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RP

DESCRIPTION AND TESTING OF AN APPARATUS FOR ELECTRICALLY INITIATING FIRES THROUGH SIMULATION OF A FAULTY CONNECTION

Barry L. Spletzer
Frank Horine*

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Sandia National Laboratories
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*K-Tech Corp.

ABSTRACT

An apparatus has been developed that allows the simulation of a faulty connection in an electrical circuit by placing a small resistance heater at the screw of a terminal strip. The apparatus and associated control system are described in detail. Details of a typical fire produced with the apparatus are presented, along with results of electrical fire initiation attempts with both IEEE-383 qualified and unqualified nuclear power plant cable.

Repeated use of the apparatus has shown that a self-sustaining fire can be reliably initiated in unqualified cable with power levels to the apparatus not exceeding 200 W. Such fires may be initiated in approximately 10 min. Large-scale fires have been initiated with the apparatus, indicating that propagation to any desired fire size is possible. Similar efforts with IEEE-383 qualified cable have begun, but the results are not yet conclusive.

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EXECUTIVE SUMMARY

A credible source of reactor plant fires is that of elevated temperatures caused by heat generated in electrical circuits that are faulty in some aspect. Previous work in electrically initiated fires has concentrated on heat generation through large current overloads. An apparatus has been developed to simulate heat generation at a faulty terminal strip connection, allowing initiation of a fire without overload currents. The purpose of this work is to provide a method for initiating larger fires in a reliable and reproducible manner for purposes of testing. In developing the apparatus, emphasis has been placed on realism within the parameters of circuit design. The apparatus serves to produce a source fire for testing the manner in which small electrical fires can threaten electrical cabinets and cabling in nuclear power plants.

The heat-generating portion of the apparatus is a metal oxide washer placed under the head of a terminal strip screw. Controllable power levels of up to 300 W are achievable with this configuration. Several self-sustaining fires have been initiated with this apparatus with peak intensities of up to 800 kW. Power input to the apparatus needed to initiate such fires is about 200 W for less than 2 min after an initial 10-min preheat at 50 W.

The initiation of fires with such low wattages and with a series resistance is of interest since power levels of greater than 200 W are available to a series resistance in any 120-Vac circuit that normally draws more than 7 A. Further, the introduction of a series resistance will not cause an overcurrent device to deenergize the circuit to prevent the initiation of the fire.

Self-sustaining fires have been repeatedly initiated in an unqualified cable (not qualified to IEEE-383 standards) with polyethylene/polyvinylchloride insulation. Similar efforts in IEEE-383 qualified cable with cross-linked polyethylene insulation have begun but are not yet conclusive.

1. INTRODUCTION

Based on plant operating experience over the last 20 yr, it has been observed that nuclear power plants are likely to have three to four significant fires over their operating lifetimes (i.e., on the order of one fire every 10 yr or a frequency of 0.1/reactor-yr) [1]. Previous probabilistic risk assessments (PRAs) have shown that fires are a significant contributor to the overall core-melt probability, contributing anywhere from 7% to 50% of the total (considering contributions from internal, seismic, flood, fire, and other events). Because of the relatively high core-melt contribution, fires need to be examined in detail. Approximately 50% of the fires observed have been of electrical origin [1]. Therefore, a credible source for these fires is that of electrical initiation. Previous work in electrically initiated fires has concentrated on passing large currents (typically more than 90 A in #12 AWG wire) through cables to generate sufficient heat within the conductor to cause the surrounding insulation to ignite [2]. Many circuits are protected by overcurrent devices such that currents of 10 to 15 A will cause the circuit to be deenergized.

This report describes the development of an apparatus to produce electrically initiated fires in electrical cables without activating circuit-protective devices that are sensitive to overload currents. The technique of passing rated currents through appropriate conductors is not considered a credible source since circuits are designed to accommodate the rated current, and heat-generation rates at such currents are extremely low (e.g., 1.4 W/ft in #12 AWG wire at 30 A).

This effort was accomplished in support of the Fire Protection Research Program being conducted by the Adverse Environment Safety Assessment Division in the area of investigation of credible fire sources for control room fires.

2. BACKGROUND

One possible source for an electrically initiated fire in a current-limited circuit is the existence of a faulty connection. Such a connection would introduce a resistance in series with the normal load and thus serve as a limited power source, producing heat at the connection. Conduction of this heat into the surrounding wires and terminal strip could ignite the adjacent wire insulation and terminal strip under appropriate conditions. A technique has been developed by which a faulty connection at a terminal strip screw may be simulated and its power level reliably controlled to allow the effects of various heat-generation rates at faulty connections to be studied.

The maximum amount of power that may be generated at a faulty connection in an actual circuit can be determined by maximizing the power available to a resistance placed in series with the existing load in a constant-voltage circuit. It should be noted that the addition of any resistance in series with the load will reduce the total current of the circuit, thus preventing the condition from being sensed by an overcurrent trip device (e.g., a fuse or circuit breaker). Figure 1 shows a typical circuit with a load of R_l before and after the introduction of a faulty connection with a resistance R_h. The total applied voltage in both cases is V; the initial power of the circuit is P_i. The current through the circuit with the faulty connection is I_f, the voltage across the load is V_l, and the voltage across the faulty connection is V_h. Power dissipated in the faulty connection is P_h; power to the load with the faulty connection in place is P_l. The Ohm's law relation for the faulty circuit is

$$I_f = \frac{V}{(R_l + R_h)} \tag{1}$$

The power generated in the faulty connection is

$$P_h = I_f^2 R_h = \frac{V^2 R_h}{(R_l + R_h)^2} \tag{2}$$

Taking the derivative of the power generated at the faulty connection with respect to its resistance,

$$\frac{dP_h}{dR_h} = \left(\frac{V}{R_l + R_h}\right)^2 \left(1 - \frac{2R_h}{R_l + R_h}\right) \tag{3}$$

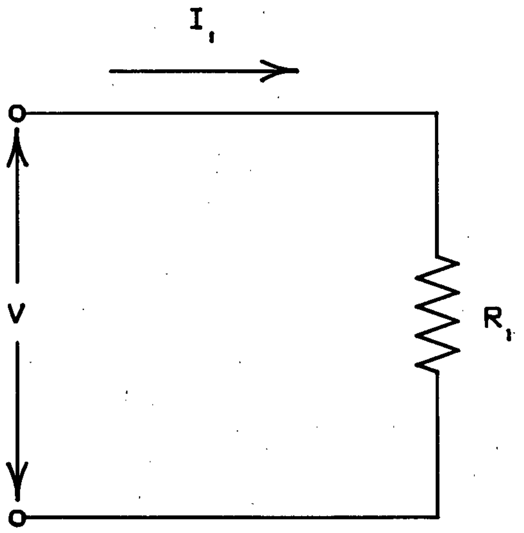
Maximizing the faulty connection power by setting the derivative equal to zero,

$$0 = \left(\frac{V}{R_l + R_h}\right)^2 \left(1 - \frac{2R_h}{R_l + R_h}\right) \tag{4}$$

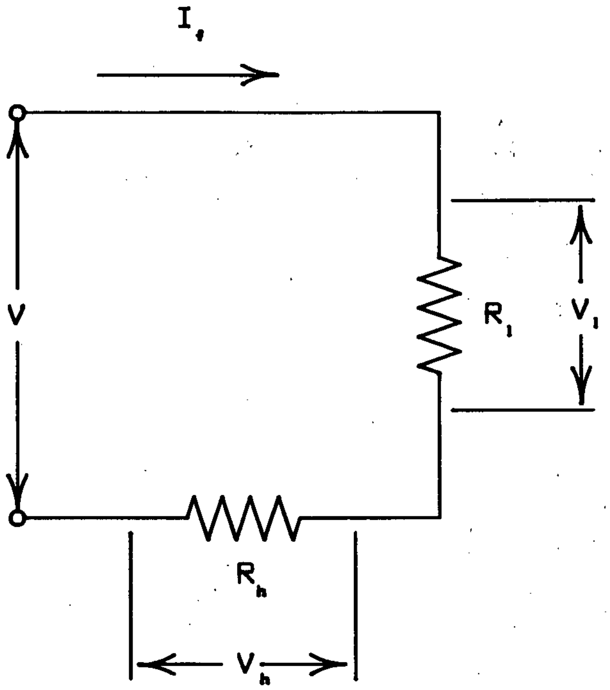
$$0 = 1 - \frac{2R_h}{(R_h + R_l)} \tag{5}$$

$$R_h = R_l \tag{6}$$

Therefore, maximum available power is obtained when the resistance of the faulty connection is equal to the load resistance. The faulty connection comprises one-half the total series resistance of the circuit; by doubling the total circuit resistance, total circuit power is halved. One-half of the reduced circuit power is dissipated in the connection. Therefore



Without Faulty Connection



With Faulty Connection

Figure 1. Typical Circuit Before and After Introduction of Faulty Contact

$$P_h = \frac{0.5\ V^2}{R_h + R_l} = \frac{0.5\ V^2}{2R_l} \qquad (7)$$

and since

$$P_i = \frac{V^2}{R_l} \qquad (8)$$

it follows that

$$P_h = 0.25\ P_i \qquad (9)$$

The maximum power available is then one-fourth the initial circuit power, and this power may be dissipated at a bad contact without tripping any overcurrent protective devices; in fact, the total circuit current is one-half the normal value.

