 3. Partial schematic diagram of 30.5-cm black and white TV receiver

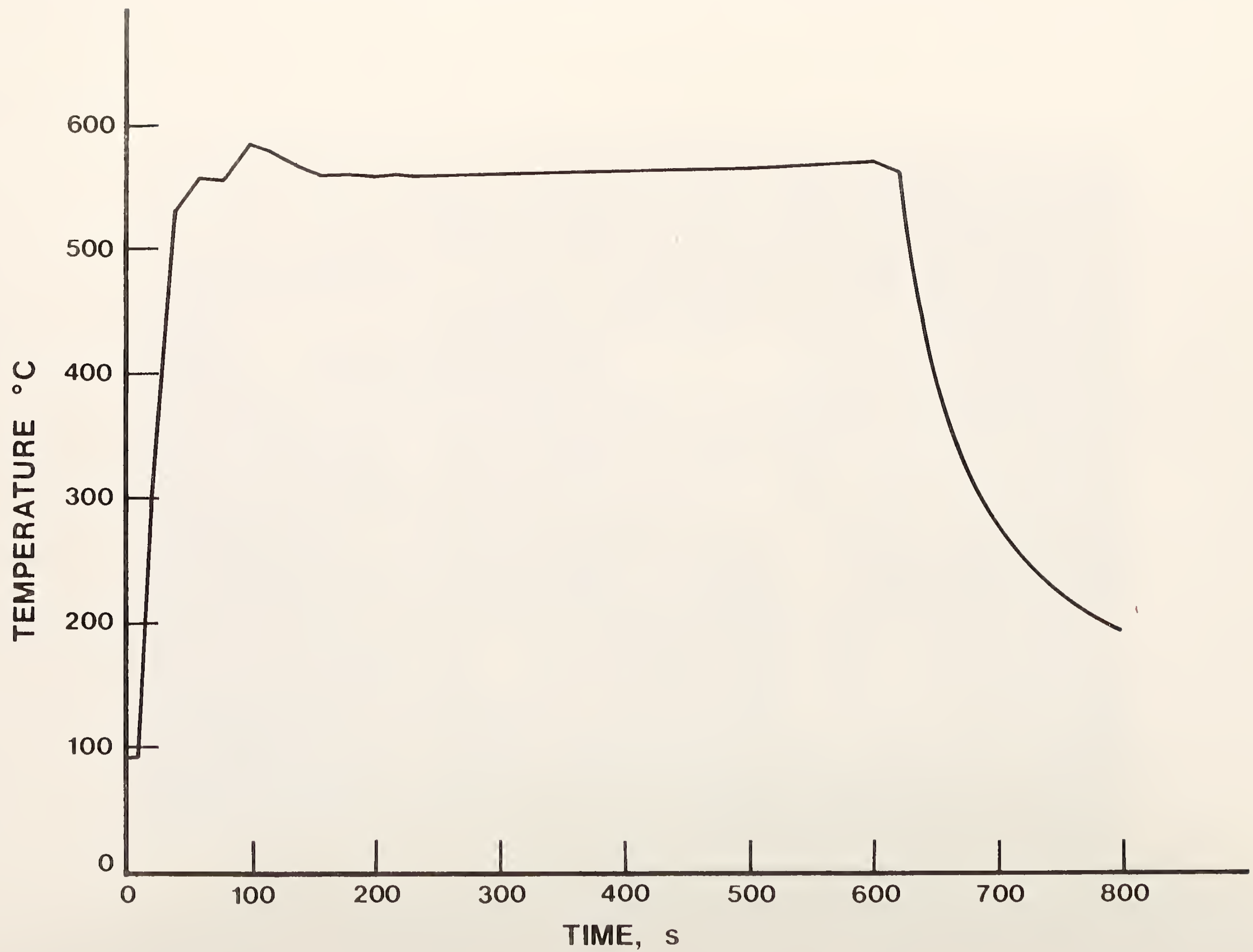

Figure 4. Test 2, 30.5-cm black and white, temperature of resistor R5

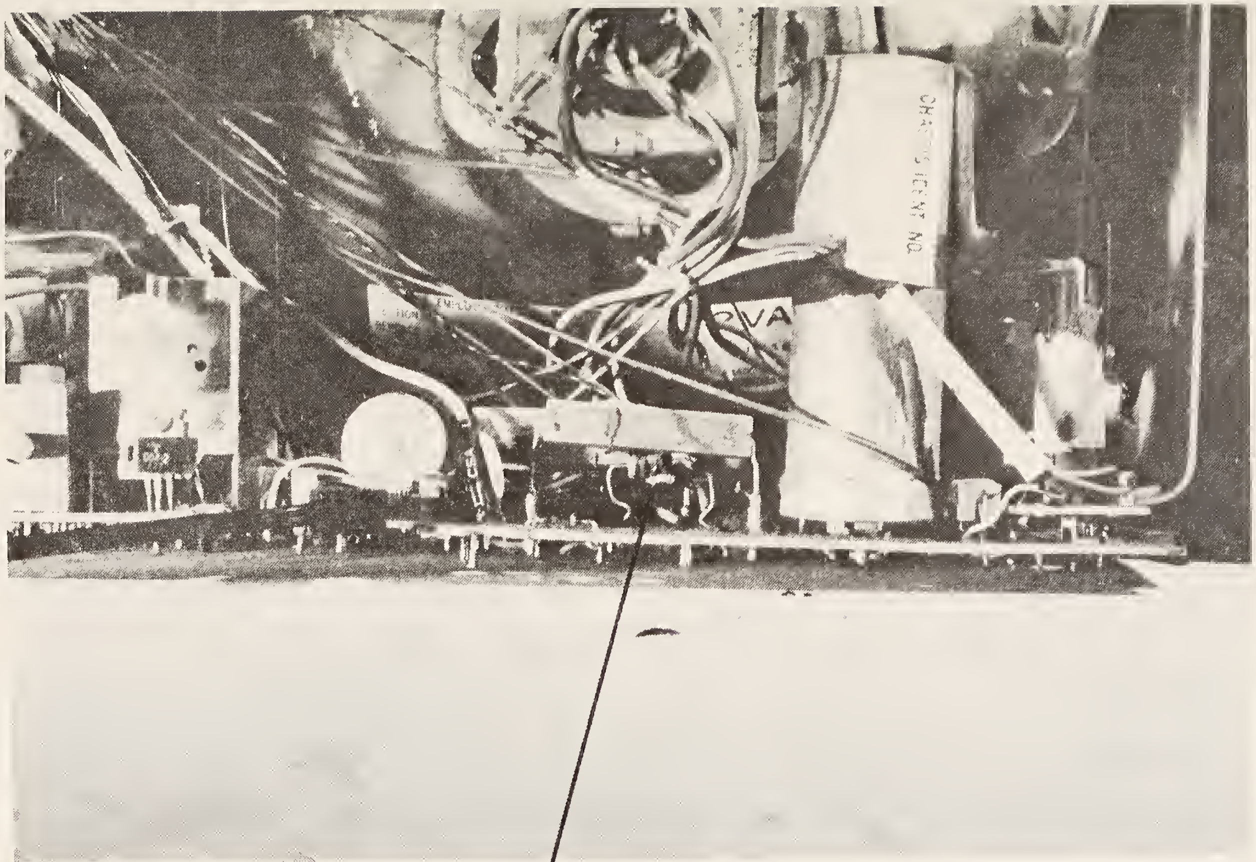

Figure 5. 30.5-cm black and white, placement of resistor R1

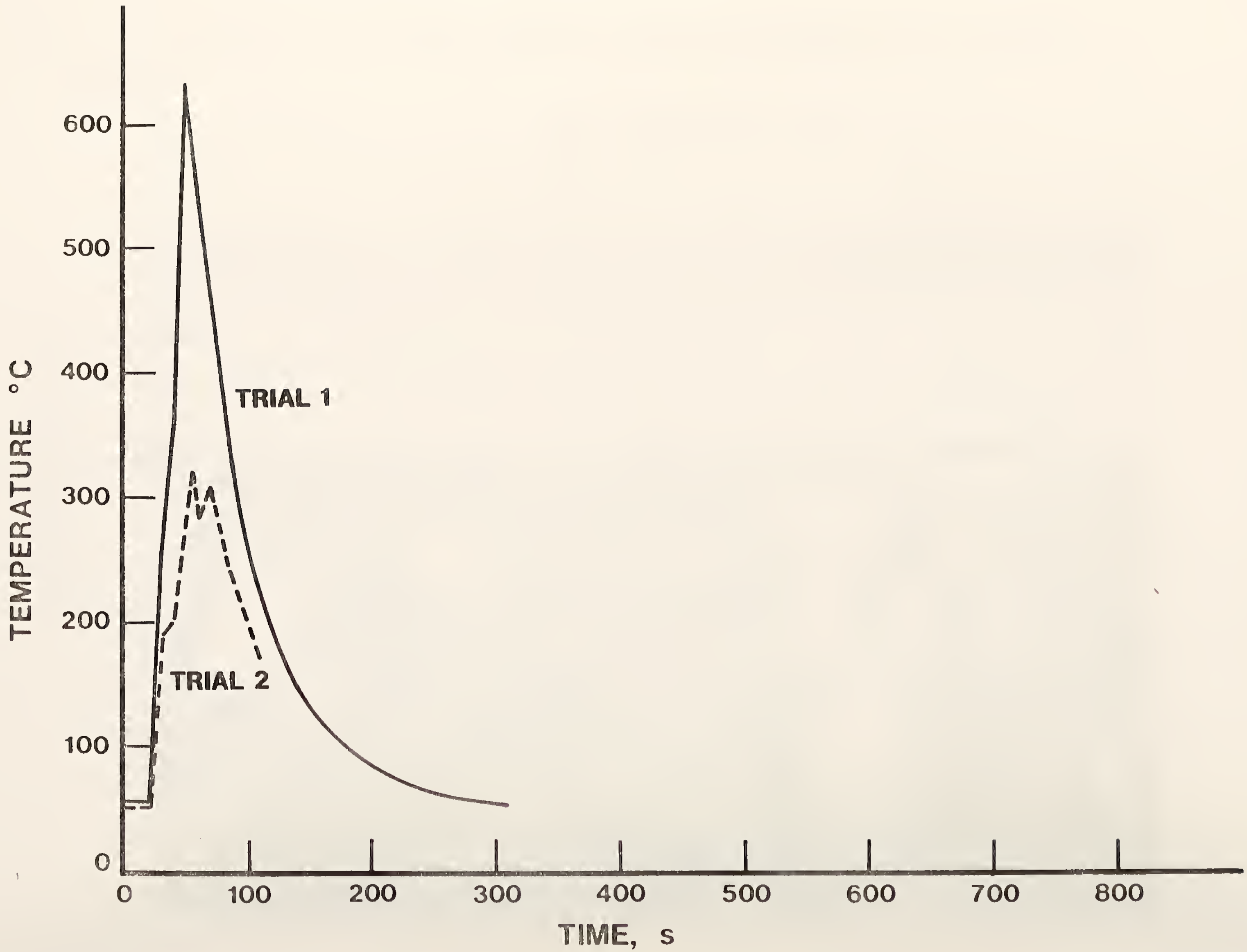

Figure 6. Test 3, 30.5-cm black and white, temperature of resistor Rl

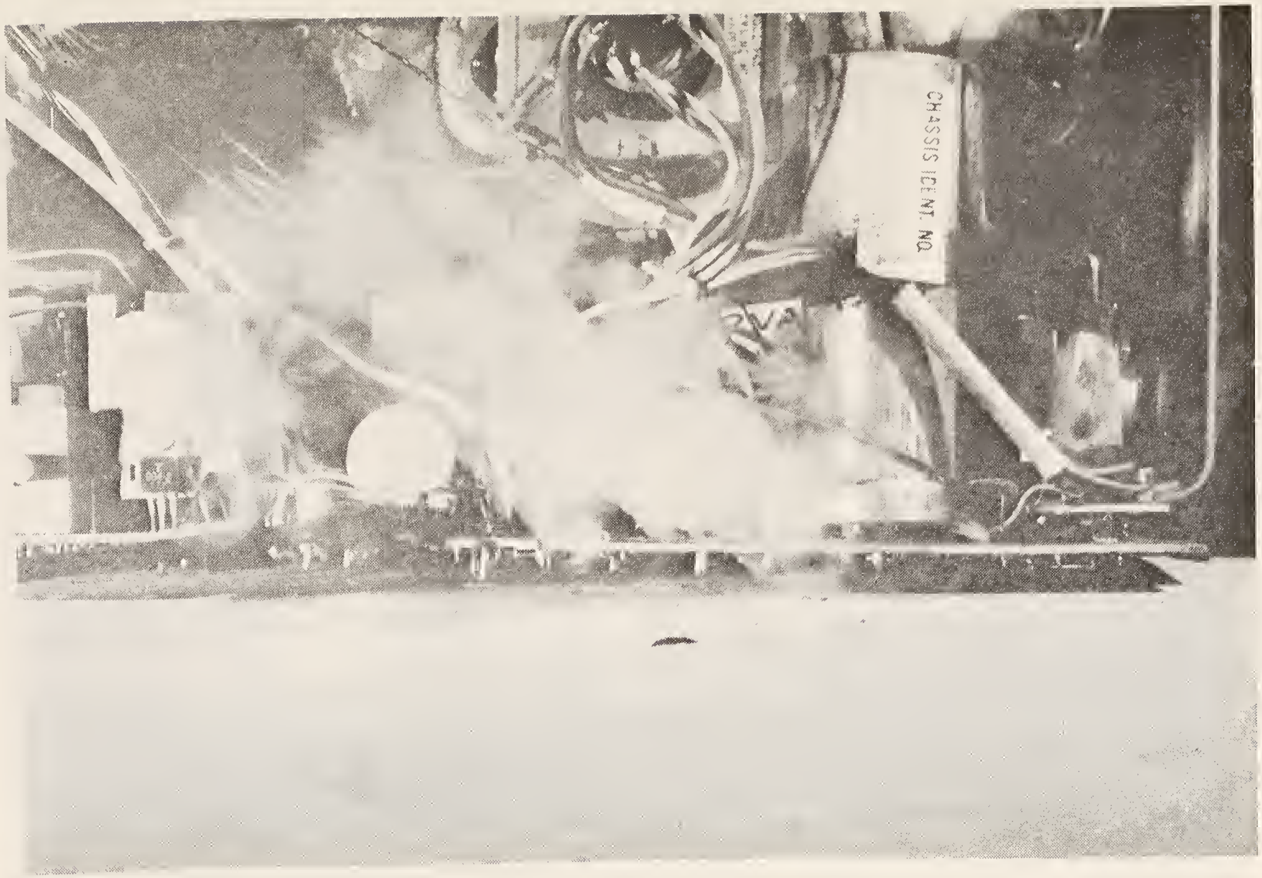

