

Report on Fire-Damaged Telephone Cord

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Conclusions

1. Evidence was found of a short in the telephone cord at a point approximately 10 feet from the plug.
2. A 110 volt potential over a 10 foot shorted length of telephone cord would give more than enough heating to ignite the cord.
3. The voltage would have to be maintained a few minutes for the cord to become heated through.
4. Evidence was found which showed that heat was being created within the individual wires in the cord.
5. No evidence was found of a short within the telephone itself.

General

On 2 September 1970, a Bell "Trimline" telephone and cord was delivered to me. The cord was approximately 24 feet long and had been burned into three pieces. (See Figure 1). About 1 foot of well-charred cord was connected to a 4-pin plug. There was a 7 foot piece that had been burned from the middle of the cord, and a 16 foot segment still connected to the telephone. There was an approximately 2" diameter loop about 2 feet from the end of this last segment of cord. The crossed cords had been pressed together by some rounded object which had left an impression. The insulation on the loop was charred and the wires were partly bare over a short region. There was evidence of external fire damage at only four points: the two places the cord had burned through, at the loop, and near the plug.

The cord (Shown in Figure 2) was a 3-wire arrangement with red, green and yellow insulated wires packed with some fiber into the outer sheath. Each of the three wires consisted of an outer sheath, some fibers, and then a copper wire made of fine strip wrapped around an internal core of fibers.

The overall cord diameter was about 1/4" and the copper wires were .017" in diameter.

The purpose of this investigation was to find whether the telephone could have, in some way, initiated the fire.

Investigation

The telephone was checked for electrical shorts with a D-C ohmmeter. Resistance readings were made between the terminals where the three wires connected, with the receiver both on and off the hook. A resistance reading of 1000 ohms was obtained between the terminals for the green and red wires with the receiver off the hook. All other readings indicated an open circuit so there was no evidence of a short circuit in the telephone.

Resistance measurements were made on each of the three wires in the piece of cord that had been burnt out of the middle. The insulation was laid bare to obtain good electrical contact. Measurement was made over a 5 foot length with both a Wheatstone bridge and a Keithly 502 milliohmmeter. In all cases, the reading was between 1.9 and 2.1 ohms so the resistance of the wires is very close to 0.4 ohms/foot.

Let us now calculate the effect of a direct short at the loop with 110 volts across the shorted wires. The total current path would be about 20 feet and the resistance 8 ohms. The heating is thus 1500 watts, or 1.18 cal/sec per centimeter of cord. This heat is released internally and must be conducted through the various layers of fiber and insulation to the atmosphere. There must be a temperature difference between the copper wire and the exterior of the cord for heat to be conducted. Taking $4 \times 10^{-4} \text{ cal/cm} \cdot \text{sec} \cdot ^\circ K$ (Chemical Rubber Handbook) as a reasonable estimate of the radial thermal conductivity of the cord and using simple heat-conduction theory, we find that a temperature difference of $1700^\circ F$ is required to conduct the heat through to the atmosphere. If the voltage is intermittent, for example is only one half of the time with an on/off cycle of a few seconds, then half the temperature difference or $850^\circ F$ is needed. With less than a direct short, or less than 110 volts potential, the heating would be proportionally reduced.

The thermal diffusivity of the insulation is the order of $10^{-3} \text{ cm}^2/\text{sec}$ (Chemical Rubber Handbook) so a time the order of a few minutes would be needed for the heat to penetrate through to the outer surface of the cord.

The cord was stripped to the copper wire at two places to permit accurate resistance measurement. At one location, (Figure 3) the wires and insulation were in good order. At the other location, the copper wires (within the yellow and red sheaths) were blackened and the fiber immediately around the copper was darkened. (Figure 4). The wire in the green sheath was not blackened. All the outer insulation was in good order so the heat could not have reached the wires from outside the cord. Also, the stripping was done about 2" from any fire damage so the heat was not conducted along the wires. We must therefore conclude that heat was generated within the red and yellow clad wires in adequate quantity to blacken copper.

Discussion

Simple calculations have shown that 110V shorted over 10 feet of the cord would, in a few minutes, produce more than enough heat to ignite the cord. The calculations assumed uniform heat dissipation, hence would give an underestimate of the temperatures created due to the existence of hot spots. Any region of the wire with a higher than average resistivity would be heated preferentially, which in turn would increase the local resistance further and create a hot spot. Because of this, one would not expect the entire cord (if shorted) to be heated uniformly, and ignition would occur only at the hot spots.

The observation of blackened copper wires and fiber-wrapping inside an otherwise unaffected region of the cord shows that heat was being produced in considerable quantity inside the wire.