The above discussion indicates that a faulty connection can dissipate a theoretical maximum of one-fourth the original circuit power. A device to simulate a faulty connection is considered realistic if it can produce the desired power level in a compact space. Further, the initiation of a fire by such a device can be considered credible if the power to the device does not exceed one-fourth the designed circuit power. A 120-Vac circuit drawing up to 15 A consumes as much as 1800 W, which allows a maximum of 450 W to be dissipated in a correctly matched faulty connection.

3. APPARATUS DESCRIPTION

Initial attempts to develop an apparatus to electrically ignite cables concentrated on producing a measured amount of heat at the end of a wire. The two techniques most widely attempted were (1) heating the wire end by direct attachment to a high-current metal heater and (2) flame application to the wire end with a refractory insulation connecting the bare portion of the heated wire to the insulated portion. Both techniques lacked the ability to provide the correct amount of heat to the wire and had a low degree of geometric similarity with an actual faulty connection. Further, no self-sustaining fire was initiated with either technique.

To provide heat transfer characteristics similar to those found in actual circuits, the optimum apparatus should be as similar in geometry as possible to an actual connection. The final, and successful, effort in developing a source for electrical fire initiation centered on developing a resistance heating element capable of withstanding the high temperatures to be encountered, yet small enough to fit under the head of a terminal strip screw. The use of such an element allows the cables being ignited to carry the current necessary to supply the heater. The geometry of the space around a terminal screw is such that any heating element of homogeneous composition must have a very small aspect ratio (length of current path divided by area perpendicular to current flow). The low aspect ratio, coupled with the relatively low allowable heater current to be carried through the conductors to be ignited, requires a high-resistivity heater material to prevent the required current from causing excessive heating of the wire.

Based on previous work in the initiation of cable fire by high currents [2], and on National Electrical Code standards, a current of 30 A, for the #12 AWG conductors used, is considered to be an acceptable maximum level that will not generate significant heat in the conductors.

From the geometry of a typical terminal strip, a heating element aspect ratio of no more than 10/inch can be accommodated. A maximum current of 30 A must produce power levels near the expected 450-W maximum, which requires a total heating element resistance of about 0.5 ohm with a resulting resistivity of 5 ohm-inches. Several materials were considered for the element but were eliminated because of low resistivity. Major materials considered included carbon (0.02 ohm-inches) and Nichrome™ (4 x 10^{-5} ohm-inches). The material chosen for the element was a metal oxide used in thermistors; specifically, the thermistor used was a model FRT1, manufactured by GC Electronics of Rockford, Illinois. Resistivity of this material ranges from 30 ohm-inches to 0.25 ohm-inches over the temperature range of interest. Although the current through the heater was greater by a factor of 2 than the current in an actual circuit, the power applied, and thus the heat available to electrically initiate a fire, would be readily available in an actual circuit. A material capable of withstanding the thermal environment, while exhibiting a resistivity about twice that of the material described here, would provide volt-ampere characteristics identical to those of a faulty connection producing maximum heat.

Figure 2 is a cross-sectional diagram of the apparatus developed; Figure 3 is a photograph of a typical configuration ready for testing. The apparatus consisted of a phenolic terminal strip with a brass conductor strip, riveted to the phenolic, upon which were mounted the heating element and the necessary electrical connections. The power to the heater was supplied by establishing a voltage difference between the wires attached to the two screws of the conductor strip.

The screw to the left of the Phillips-head screw in Figure 3 was attached directly to one wire, while the Phillips-head screw was configured as shown in Figure 2. The terminal lug in Figure 2 was attached to the second wire and made electrical contact only with the upper surface of the heating element. A mica washer provided electrical insulation between the screw and the terminal lug while withstanding the high

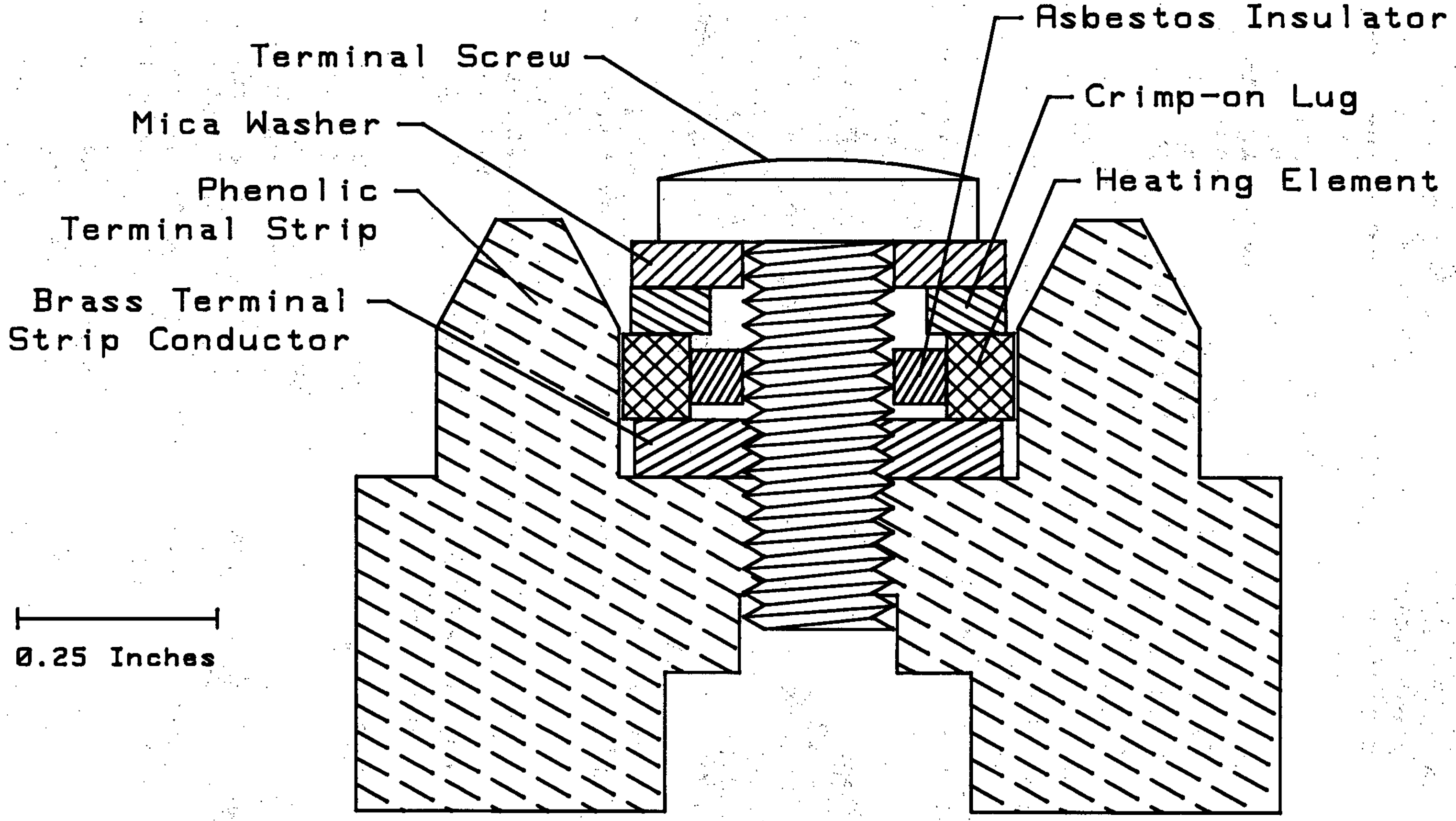


Figure 2. Cross-Sectional View of Typical Electrically Initiated Fire Apparatus

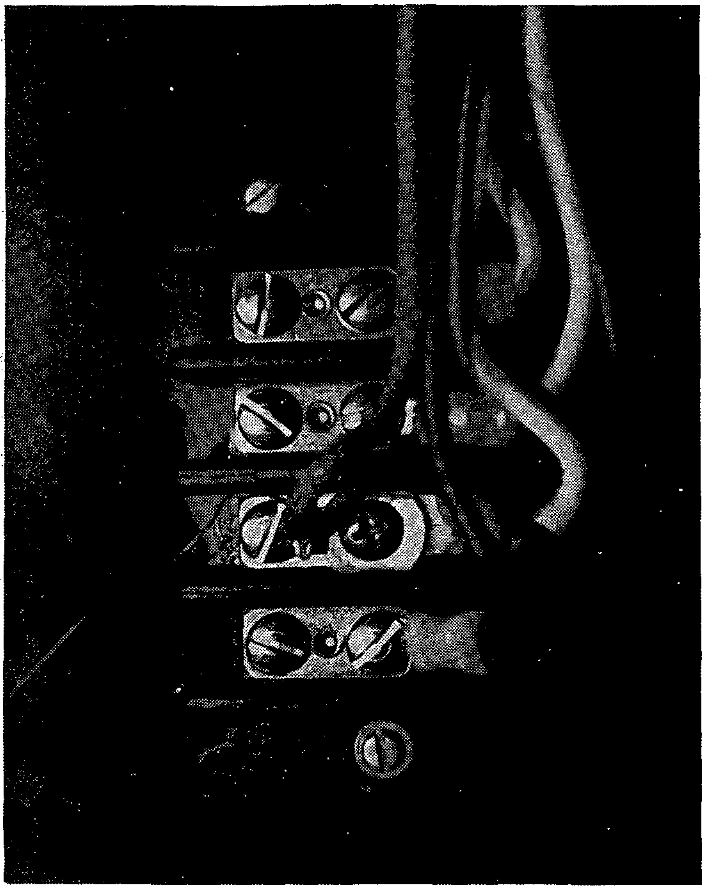


Figure 3. Electrically Initiated Fire Apparatus Before Test

temperatures generated during operation. The insulation was required here to allow the desired voltage across the heating element to be established. The lower surface of the heating element was in contact with the terminal strip conductor, which was connected through the other terminal screw to the first wire. The heating element had an internal concentric asbestos insulator that prevented it from contacting the terminal screw and prevented molten metal from establishing a current path during high-power tests. This arrangement of insulation and electrical connections ensured that the applied electrical current passed axially through the heating element.