Figure 7. Smoke produced by resistor R1

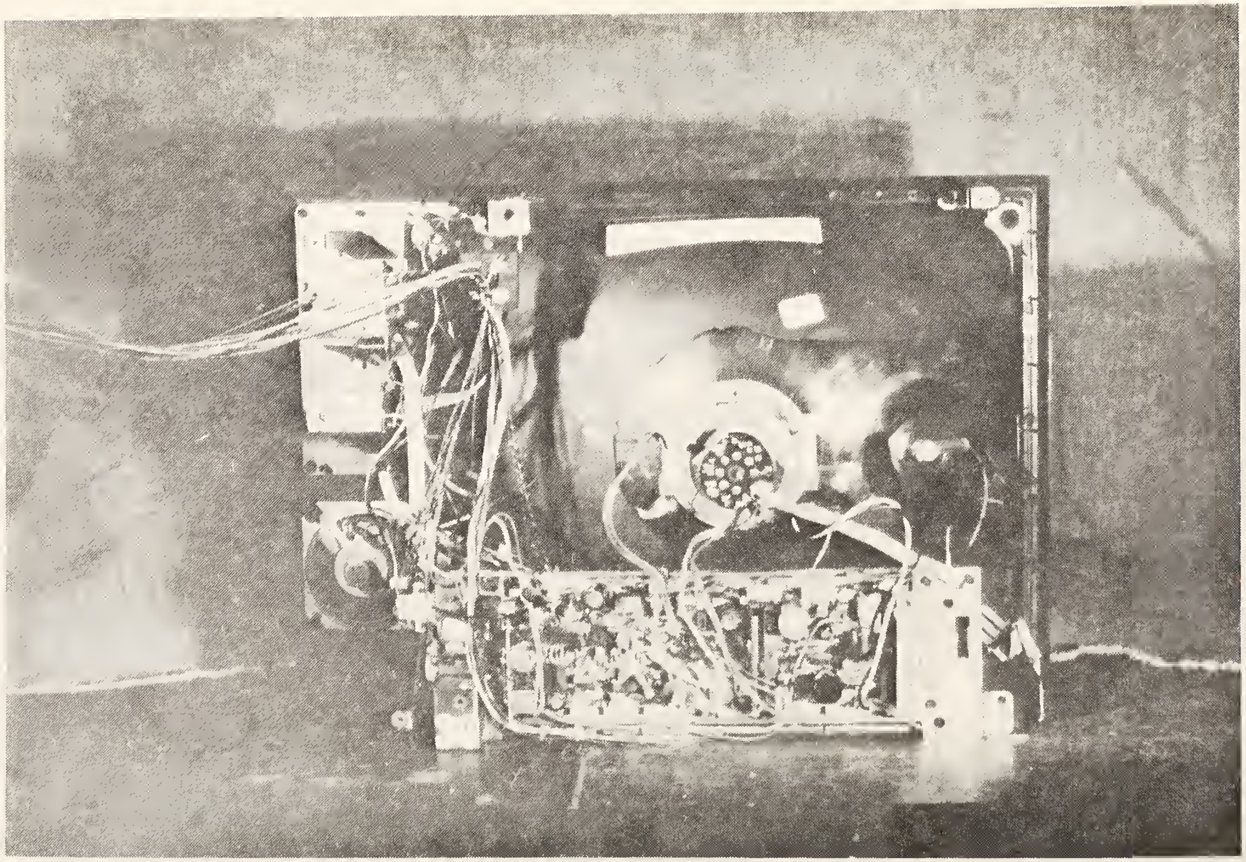

Figure 8. 48.3-cm black and white receiver, back cover removed

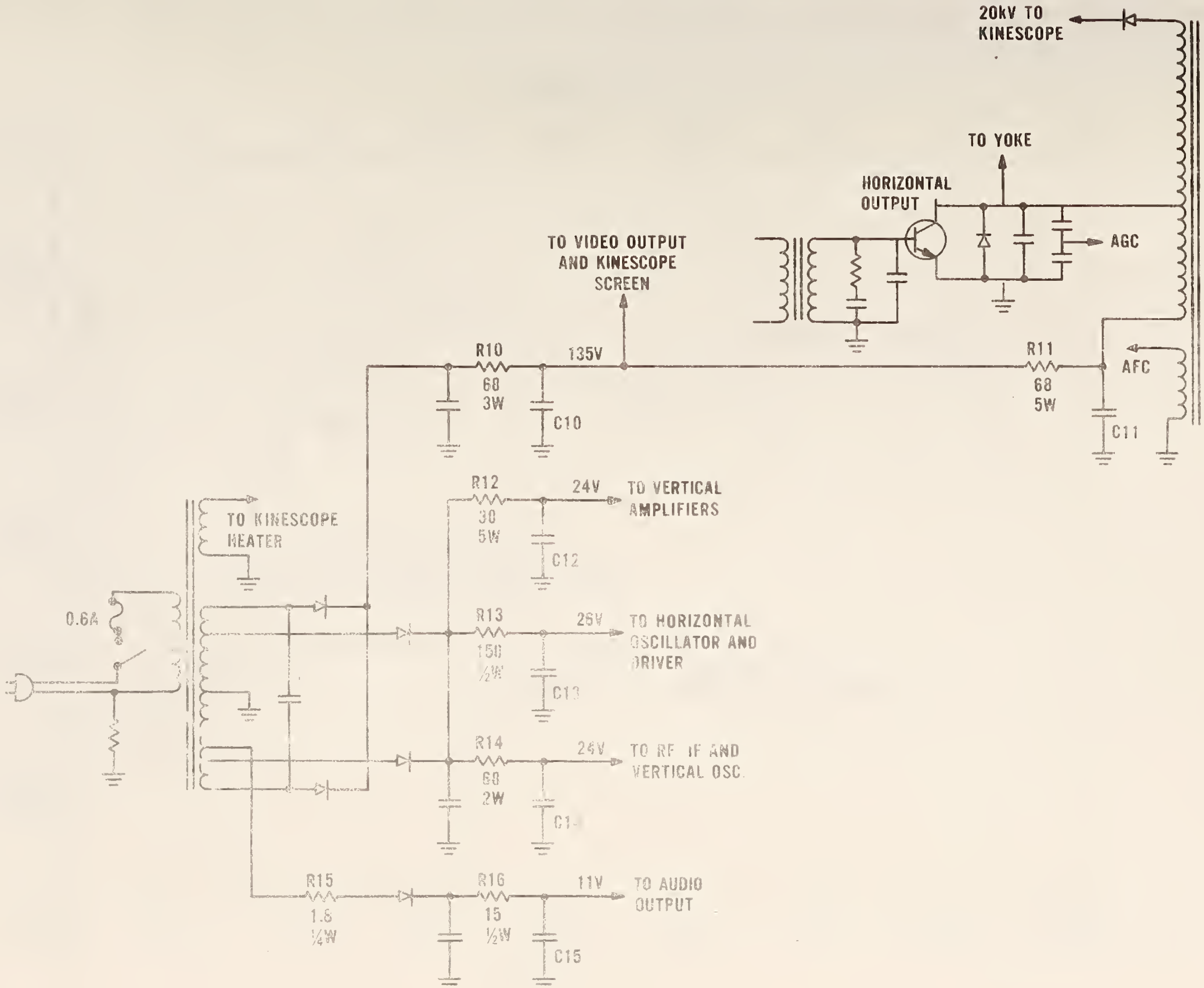

Figure 9. Partial schematic diagram of 48.3-cm black and white TV receiver

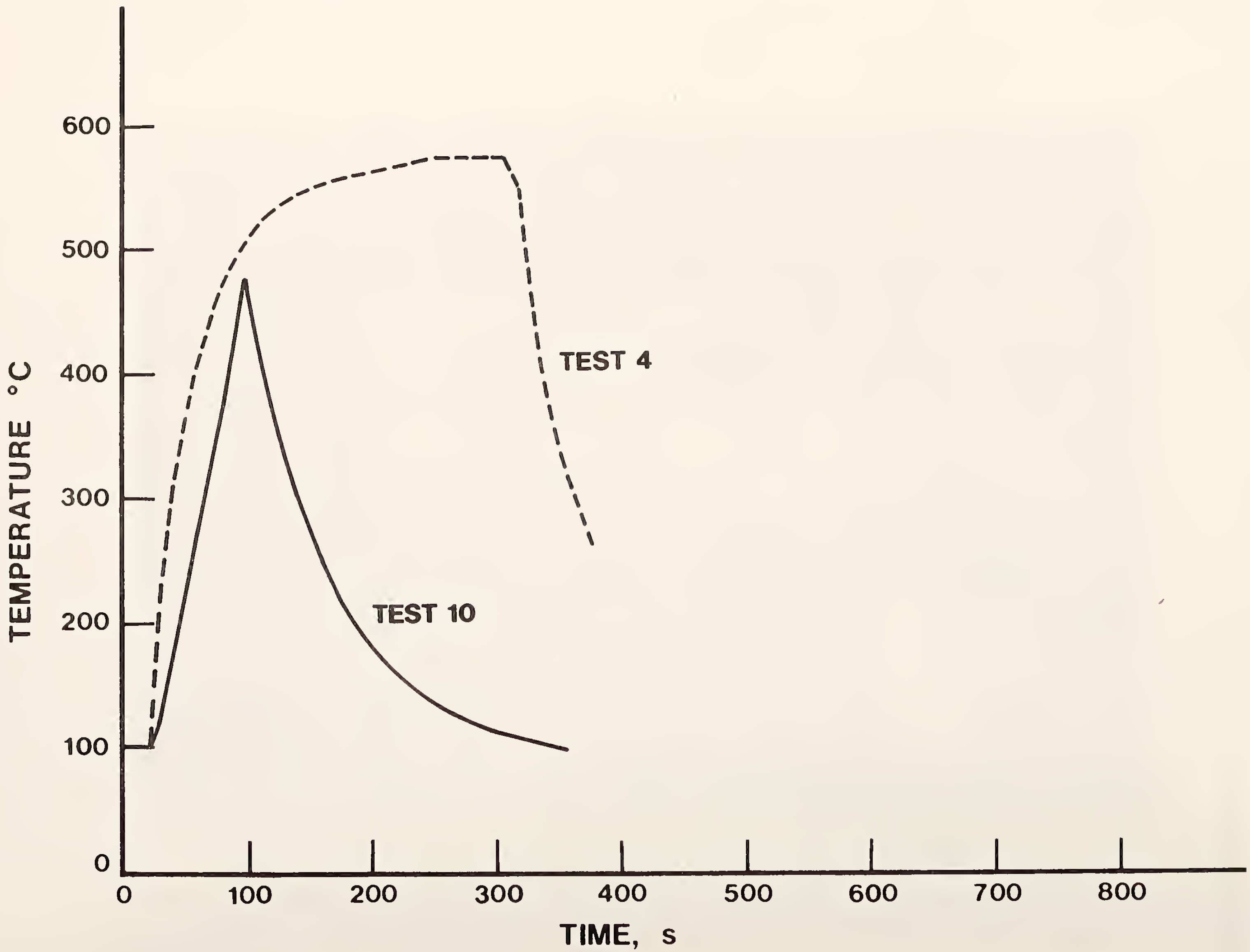

Figure 10. Tests 4 and 10, 48.3-cm black and white, temperature of resistor R14

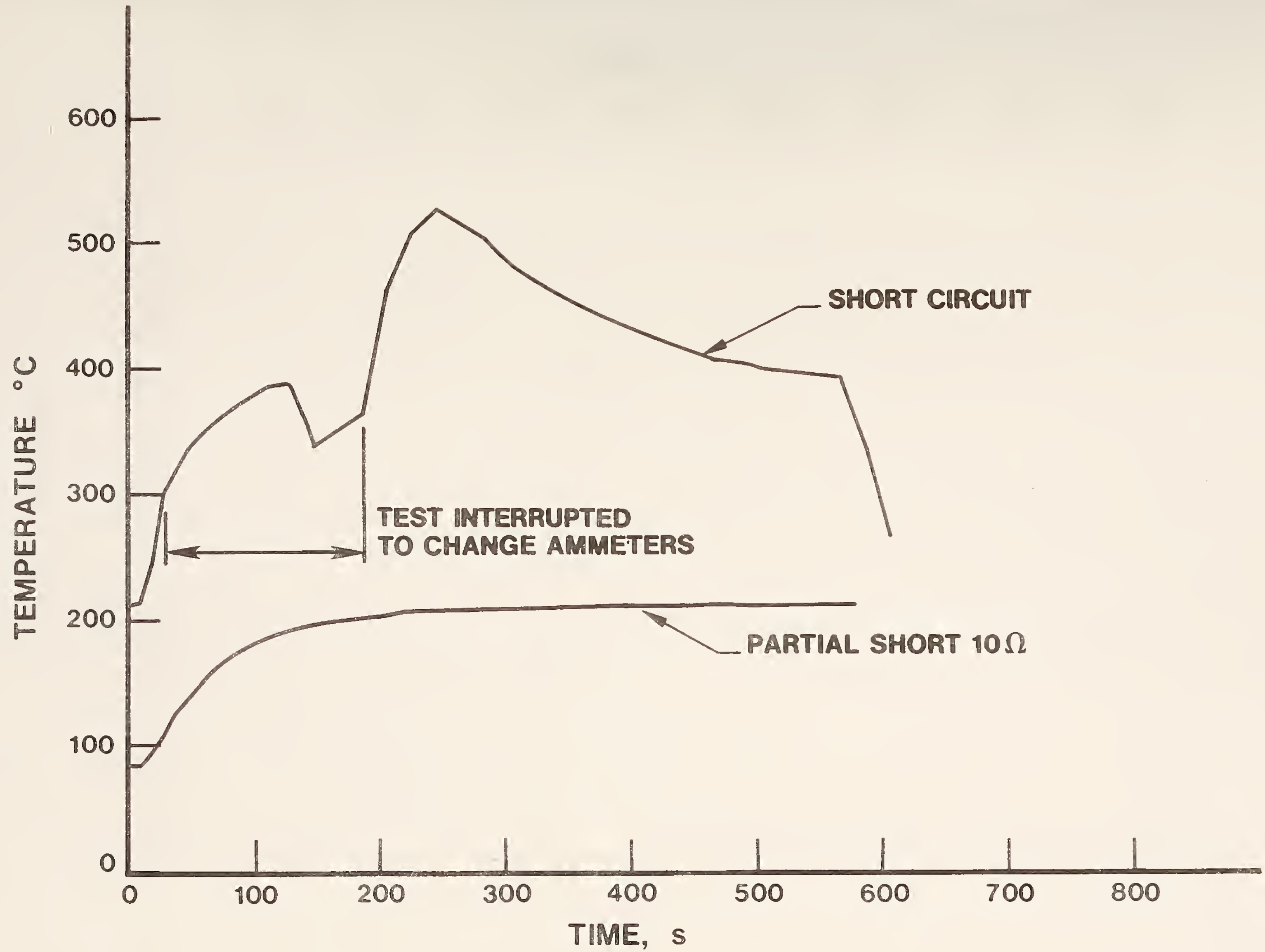