The specifics of the heating element are not essential to the operation of a successful apparatus. The parameter of primary importance is the generation of enough heat in a small enough space for a sufficient time. The apparatus described here presents a set of parameters proven to provide a reliable source of electrical fire initiation. Approximately 25 self-sustaining fires have been produced with this type of apparatus.

Figure 4 is a dimensioned drawing of the heating element. The element was constructed by slicing a commercially available, tubular-shaped, metal oxide thermistor into sections of appropriate length. The element was then fitted with a washer of suitable material to provide electrical insulation between the element inner surface and the terminal screw. Asbestos gasket material was used to make the inner washer. The metal oxide thermistor was chosen because of its relatively high resistivity and stability at elevated temperatures. However, the thermistor is intended to exhibit a negative thermal coefficient of resistivity, which, for the purpose of these tests, made control of the power to the heating element somewhat difficult. The resistance value of a heating element can change by a factor of 100 over the temperature range of interest, typically 70° to 1500°F (21° to 816°C).

Most of the attempts at electrical initiation during the development of this apparatus were unsuccessful because the heater lacked the ability to operate for a sufficient time. The heater was required to operate for approximately 1200 s (20 min) and may have reached temperatures as high as 1600°F (871°C) during operation. Most failures in heater operation have been attributed to the following causes:

- Short-circuiting of the power supply caused by melting of the conductor strip and flowing of the molten metal through the heater center. Such failures were primarily due to excessive power levels early in a test.

- Melting or severe corrosion of the connecting terminal lug, corrected by using a heavy-gauge lug and reducing the duration of high power levels.

- Heating element cracking. The arrangement of the element provided that axial or radial cracking would not significantly affect the heater. Cracks with a circumferential component greatly raise the element resistance. Cracks appeared to be caused by excessive power levels or power transients. The operating technique developed during the tests has eliminated these causes. Care must be exercised during installation to prevent excessive cracking in the relatively brittle metal oxide element. However, cracking during installation tends to have no circumferential component and may not significantly affect element performance.

A schematic of the heater power supply is shown in Figure 5. The voltage to the heater was controlled by the manual variable autotransformer. The power transformer was needed to reduce the voltage and increase the current to the heater to obtain the desired range of power. The power applied to the heater was supplied by a variable 60-Hz alternating current of varying voltage, continuously monitored with the wattmeter and logged at 1-s intervals during the tests. An approximate

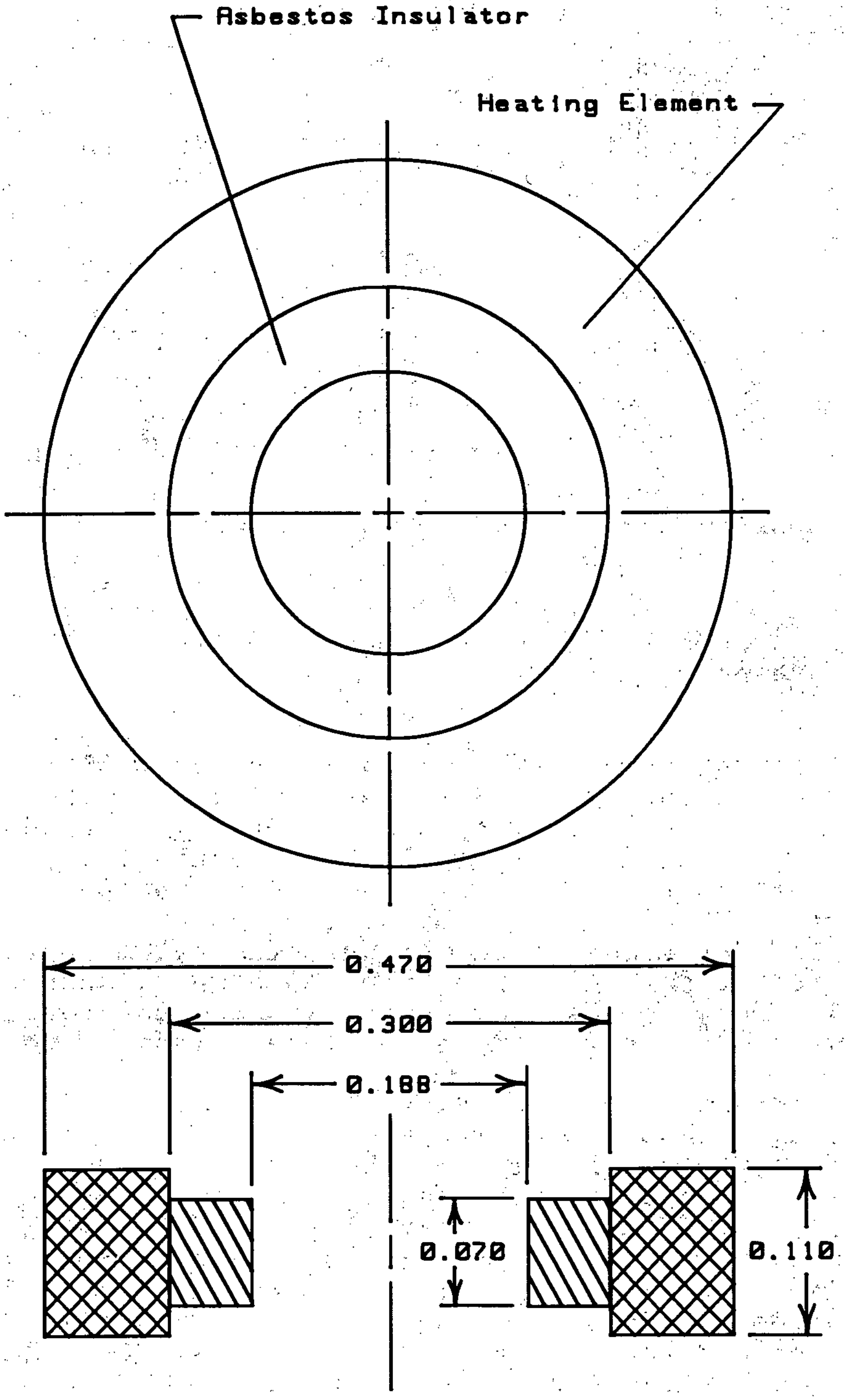


Figure 4. Drawing of Heating Element

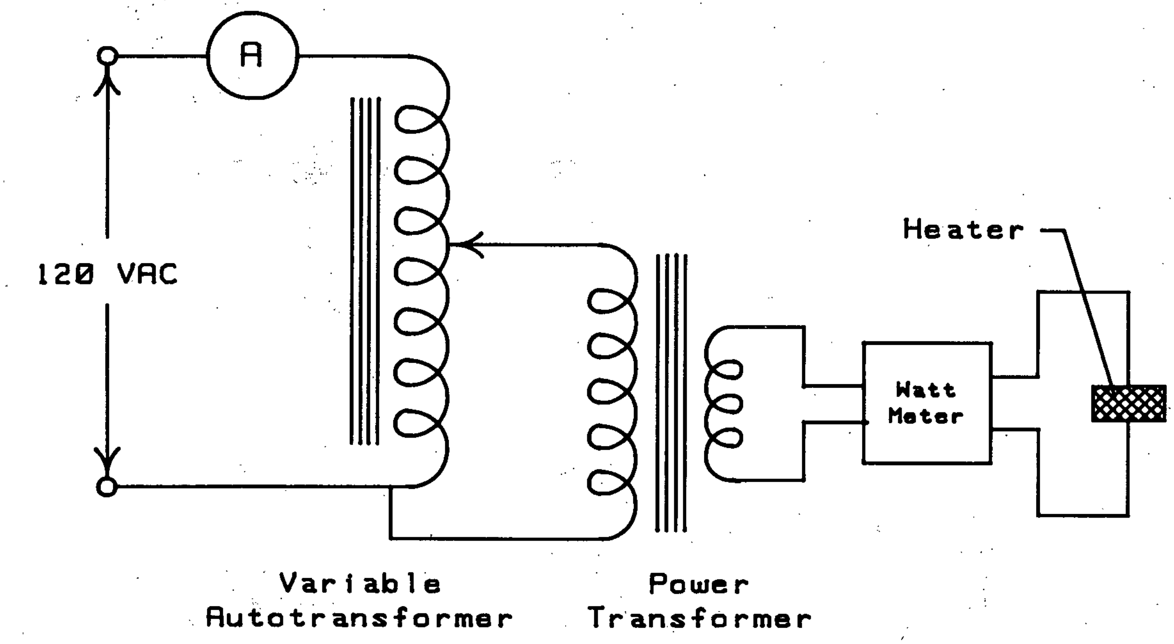


Figure 5. Schematic of Power Supply for Electrically Initiated Fire Tests

reading of heater power level was obtained by monitoring the input current to the autotransformer. Since transformer efficiencies are relatively constant over a wide range of power levels and input voltage of the autotransformer is constant, the input current was directly proportional to the heater power. This technique of monitoring power level has proven useful for remote ignition when the autotransformer must be situated some distance from the power transformer and heater [3]. In practice, the remote monitor can indicate the actual power level to within 5% for levels from 30 to 250 W.