Figure 11. Test 13, 48.3-cm black and white, temperature of resistor R14

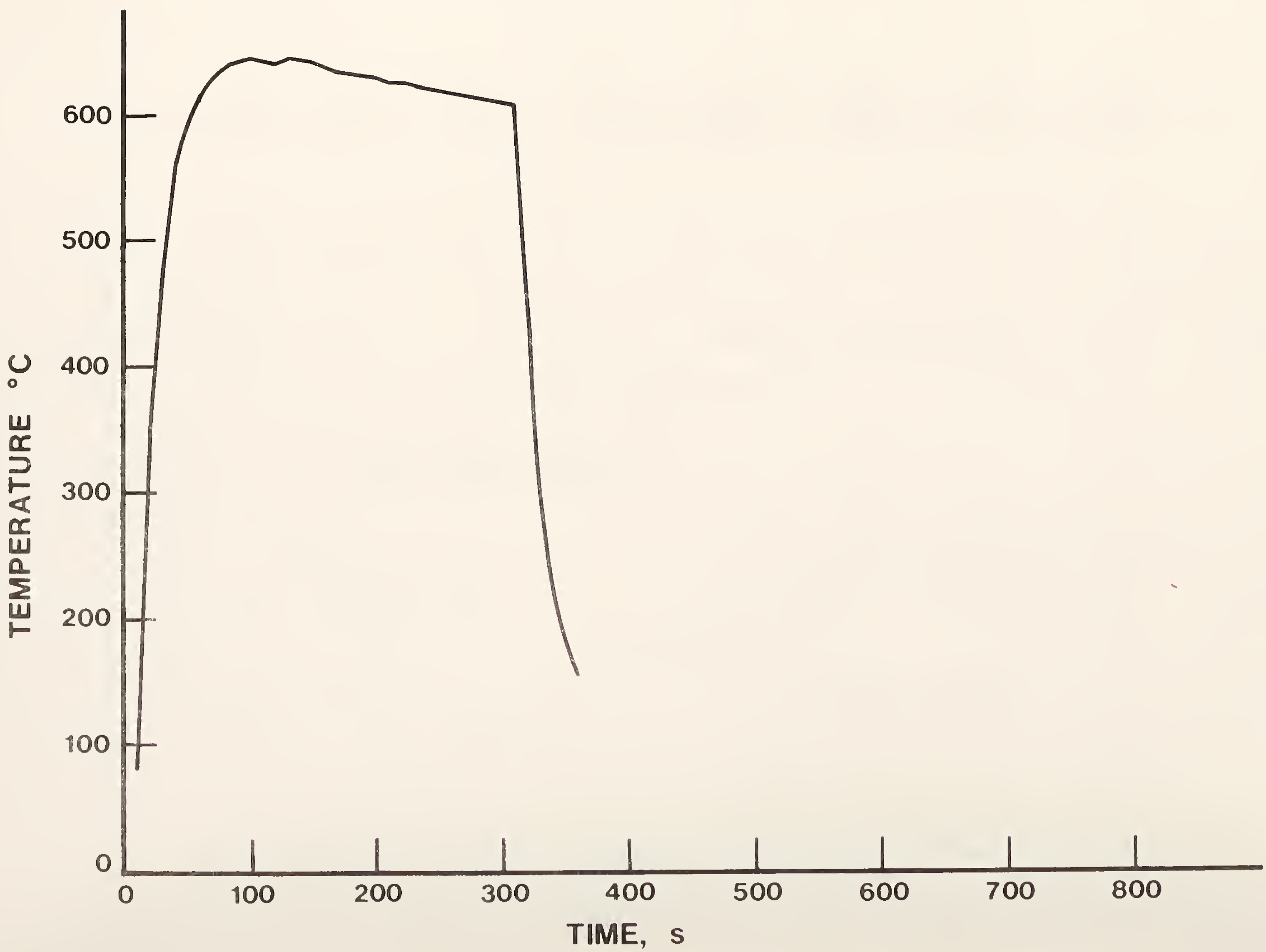

Figure 12. Test 5, 48.3-cm black and white, temperature of resistor R13

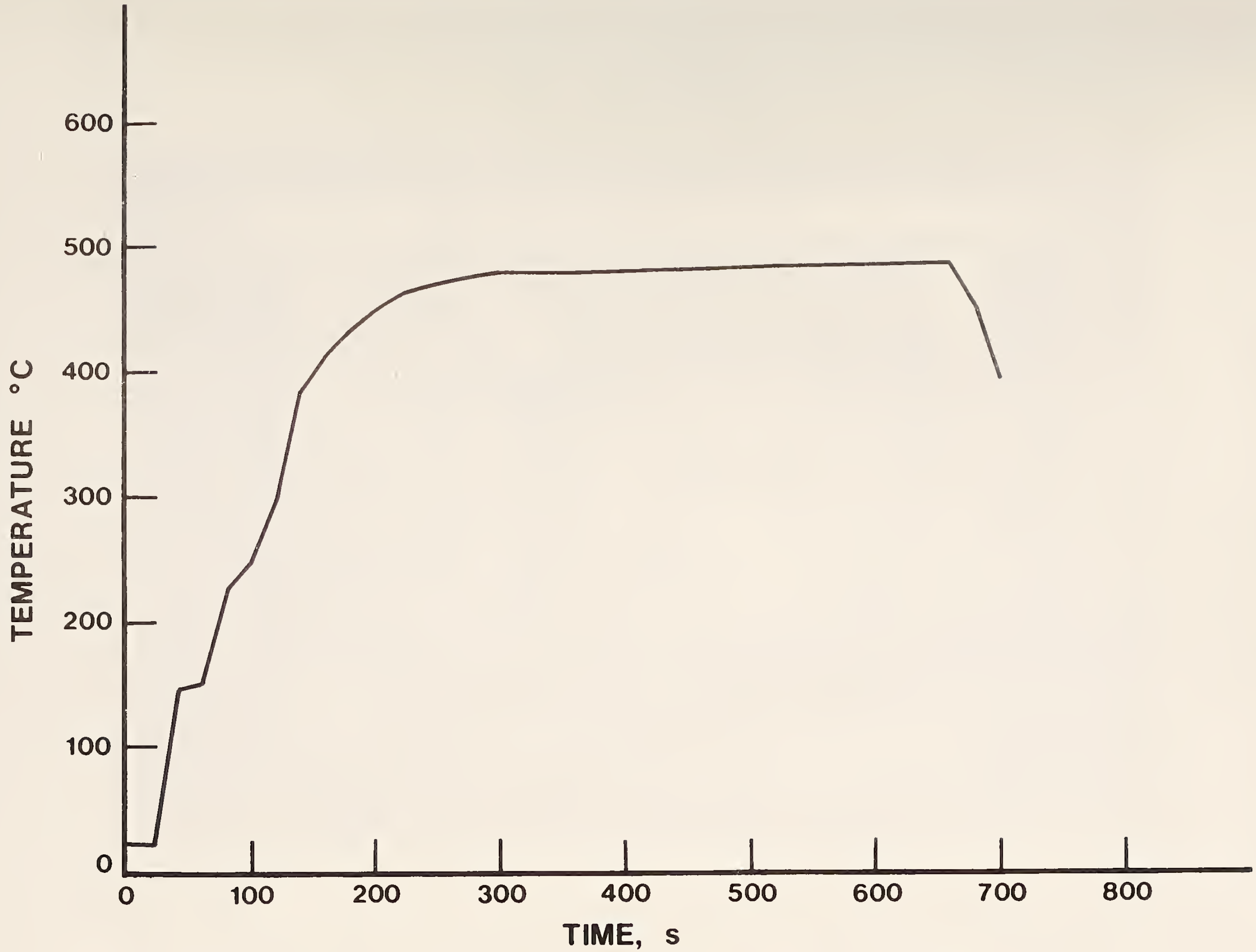

Figure 13. Test 11, 48.3-cm black and white, temperature of resistor R12

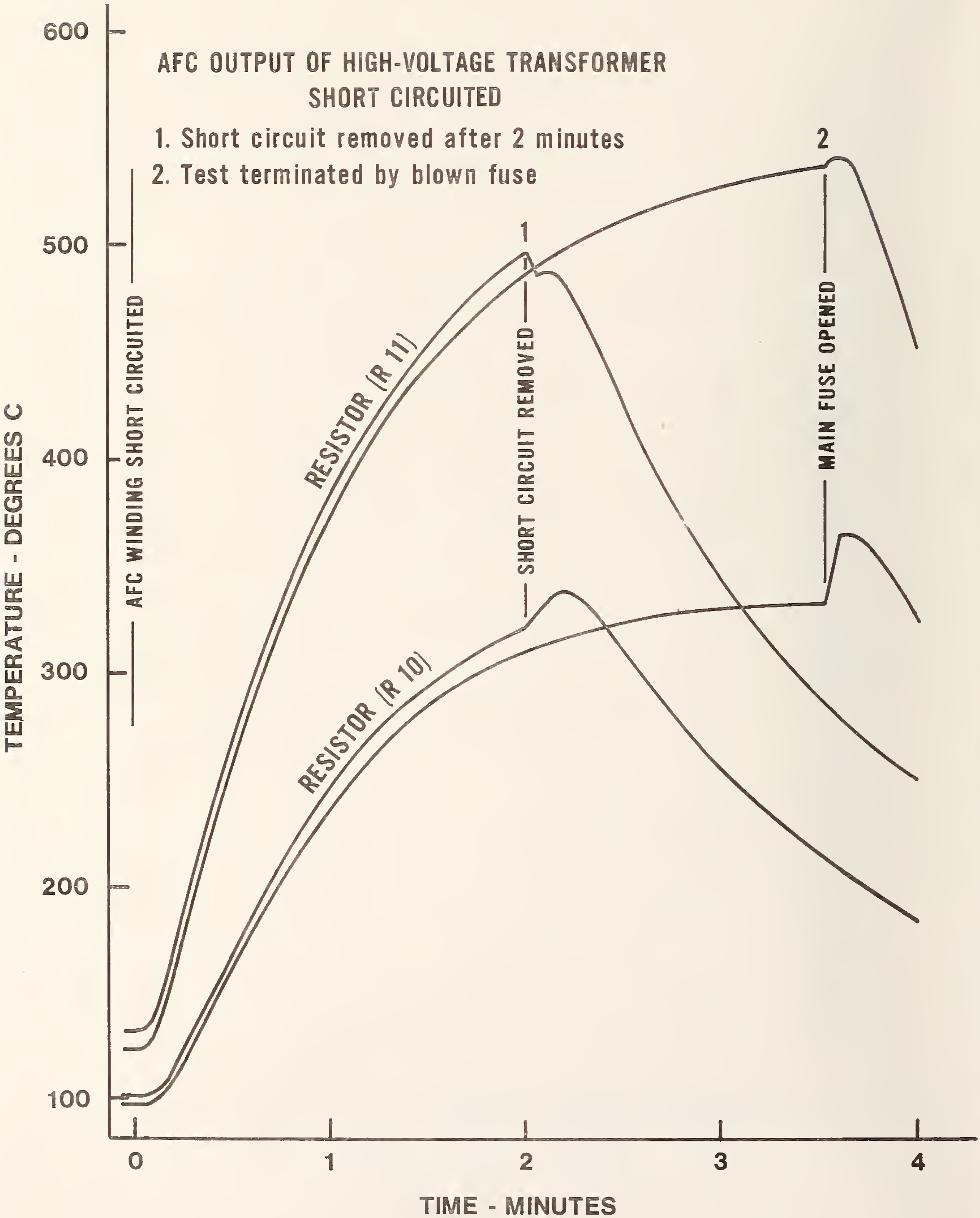

Figure 14. Test 14, 48.3-cm black and white, temperature of resistors R10 and R11

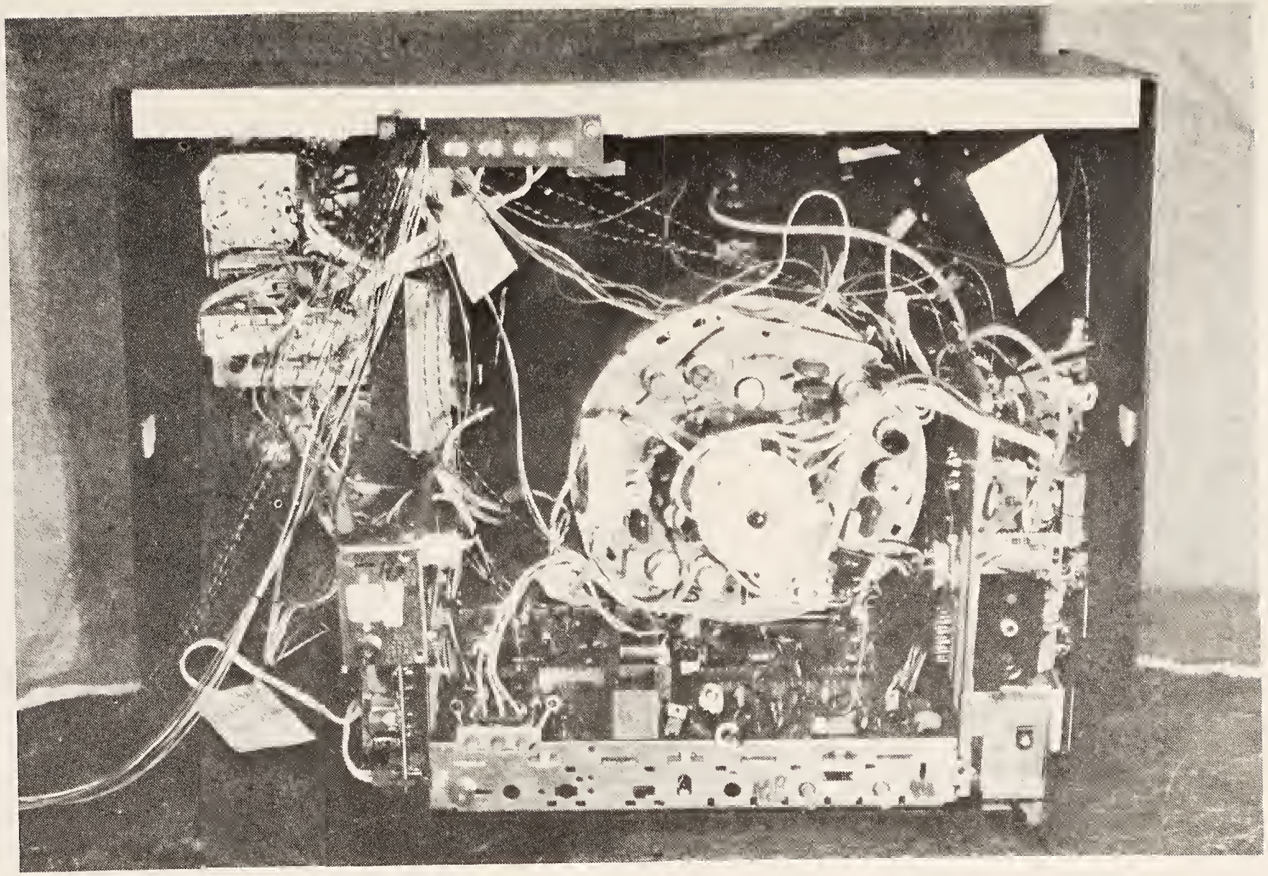

Figure 15. 48.3-cm color receiver, back cover removed

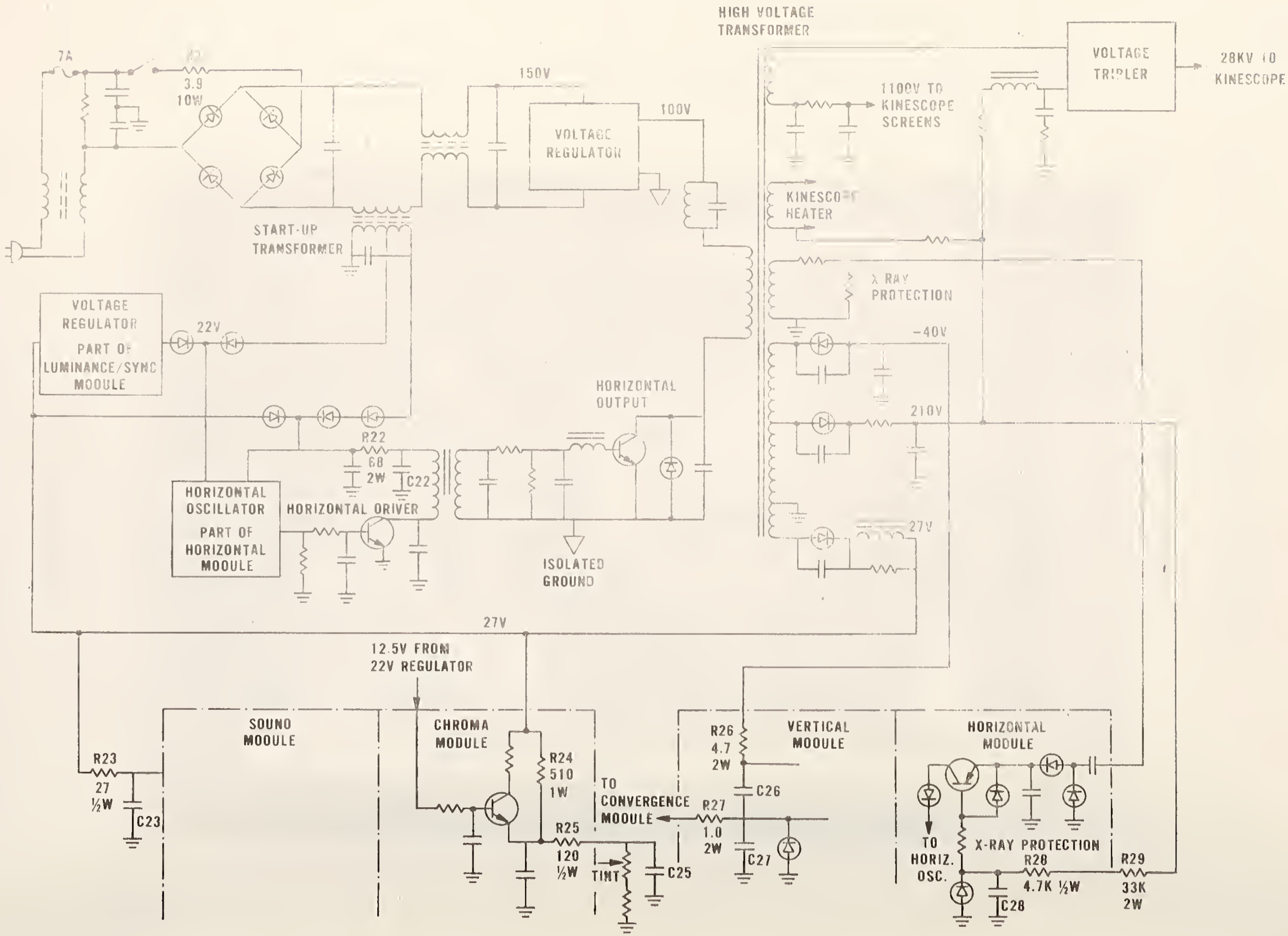

Figure 16. Partial schematic diagram of 48.3-cm color TV receiver

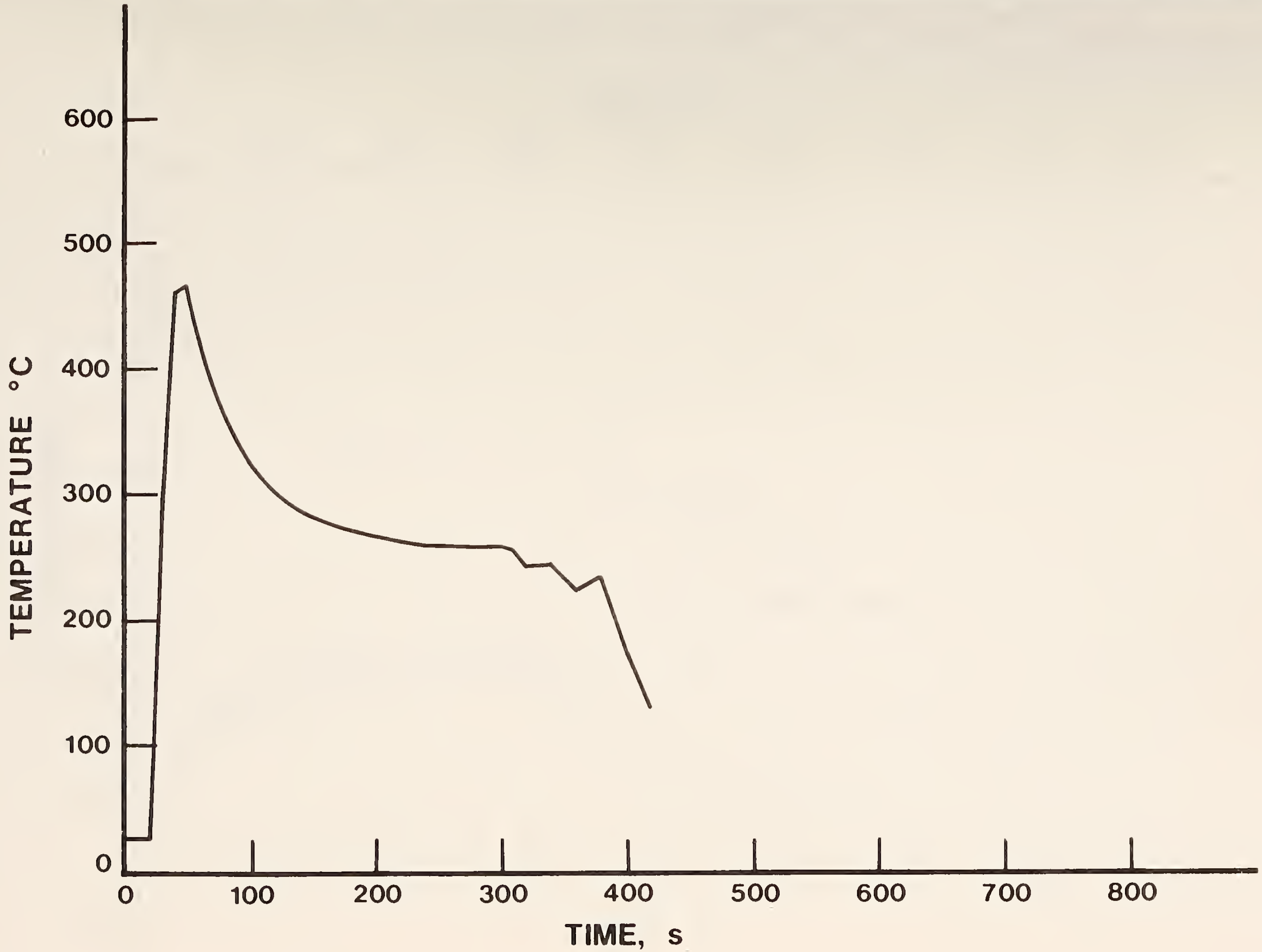

Figure 17. Test 15, 48.3-cm color, temperature of resistor R23

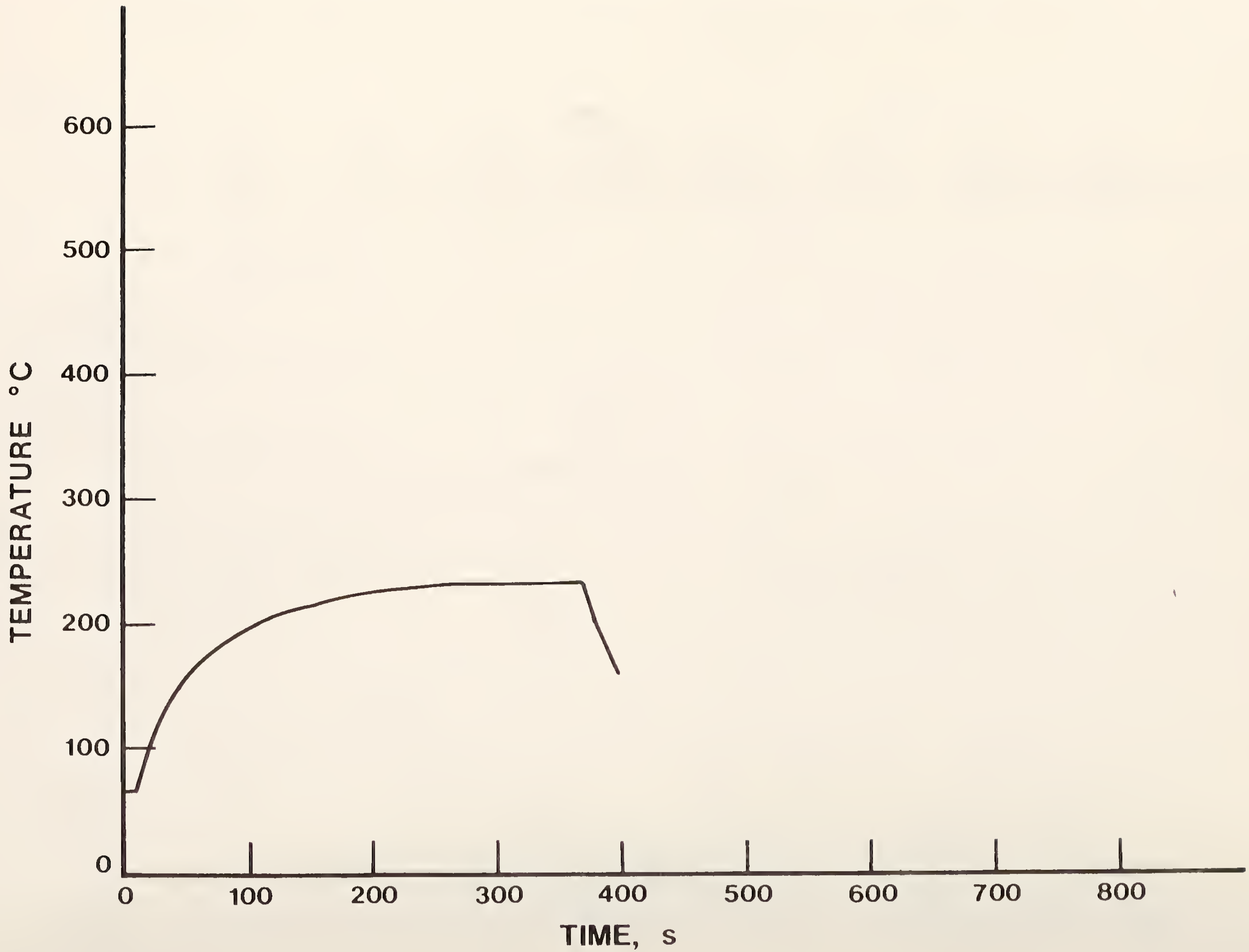

Figure 18. Test 19, 48.3-cm color, temperature of resistor R22

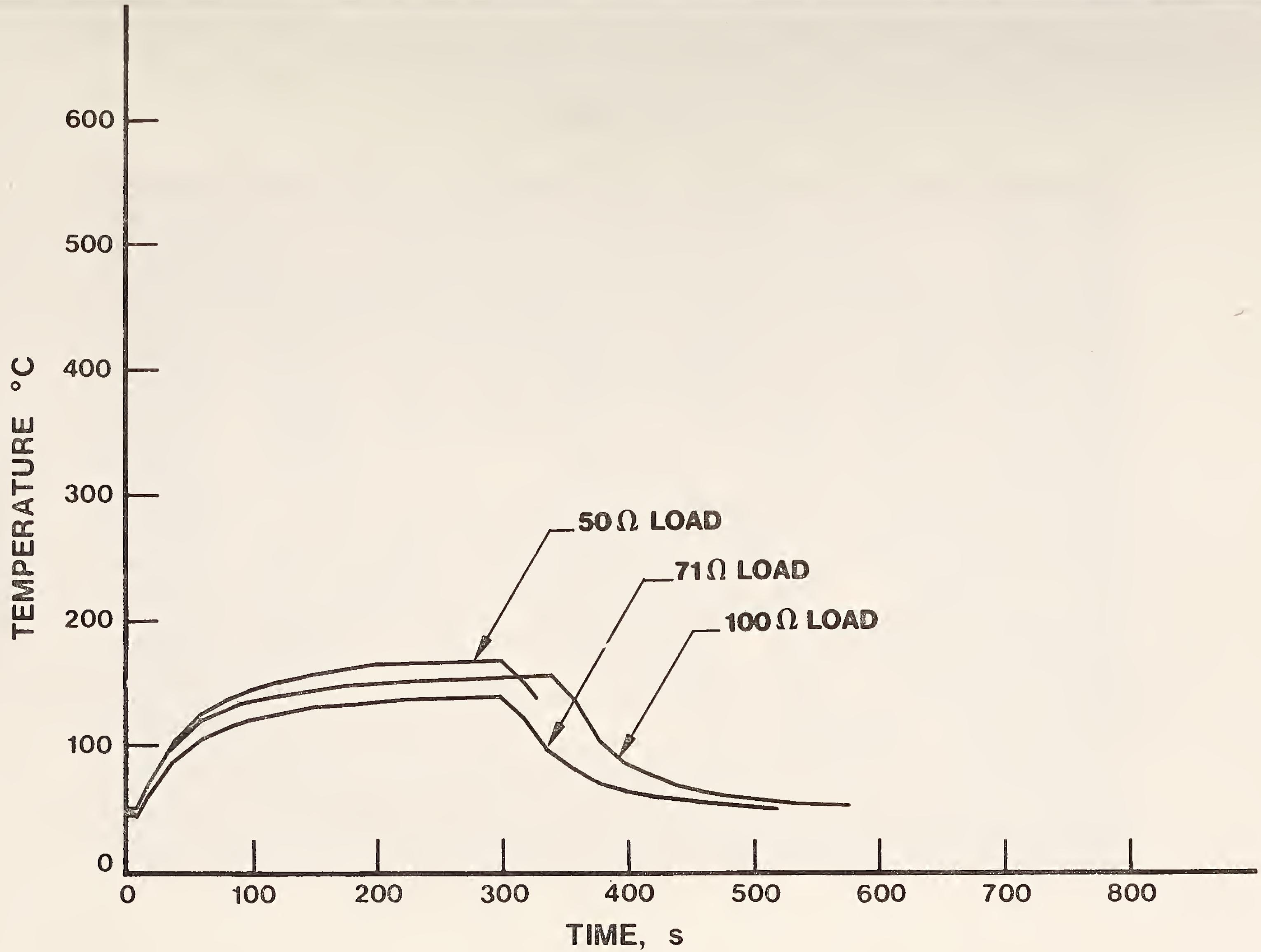

Figure 19. Test 18, 48.3-cm color, temperature of resistor R23

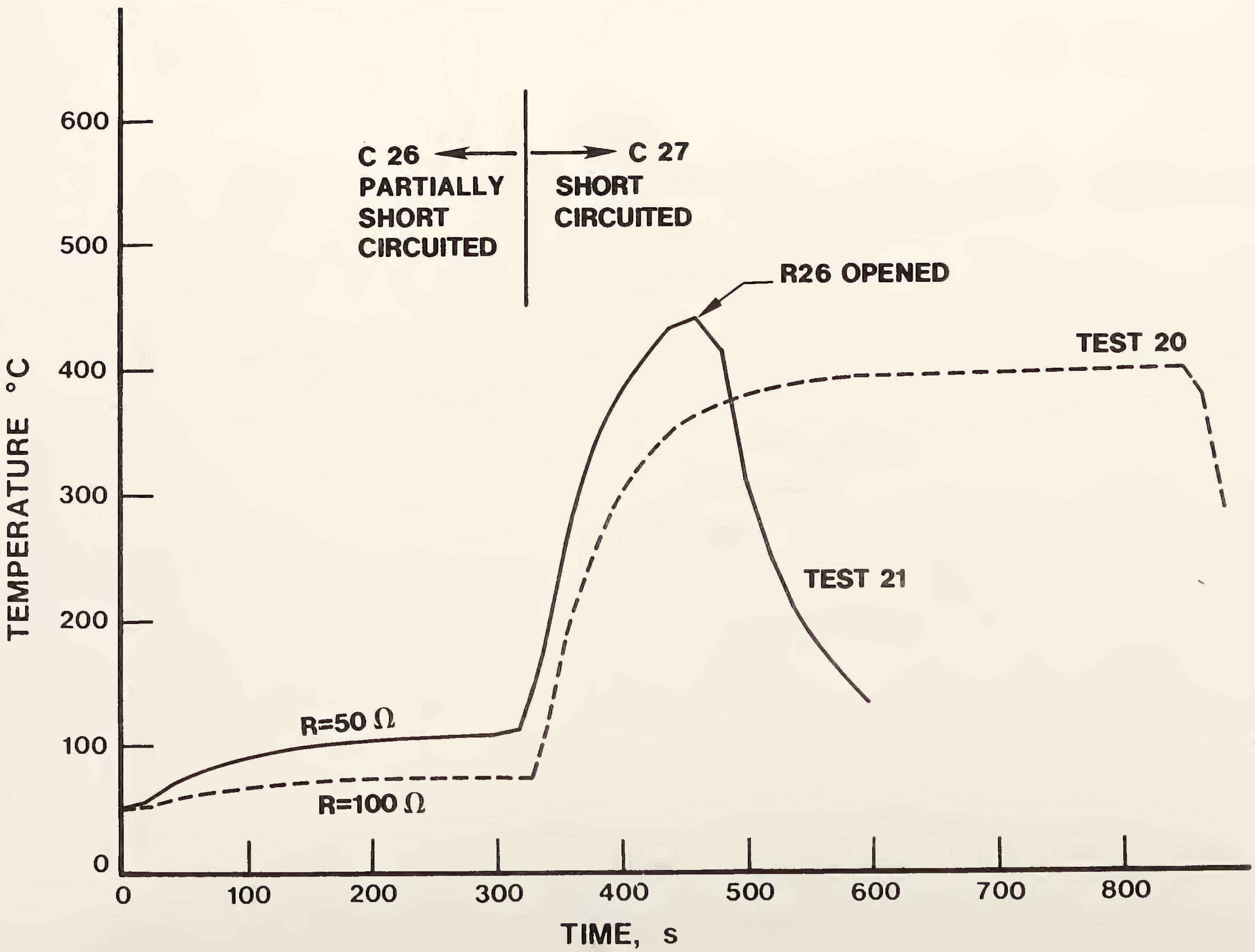