Since the resistance of a heating element varies by a factor of 100 during a test, the power supply must be sized to be adequate over the entire temperature range of interest. Figure 6 is a plot of voltage and current of a heating element during a typical test. Initially, 20 V is required to begin raising the element temperature. This initial voltage corresponds to about 13 W of power to the element. The peak power requirement of 200 W occurs at about 900 s (15 min) into the test and requires a current of 28 A. For the tests conducted, a stepdown transformer with a 120-V primary and a 36-V, 24-A secondary, and a variable autotransformer rated at 7 A, were used.

The power supply performed adequately because of the short duration of current above 24 A and the low voltage required at the high current. The use of a heater with a smaller

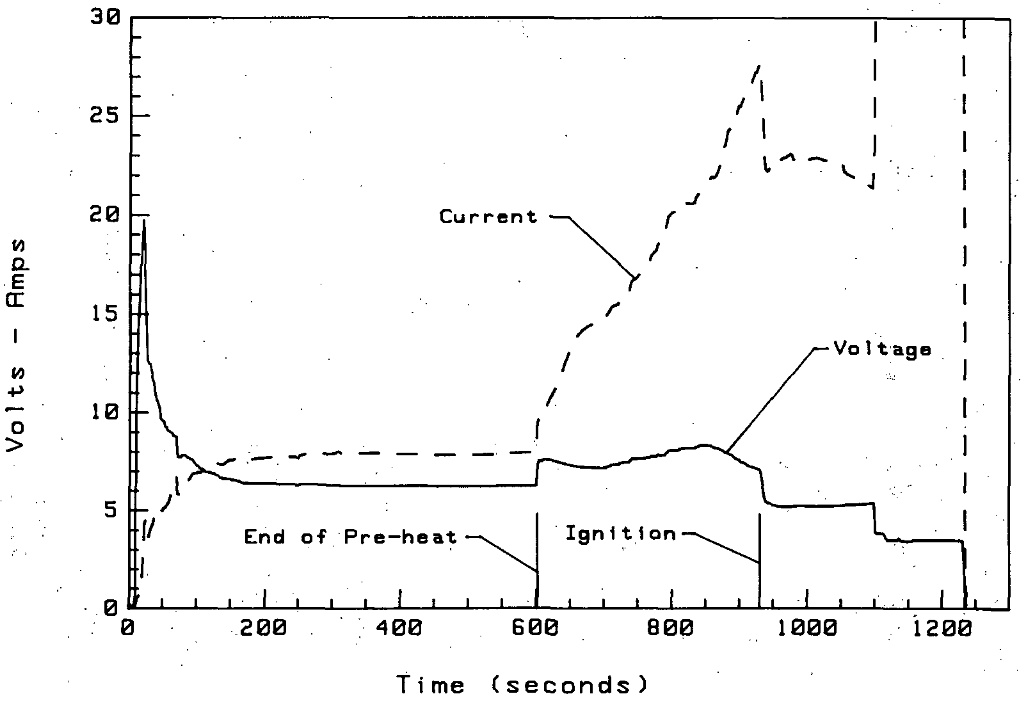


Figure 6. Heater Voltage and Current During Electrical Fire Initiation

thermal coefficient of resistivity would simplify the selection of a power supply by providing a more constant voltage-to-current ratio.

Control of the power to the heater was complicated by the heater's negative thermal coefficient of resistivity. This feature caused the resistance of the heater to decrease with increasing temperature. The power supply, driven by a manually controlled variable autotransformer, provided a controlled voltage to the heater, which caused the power level of the heater to be inversely proportional to the resistance. If the temperature of the heater should increase from an equilibrium power-temperature state, the power level would also increase, tending to elevate the temperature further. The converse would be true for a temperature decrease. The heater would therefore be difficult to control, especially when a change in heater temperature was required.

This effect is most pronounced during initial heatup, in which typically the supply voltage is increased until a power level of about 50 W is reached, at which time the voltage is decreased at a controlled rate while a 30- to 50-W power level is maintained. A relatively smooth decrease in heating element voltage can be seen in the first 200 s of the Figure 6 plot. Figure 7 is a plot of the power level corresponding to the voltage and current plot in Figure 6. Notice the

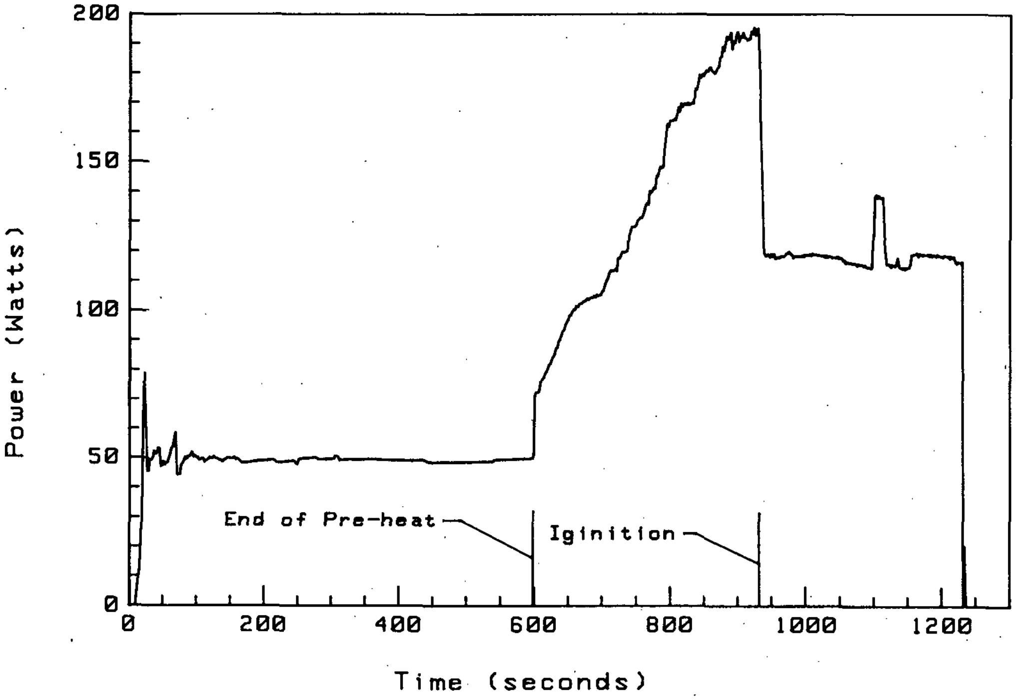


Figure 7. Conductor and Terminal Temperatures During Electrically Initiated Fire

oscillating power levels during the first 200 s of the test. Figure 8 illustrates the resistance of the heating element during the test. The rapid drop in resistance during the first 200 s should be noted.

The oscillations are caused by the heating element's power-level instability in a manually controlled voltage mode. At high temperatures, the cubic dependence of incremental heat loss by radiation on incremental temperature causes the element to be relatively stable. Even in the stable high-temperature region, the equilibrium power level is history-dependent; that is, increasing the applied voltage momentarily and returning it to the original level will result in a higher equilibrium power level. This phenomenon is illustrated by comparing the heater power to the applied voltage at 400 versus 1000 s (Figures 6 and 7). A power supply capable of providing a variable, controlled current rather than voltage control would make the response inherently stable by causing the power level to be directly proportional to the heating element resistance. Such a power supply was not deemed warranted here since sufficient control was achieved by understanding the element characteristics and closely monitoring the necessary parameters.

During the bulk of the test, the power level to the heater was stable enough to allow manual control of the voltage output

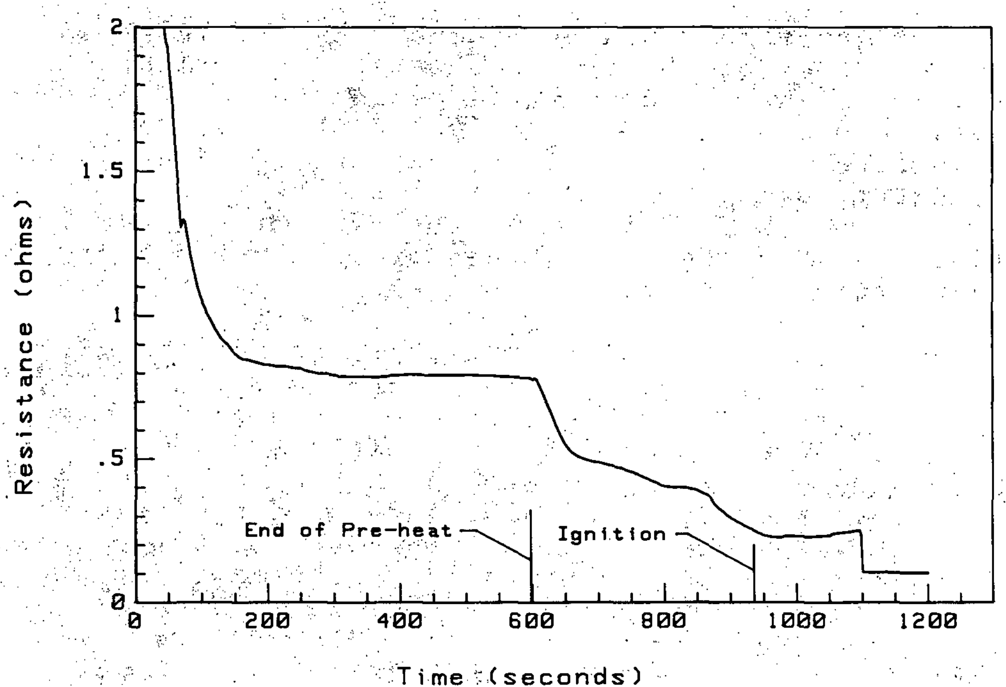


Figure 8. Heating Element Resistance During Electrical Fire Initiation

of the variable autotransformer. Upon initiation of a test, the resistance of the heating element was about 100 times the resistance at test temperature. This fact required that the initial voltage applied to the heater be much higher (about 20 V) than the voltage at elevated temperature (about 5 V). Low-voltage (less than 10 V) application was tried, but the resulting power levels were too low to provide the significant heatup of the element required to cause resistance reduction and resulting spontaneous power increase.

The negative coefficient of the heating element also appears to cause hot spots in the element. Temperature differences estimated to be greater than 100°F (38°C) have been observed during testing. If a portion of the element is hotter than the surroundings, the local resistance is lowered, and a larger local current density will occur in the area, causing additional heating and thus amplifying an initially small perturbation. This phenomenon has not been investigated but may be an important ignition source at high power levels. Such hot spots could serve the same purpose in simulated electrical fire initiation as do electrical arcs in accidental fires.

4. EXPERIMENTAL RESULTS

Tests conducted with seven-strand, #12 AWG, single-conductor wire, wire not qualified to IEEE-383 standards, with polyvinylchloride/polyethylene insulation, demonstrated that a self-sustaining fire could be produced by providing an initial power level of 50 W to the heater for 10 min, followed by gradually increasing the wattage to 150 to 200 W over the next several minutes. Figure 7 shows the applied power level for a typical test. The 10-min preheating period at 50 W is important in producing a self-sustaining fire. Tests without preheat will produce ignition, but the fire will usually self-extinguish after several inches of insulation have been burned. It appears that without the preheat period, the conductors surrounding the initiation site are at low enough temperatures to serve as a heat sink, preventing the fire from propagating. Figure 9 is a plot of temperatures measured during the test. The conductor temperature was measured in the wire attached to the heater at a point 3 in. (8 cm) above the heater. The terminal temperature was that recorded by a thermocouple placed adjacent to the heating element. From the plot it can be seen that the temperature in the conductor was 330°F (166°C), near its equilibrium level before the power was increased beyond 50 W. The terminal temperature at that time was 700°F (371°C). In steady-state temperature tests with this cable at Sandia National Laboratories, a temperature of 480°F (249°C) was found to be sufficient for cable autoignition [4]. A wire temperature of 520°F (271°C) was observed at ignition. After ignition, power to the heater was maintained until the heating element failed. During the first minute after ignition, the

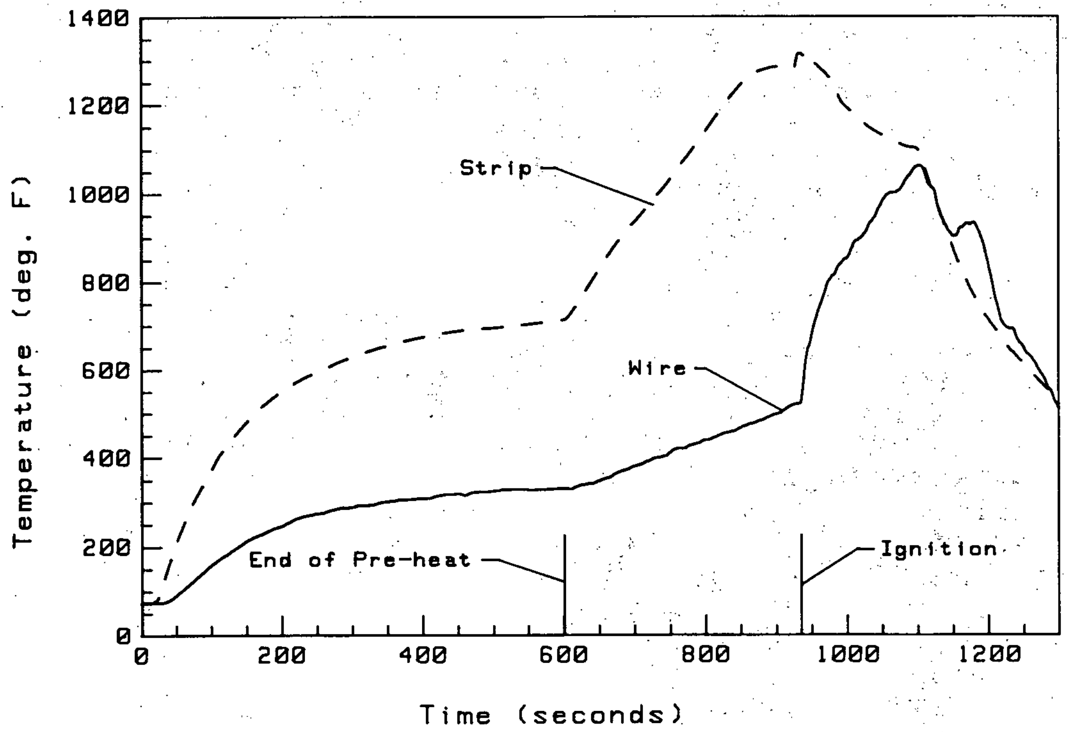


Figure 9. Conductor and Terminal Temperatures During Electrically Initiated Fire

power input of the heater contributed to the development of the fire. Once the fire had propagated several inches from the ignition site, the relatively low power level of the heater and the distance of the fire from the heater made the contribution of the heater to further propagation negligible.

The area near the heater had five individual wires positioned in a vertical bundle (Figure 3). Several other geometries with the number of wires ranging from 1 to 30 were also used. During tests with approximately 10 or more wires placed near the heater, the fire would not propagate. The failure to propagate is attributed to the heat-sinking capability of the large bundle and the limited power levels (less than 100 W during preheat) of the heater. High-power preheat of large bundles was attempted but typically resulted in rapid ignition such that true preheat was not obtained, and the fire self-extinguished within a few inches of the initiation site. Experiments with few wires have proven successful to the extent that a fire may be initiated and will propagate in a single vertical wire. The five vertical wires are capable of sustaining the fire for the entire length of the bundle (about 18 in. [46 cm]).

The five-wire bundle should pass within 2 in. (5 cm) of the heating element. Greater distances reduce the effect of preheating in all but the primary wire and make fire propagation less likely. The five-wire geometry was chosen to provide a sufficiently intense fire to ignite the additional fuel, in the form of more wires, placed 10 to 20 in. (25 to 50 cm) from the initiation site. Figure 10 shows a typical arrangement of additional fuel. Experiments with different arrangements of the additional fuel indicate that the placement is not critical to allowing the fire to propagate. No case was observed in which the initial bundle was consumed without all additional fuel being consumed also.

Figures 11 through 18 show the initiation and propagation of an electrically initiated fire. The rapid progress of the fire after initiation is shown in Figures 14 and 15, in which the fire progresses from small flames on the initial wires at 16:07 min to flames burning up the additional wires at 18:21 min. The fact that virtually all available fuel was consumed (Figure 19) should be noted.