Figure 20. Tests 20 and 21, 48.3-cm color, temperature of resistor R26

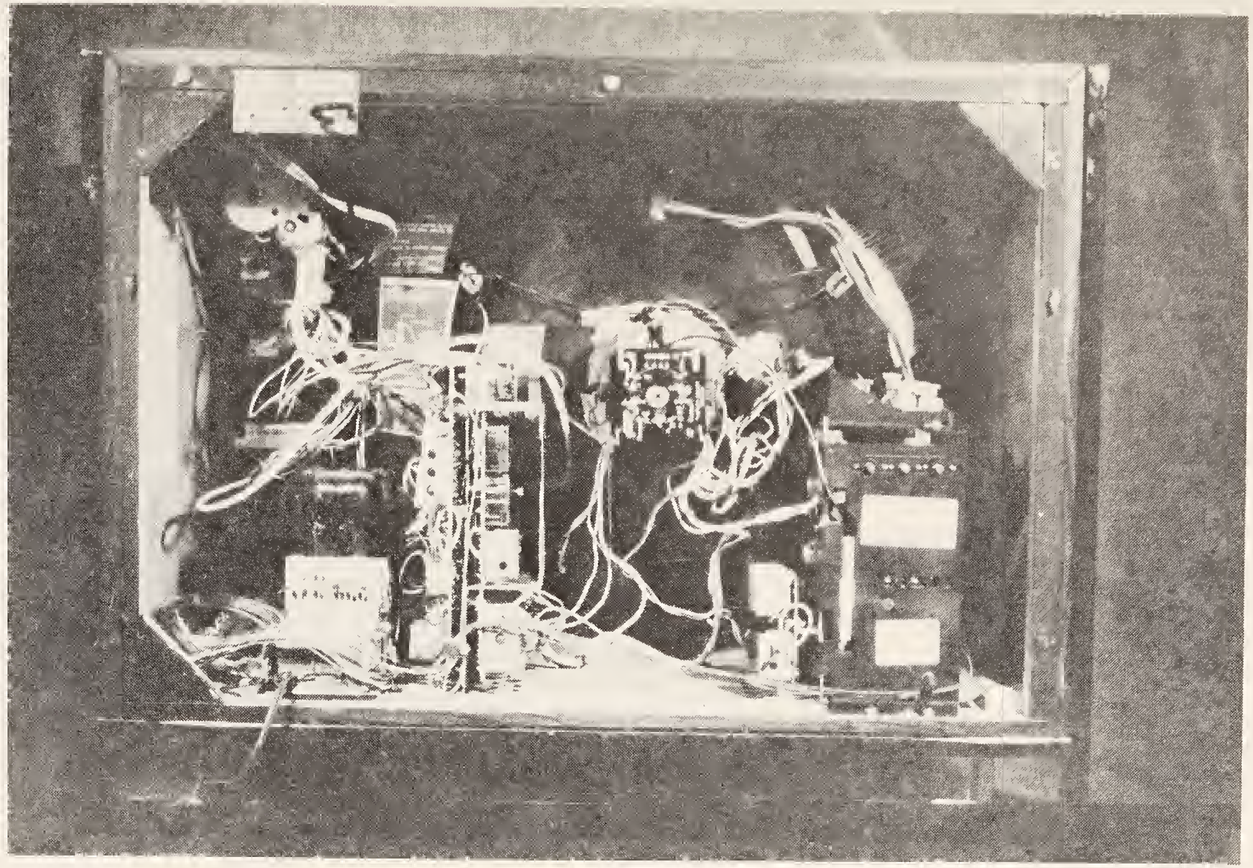

Figure 21. 63.5-cm color receiver, back cover removed

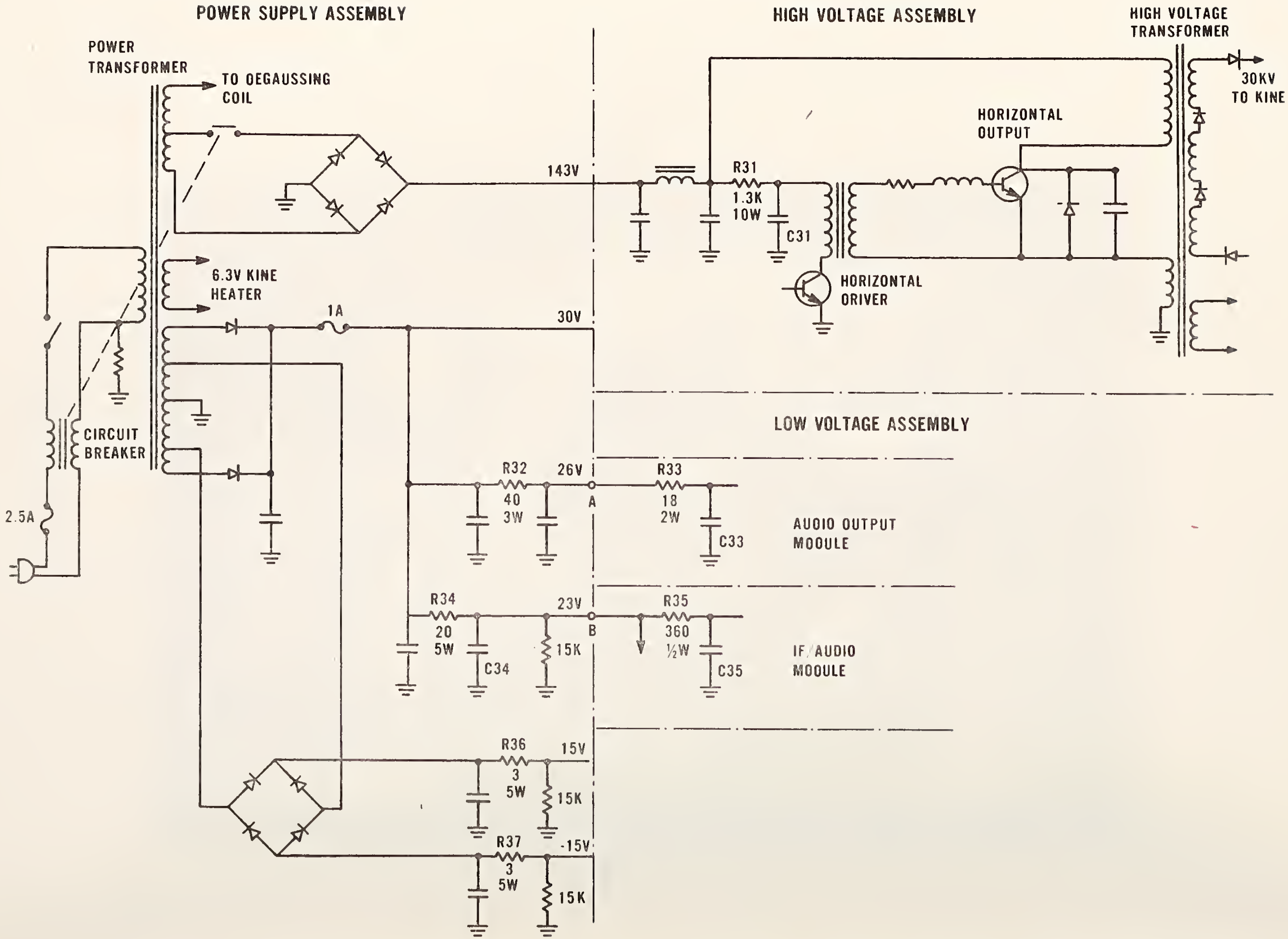

Figure 22. Partial schematic diagram of 63.5-cm color TV receiver

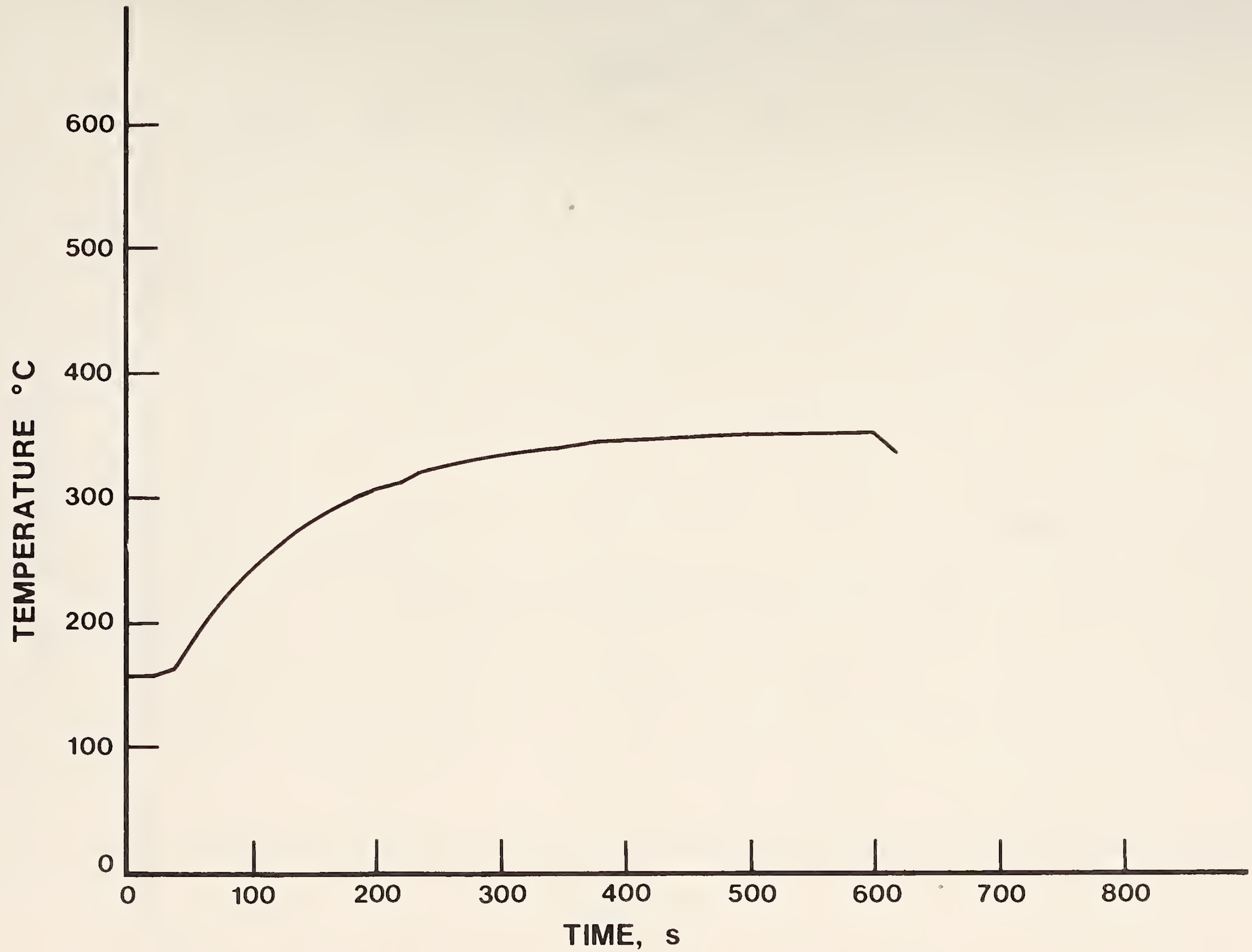

Figure 23. Test 23, 63.5-cm color, temperature of resistor R31

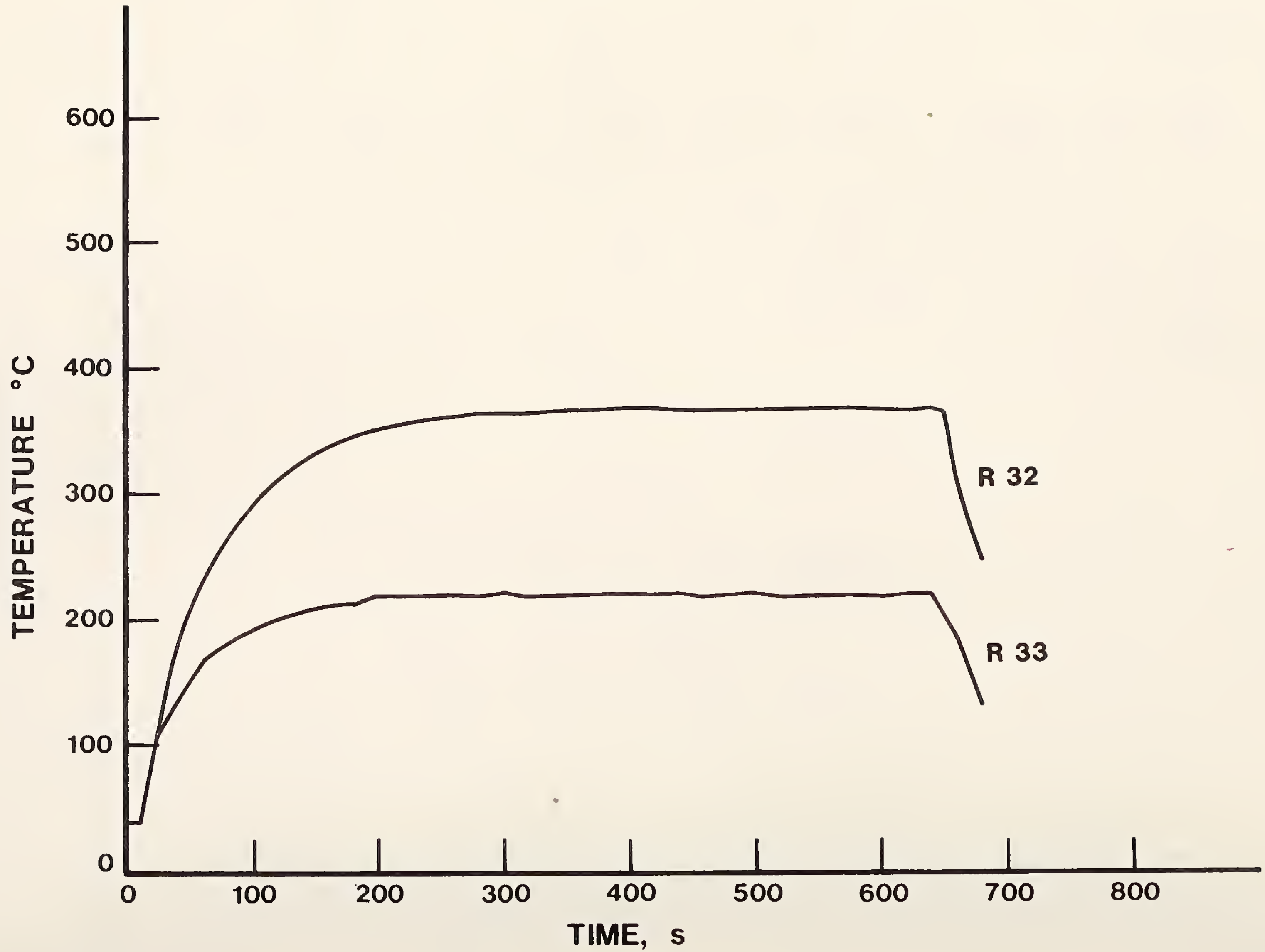

Figure 24. Test 24, 63.5-cm color, temperature of resistors R32 and R33

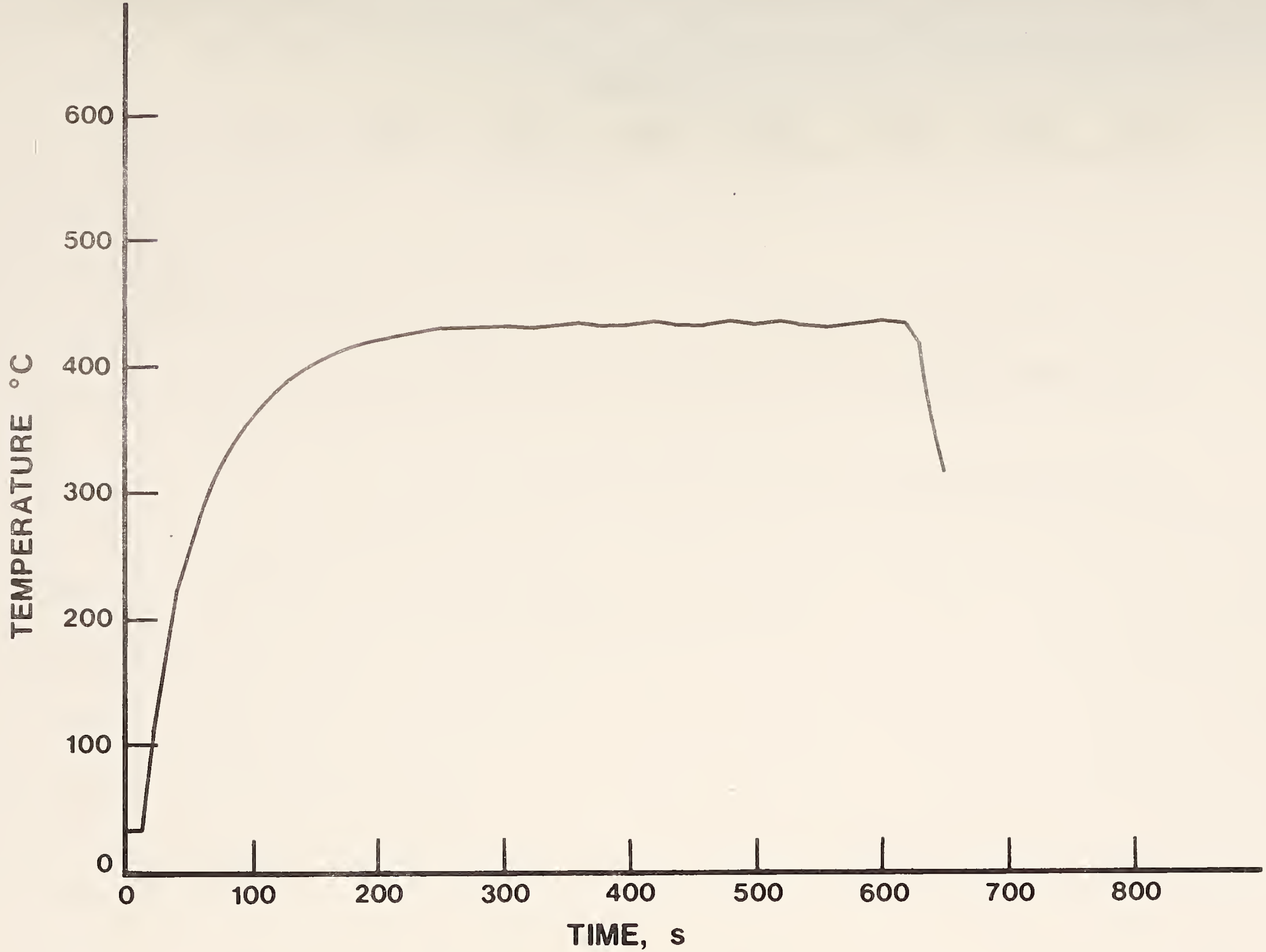

Figure 25. Test 25, 63.5-cm color, temperature of resistor R32

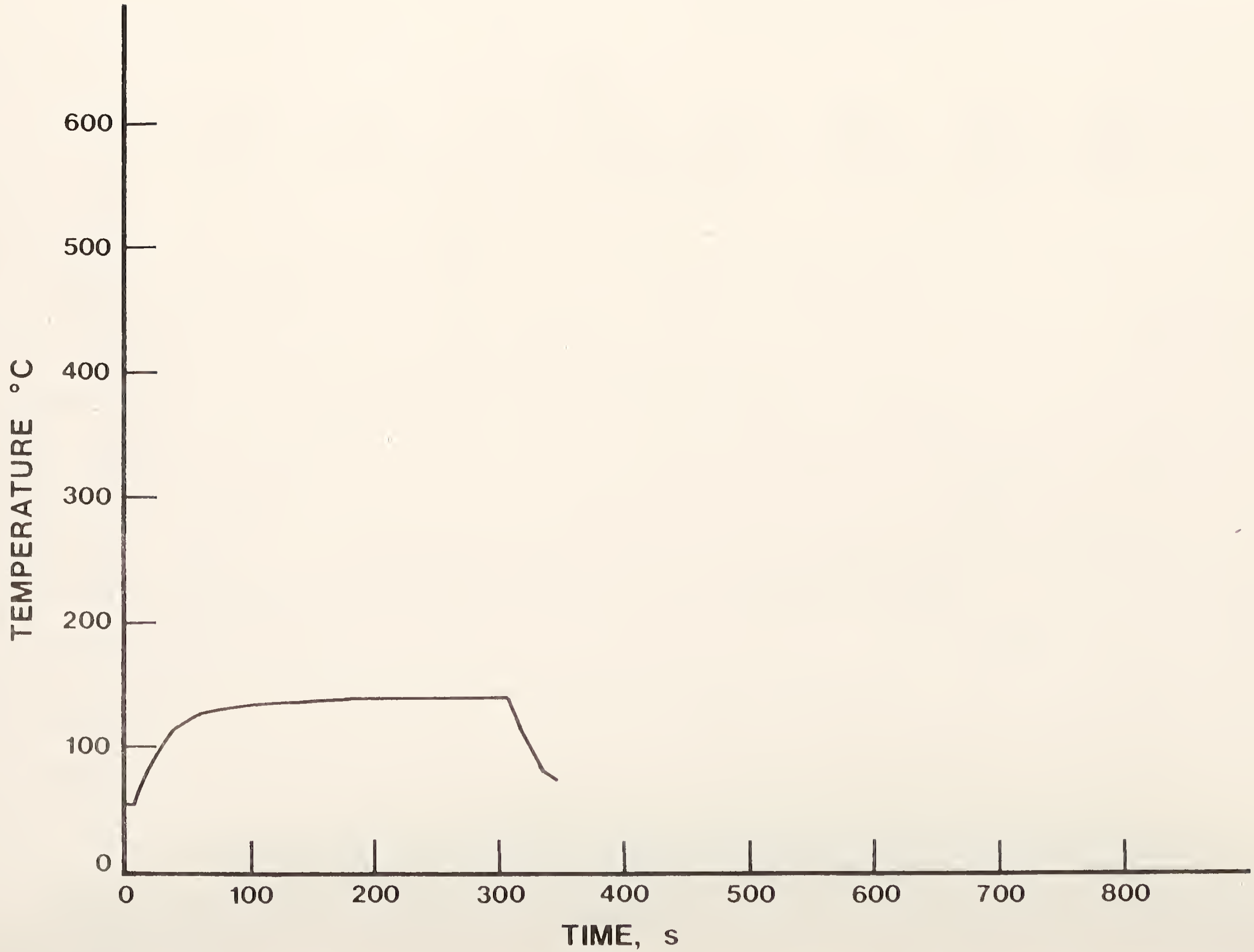

Figure 26. Test 26, 63.5-cm color, temperature of resistor R35

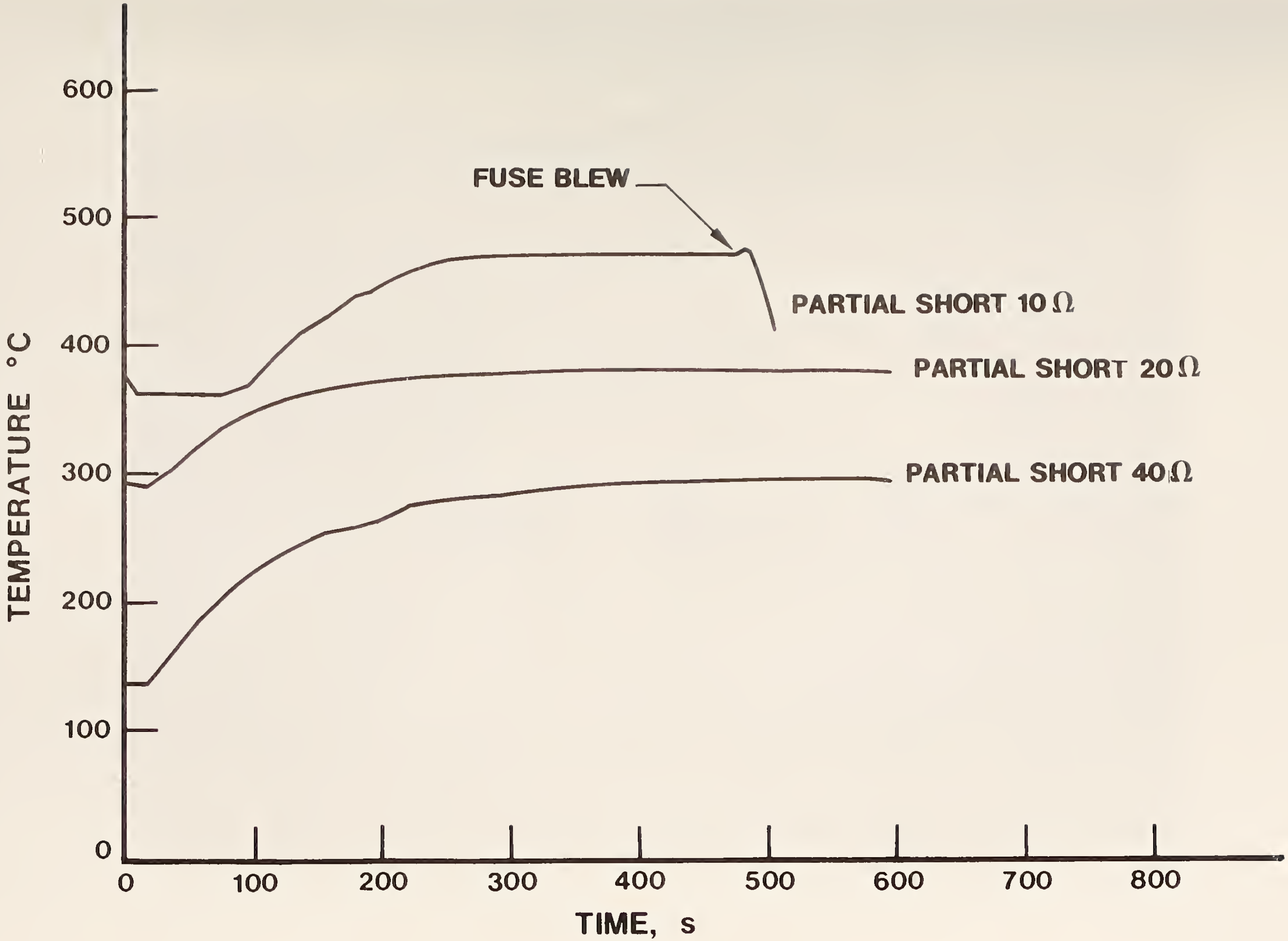

Figure 27. Test 27, 63.5-cm color, temperature of resistor R34

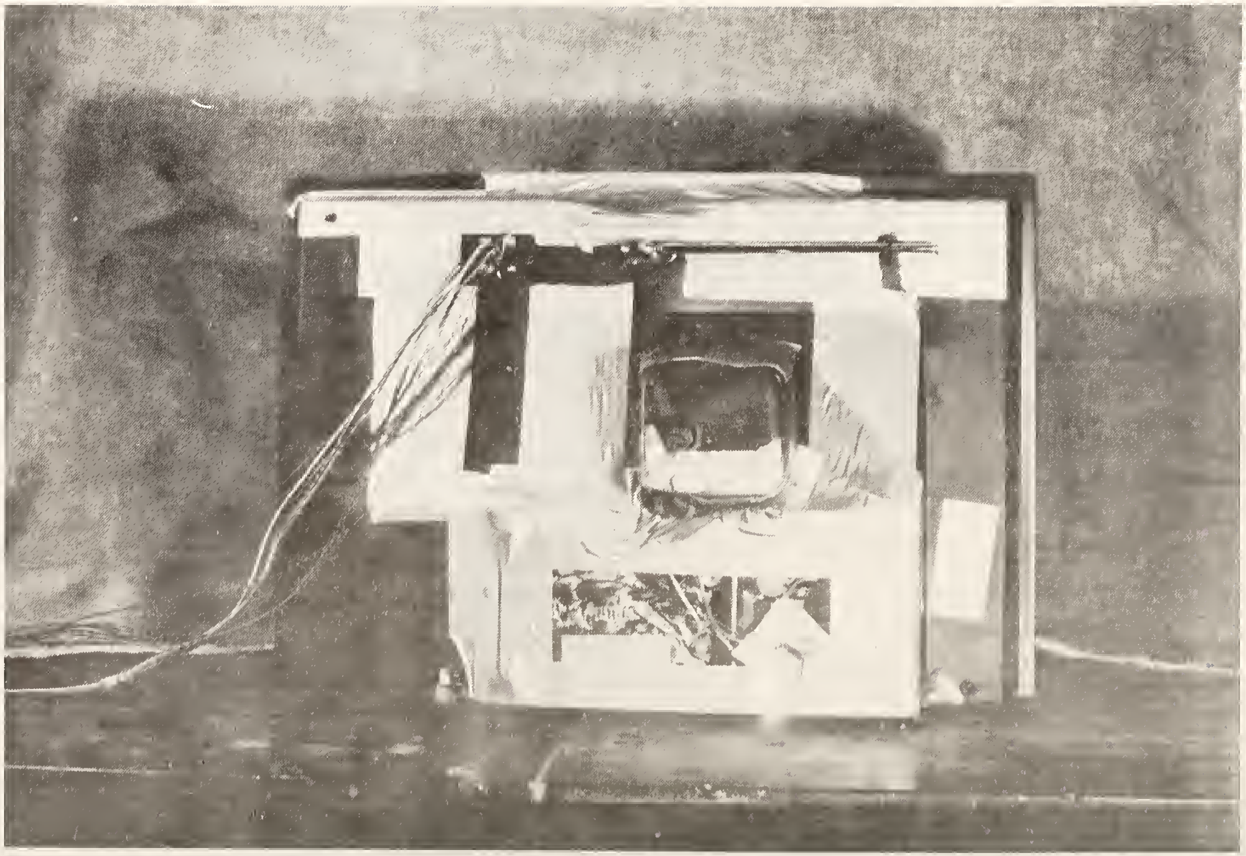

Figure 28. 48.3-cm black and white receiver, sealed for reduced ventilation test

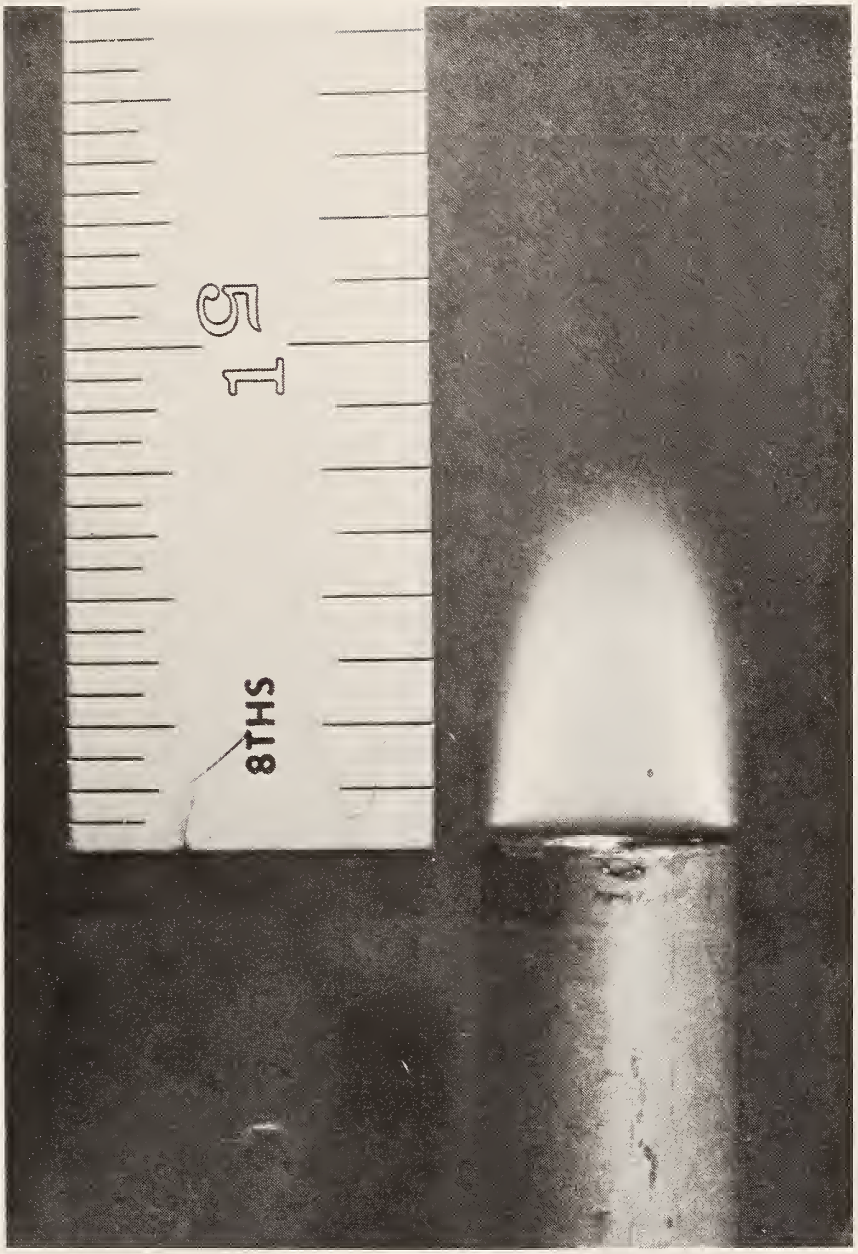

Figure 29. 1.9-cm (3/4-in) UL 94 test flame

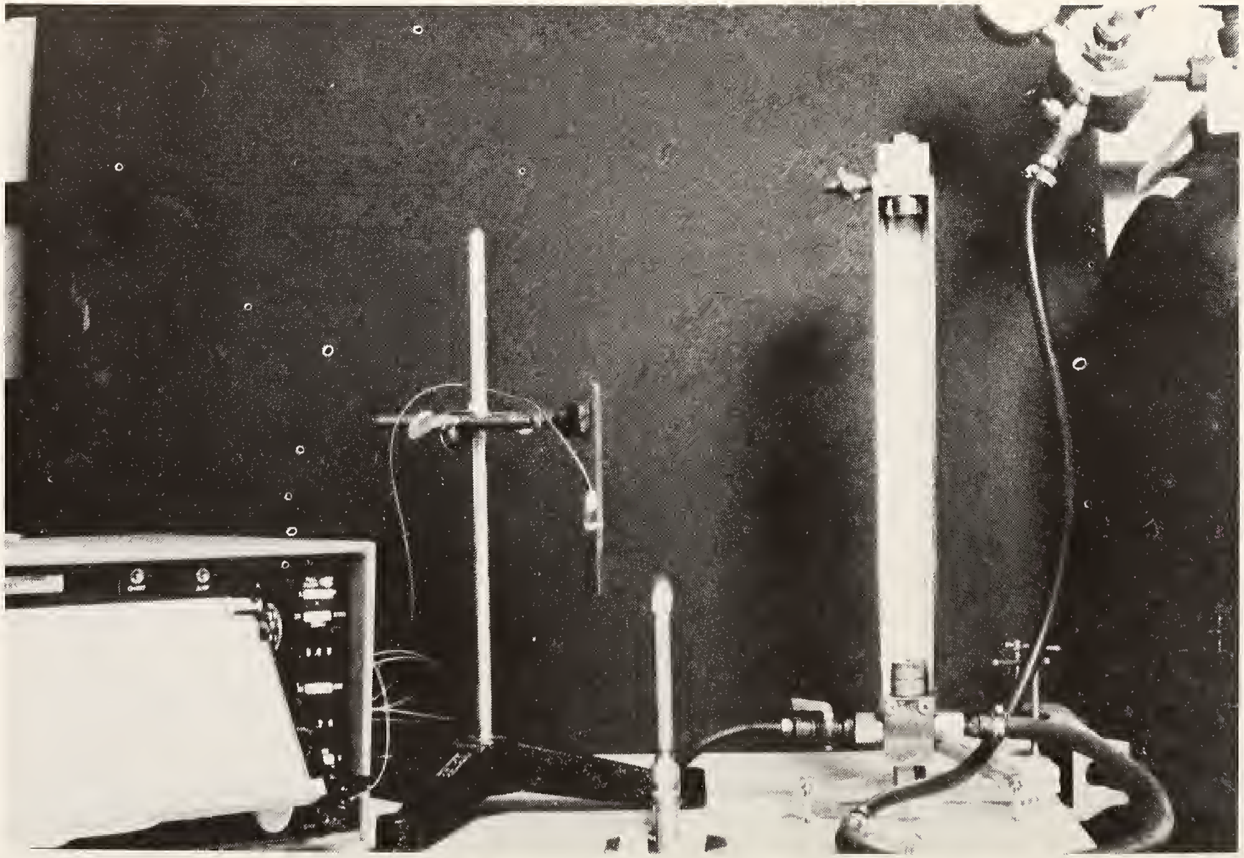

Figure 30. Test equipment for energy release rate measurements