Propagation of such a fire to much larger geometries can be accomplished without any changes to the procedure or apparatus described. In such cases, more additional fuel is positioned near the top of the the test apparatus. Numerous large-scale fire tests of this type have been performed by Sandia National Laboratories [3]. Figure 20 illustrates the setup for a large-scale electrically initiated fire; Figure 21 shows the large-scale fire in progress; Figure 22 is a view of the area after all available fuel was consumed. The

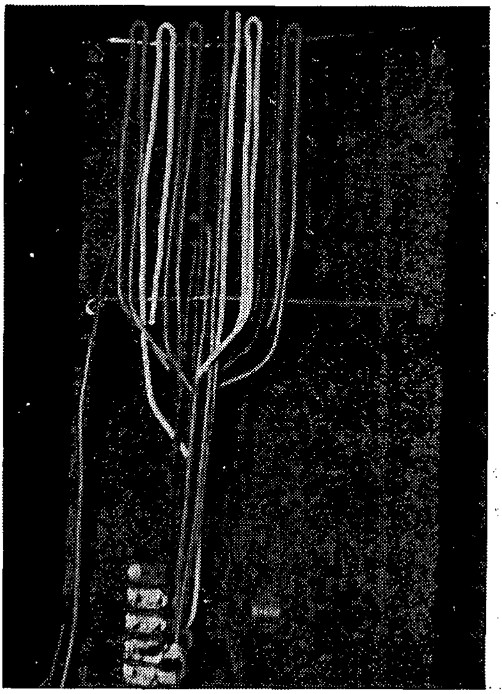


Figure 10. Additional Wires Positioned Near Initial Bundle to Allow for Fire Propagation

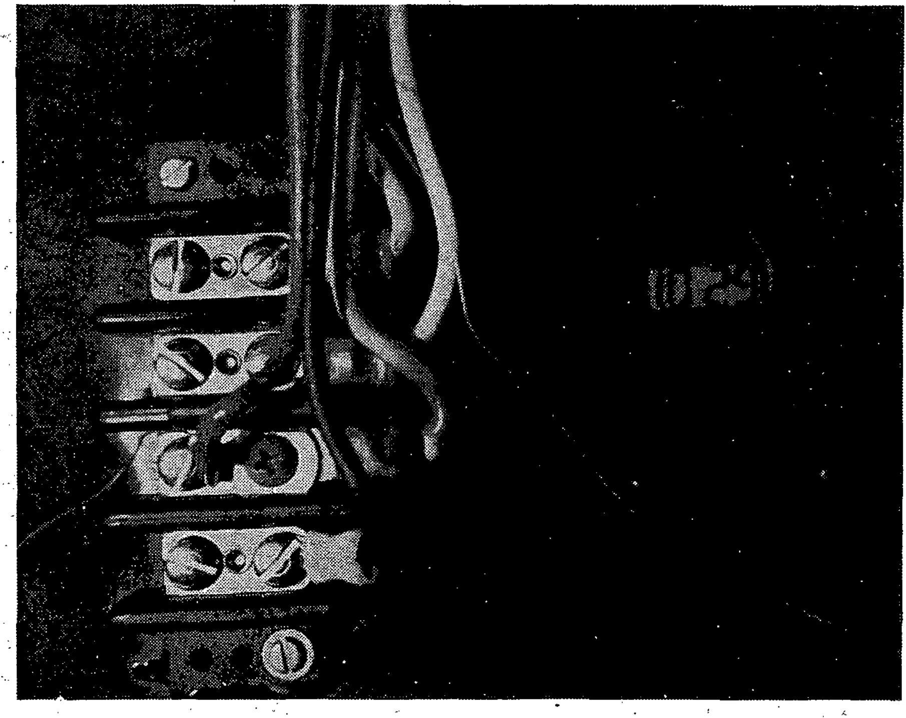


Figure 11. Early Degradation of Wire Insulation (time: 10:29 min; power: 75 W)

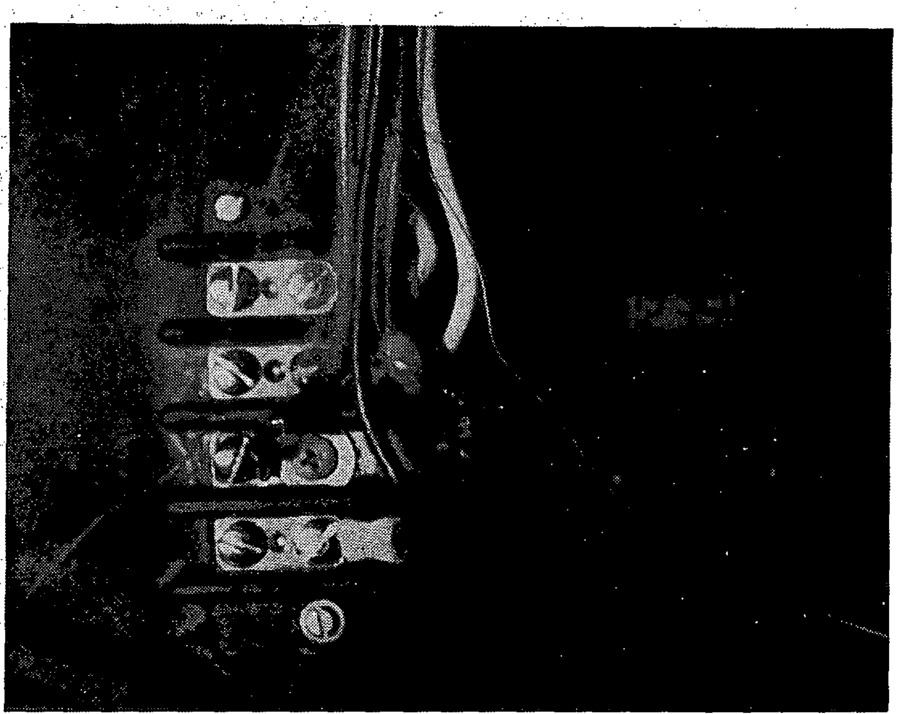


Figure 12. Smoke Generation and Blistering of Insulation (time: 12:35 min; power: 100 W)

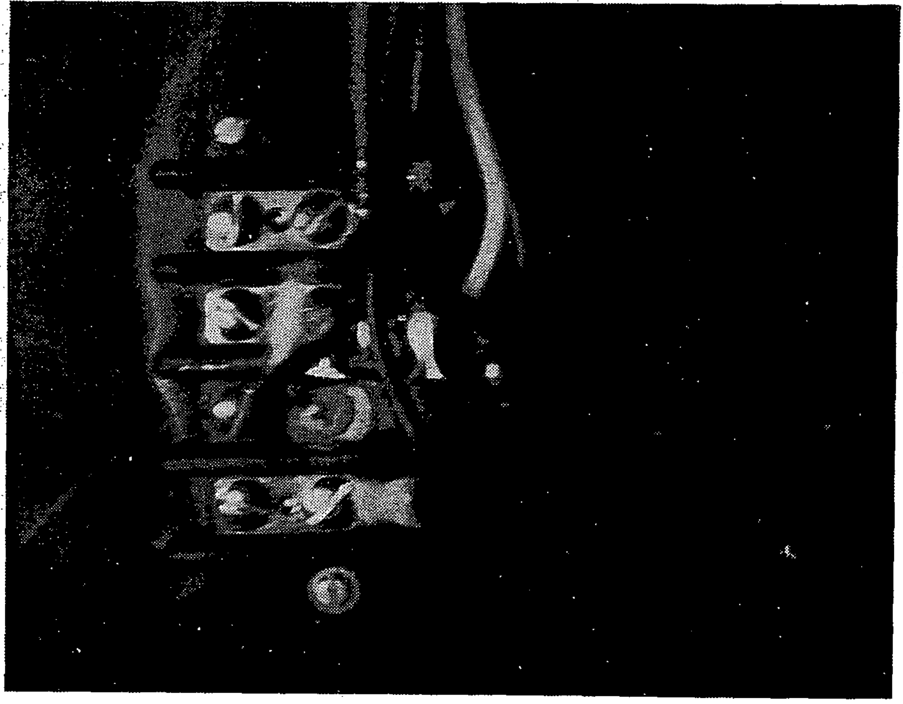


Figure 13. Fire Initiation (time: 15:33 min; power: 200 W)

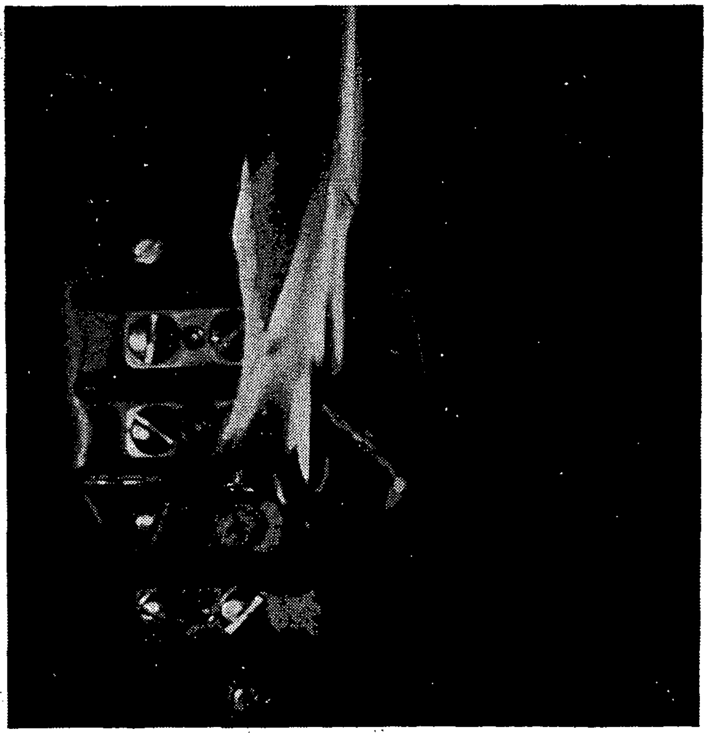


Figure 14. Fire Propagating up Initial Bundle (time: 16:07 min; power: 120 W)

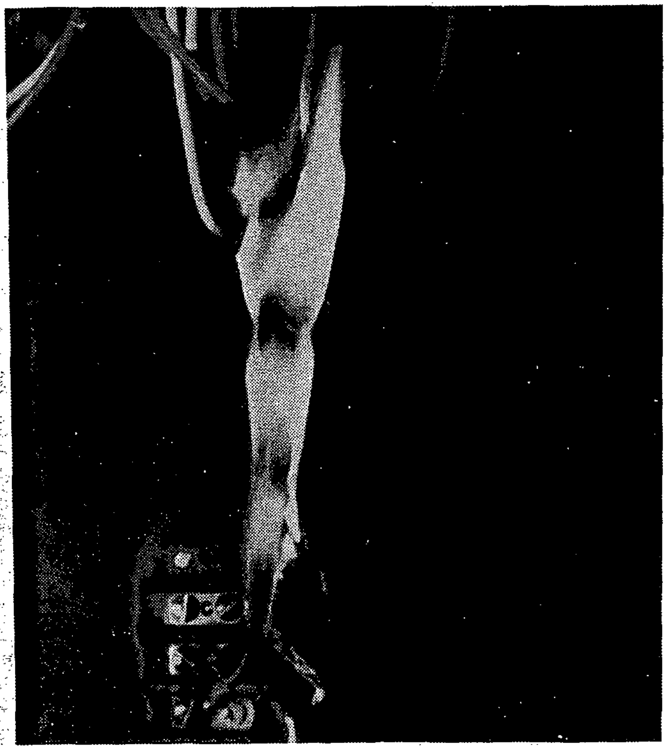


Figure 15. Fire Reaching Secondary Bundle (time: 18:21 min; power: 120 W)

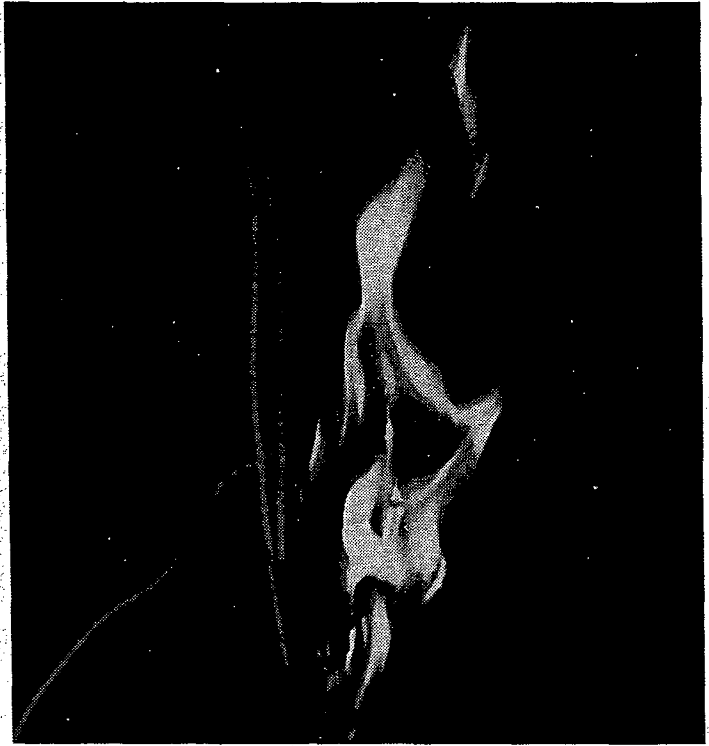


Figure 16. Fire Consuming Secondary Bundle (time: 19:51 min; power: 120 W)

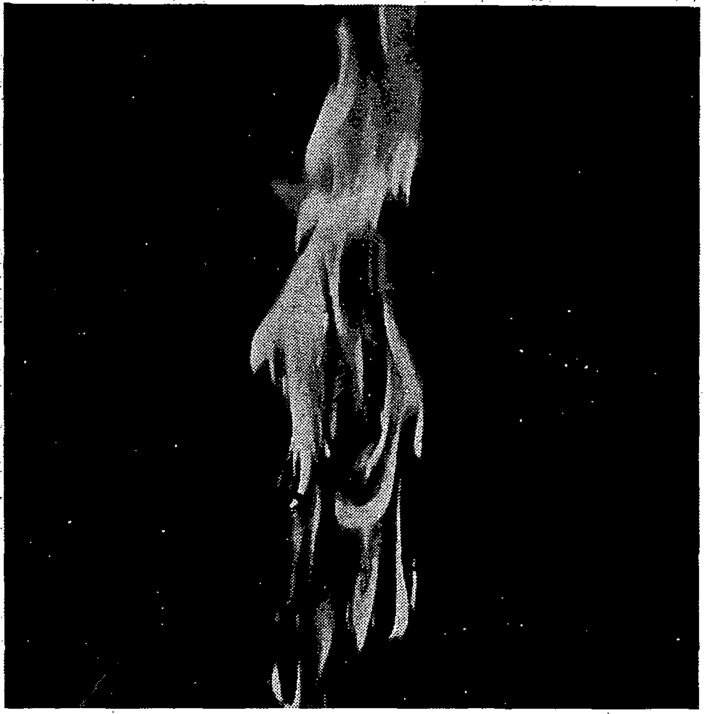


Figure 17. Peak of Fire Intensity (time: 20:45 min; power: 0 W)

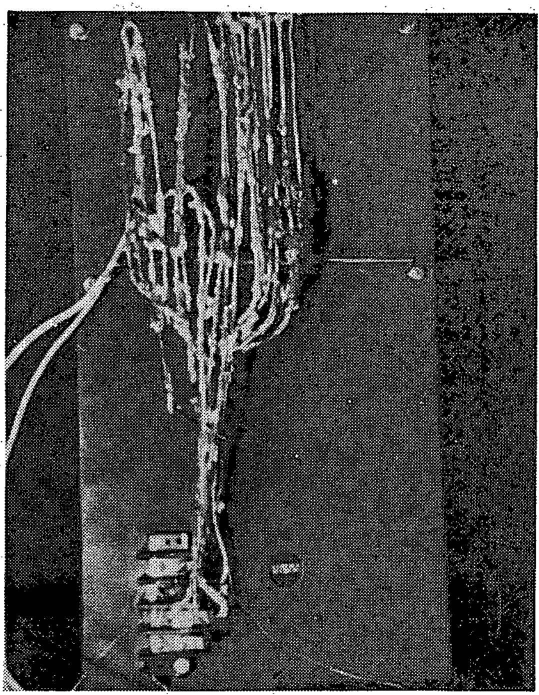


Figure 18. Fire Self-Extinguished After Consuming All Available Fuel (time: 26:59 min; power: 0 W)