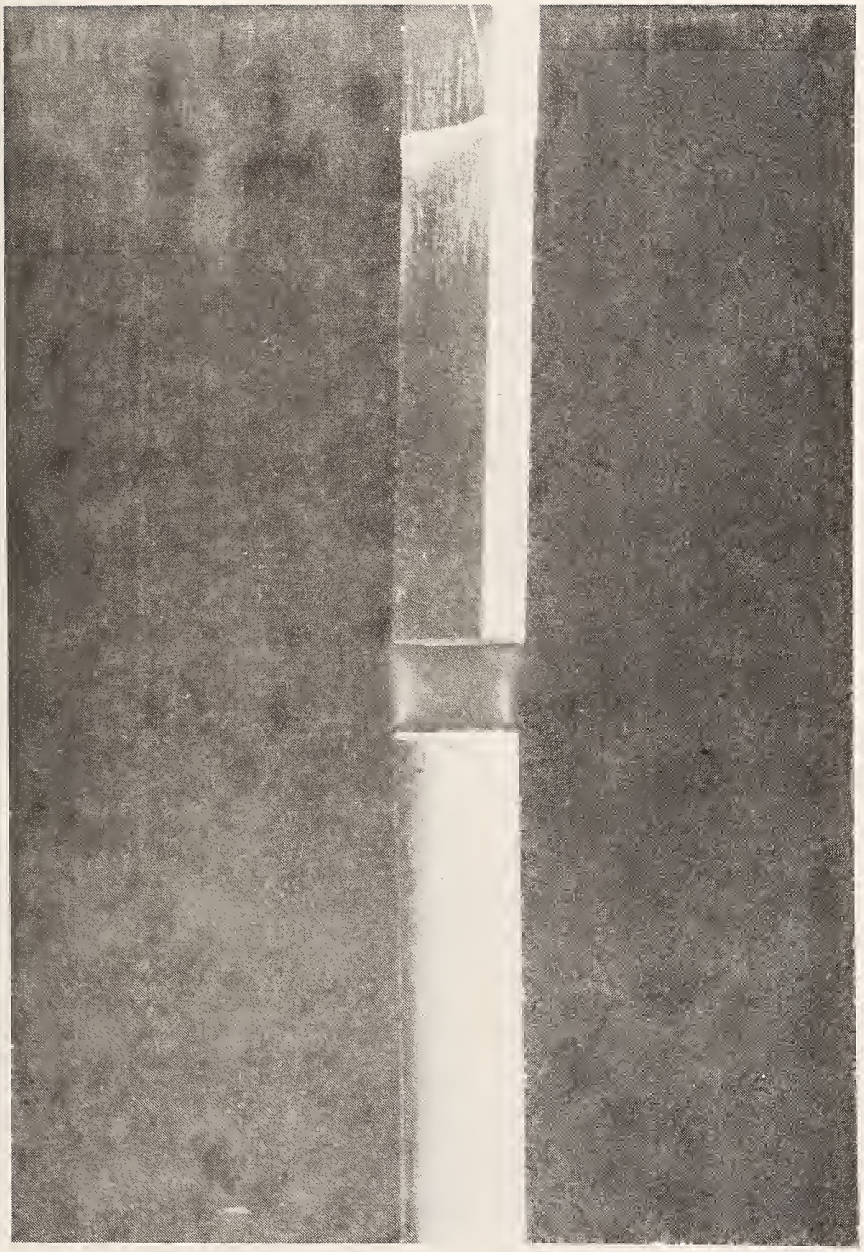

Figure 31. Copper slug UL 94 sample in flame

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The ignition of television receivers initiated by electrical failures in the circuitry was examined by studying four receivers. They were: two black and white portables, a color portable, and a color console receiver. Selected locations within the circuitry were stressed by introducing full or partial short circuits to simulate the failure of electronic components. The temperatures and increased power dissipation generated by short-circuited components were recorded. Although component temperatures greater than 500°C were achieved, no flaming ignition sources were generated.

For comparative purposes the energy release rate of the ignition source specified in the UL 1410 test procedure was measured. Supplemental measurements on the operating temperatures of chassis components under varying ventilation conditions were also made.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Electrical failure; fire containment; ignition; television fire

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