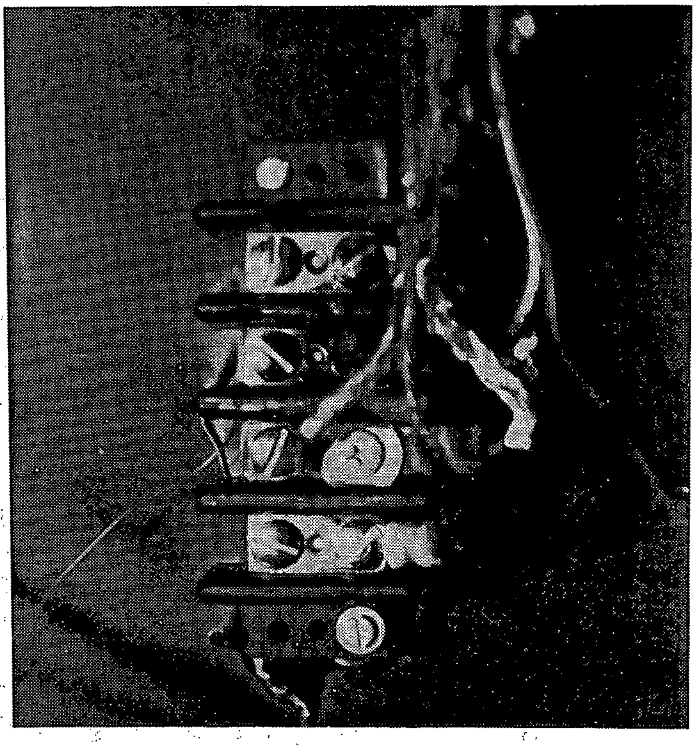


Figure 19. Electrical Initiation Apparatus Following Fire

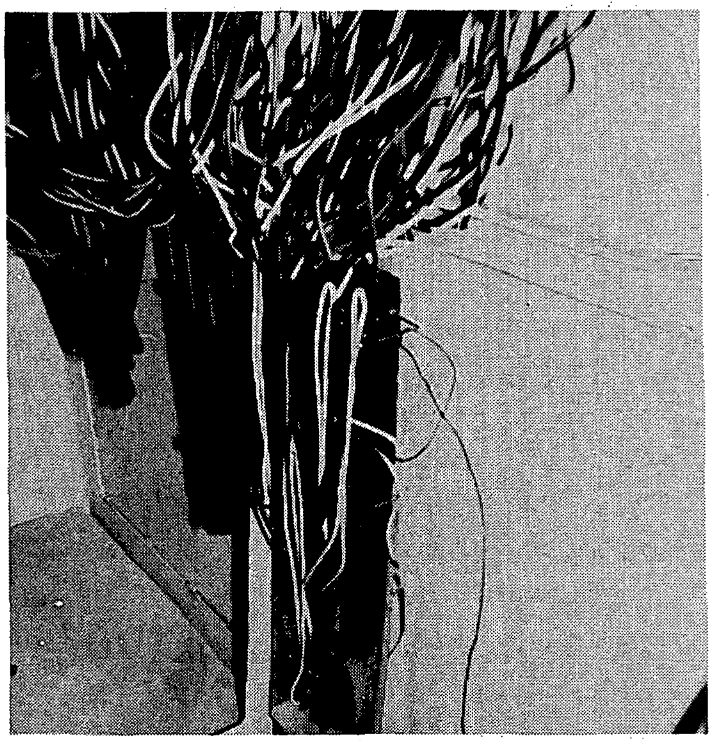


Figure 20. Setup for Large-Scale Electrically Initiated Fire

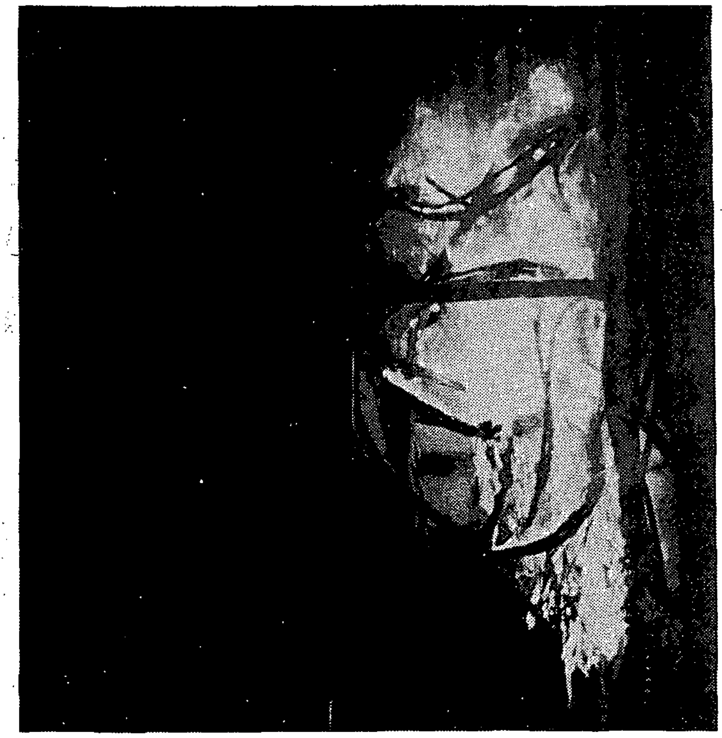


Figure 21. Large-Scale Electrically Initiated Fire in Progress

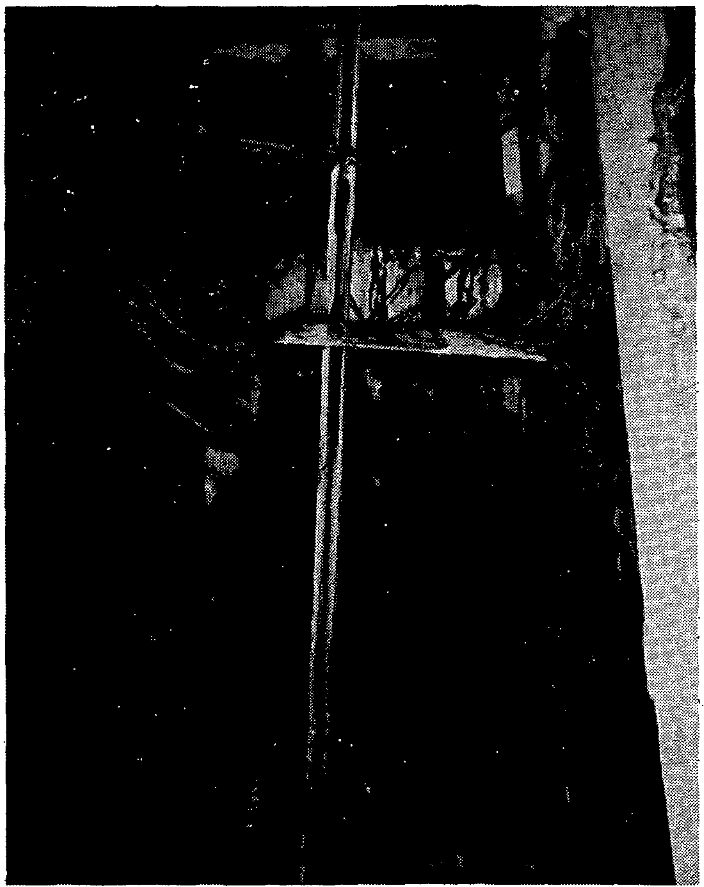


Figure 22. Large-Scale Fire Setup Following Consumption of Available Fuel

fire shown here reached a peak intensity of 800 kW from the initial apparatus power input of less than 200 W.

Efforts are currently underway to produce similar fires in IEEE-383 qualified cable. These experiments are not yet complete, but the results will be reported when sufficient data have been gathered.

5. CONCLUSIONS

The apparatus developed provides a reproducible source for electrically initiated fires which is realistic in terms of typical circuit design constraints. This source fire has been used for testing the manner in which small electrical fires can threaten electrical cabinets and cabling in nuclear power plants.

Electrically initiated fires can be repeatedly produced using heat sources to simulate faulty connections with relatively low (<200 W) power levels. Such fires have been shown to be self-sustaining and capable of propagating to proportions independent of the size of the initiation apparatus.

Although the electrical heaters presently used require lower voltage and higher amperage than are found in most power plant circuits, the proper amount of heat is generated at the simulated connection. Use of other suitable materials with higher resistivity should provide resistance characteristics suitable for producing sufficient heat from currents typically available in power plant circuits (115 Vac at <15 A).

The difficulty of power-level control caused by the inherent negative thermal coefficient of resistivity of the metal oxide heating element can be eliminated through use of materials with a less-negative coefficient. One such material is a silicon thermistor. Further, more realistic simulation of a faulty connection could be achieved using such a heater in series with the load. This configuration would current-limit the circuit such that the resistivity coefficient would not significantly upset the power levels. However, use of such a system with a constant total applied voltage might require that heater power be controlled by varying the size of the applied load.

Using the apparatus described here, fires are readily initiated and propagated in unqualified cable. No self-sustaining fire has been electrically initiated in an IEEE-383 qualified cable; the results are not entirely conclusive, and further attempts in this area are being made.

REFERENCES

1. W. T. Wheelis, "Nuclear Power Plant Fire Data Base for Use With a Personal Computer," Sandia National Laboratories, to be published.

2. D. A. Dube, "Fire Protection Research Program for the U.S. Nuclear Regulatory Commission, 1975-1981," SAND82-0431, NUREG/CR-2607, Sandia National Laboratories, April 1983.

3. "An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Control Cabinets - Vol. 1 Cabinet Effects Test," SAND86-0336, Sandia National Laboratories, to be published.

4. J. M. Chavez, "Steady-State Environment Cable Damage Testing," Quick-Look Report, Sandia National Laboratories, July 1984.

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Room 1248
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Grinell Fire Protection Co.
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10 Dorrance Street
Providence, RI 02930

Brookhaven National Laboratories
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Dr. Ulrich Heinz Schneider
Gesamthochschule Kassel
Universitat des Landes Hessen
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3500 Kassel, FRG

Dr. Heinz-Willi Brenig
Gesellschaft fur Reaktorsicherheit
Schwertnergasse 1
D-5000 Koln 1,
FRG

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Koning und Heunisch
Letzter Hasenpfach 21
6000 Frankfurt/Main 70,
FRG

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M. Allen Matteson, Jr.
Code 1740.2
Ship Protection Division
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An apparatus has been developed that allows the simulation of a faulty connection in an electrical circuit by placing a small resistance heater at the screw of a terminal strip. The apparatus and associated control system are described in detail. Details of a typical fire produced with the apparatus are presented, along with results of electrical fire initiation attempts with both qualified and unqualified nuclear power plant cable.

Repeated use of the apparatus has shown that a self-sustaining fire can be reliably initiated in unqualified cable with power levels to the apparatus not exceeding 200 W. Such fires may be initiated in approximately 10 minutes. Large-scale fires have been initiated with the apparatus, indicating that propagation to any desired fire size is possible. Fires initiated in qualified cable to date have been localized and neither self-sustaining nor capable of propagation.

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