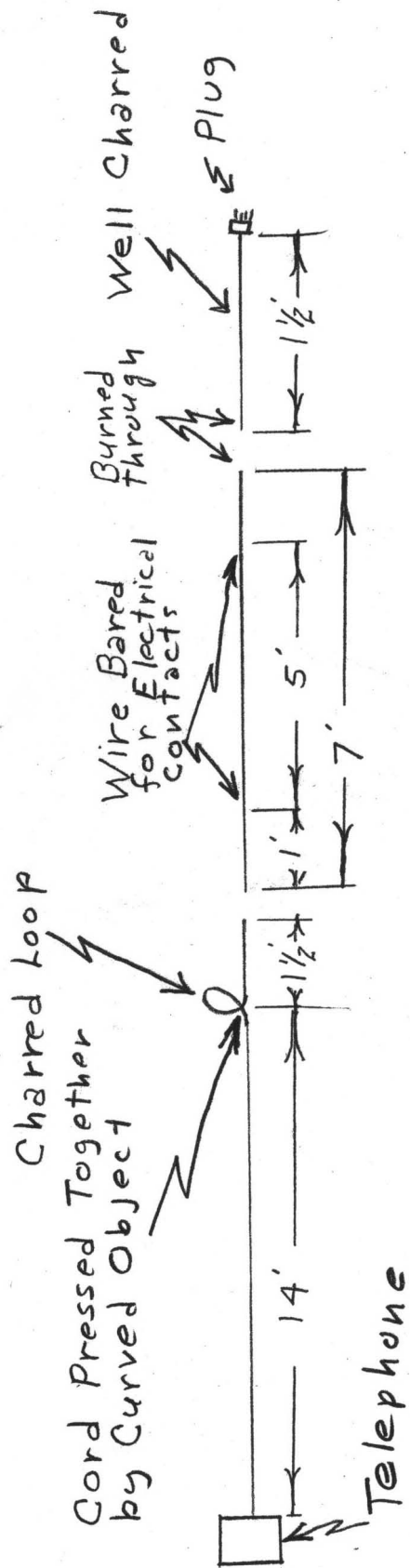


Figure 1: Sketch of damaged telephone cord (not to scale)

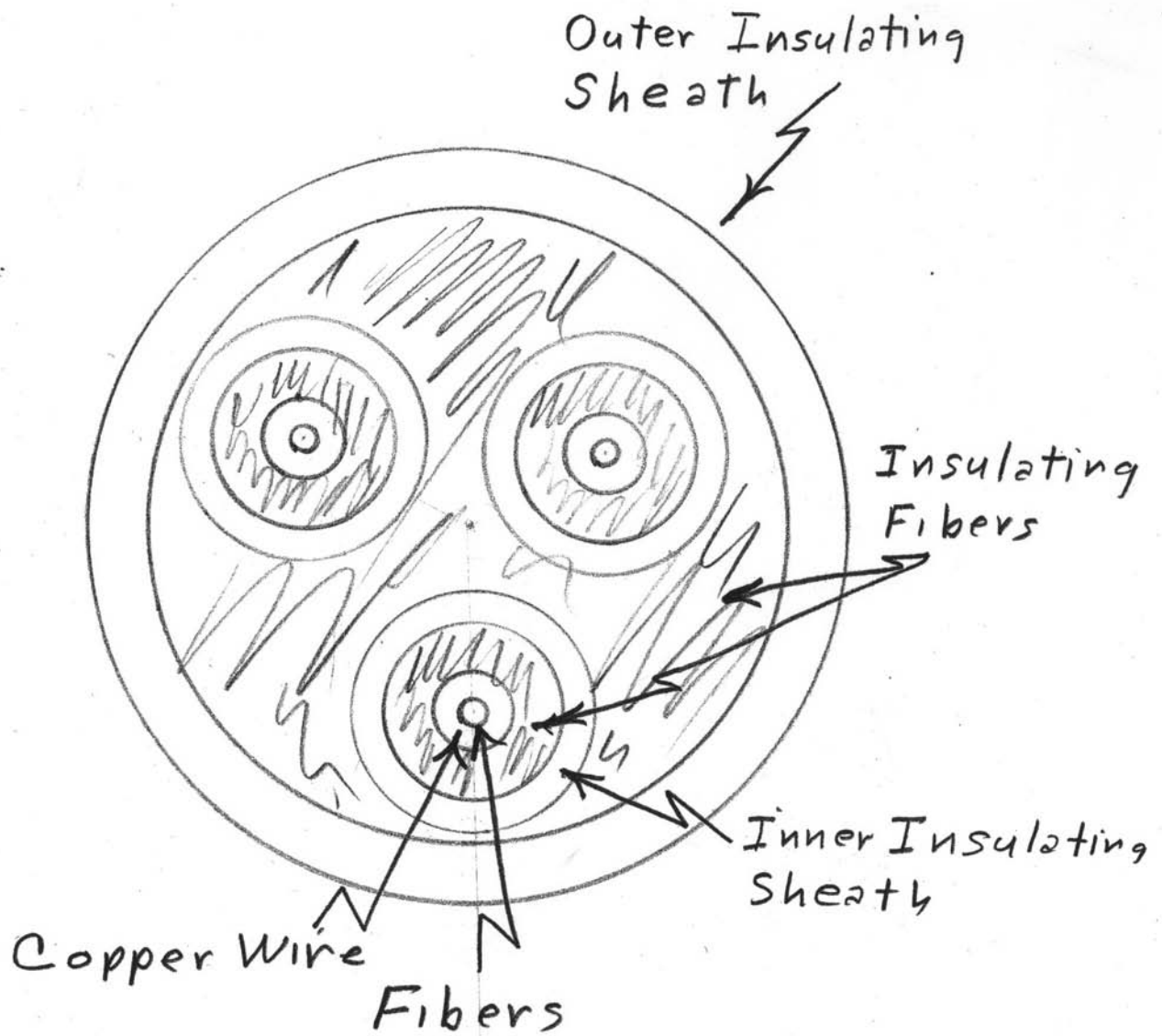


Figure 2: Schematic cross section of telephone cord (not to scale)

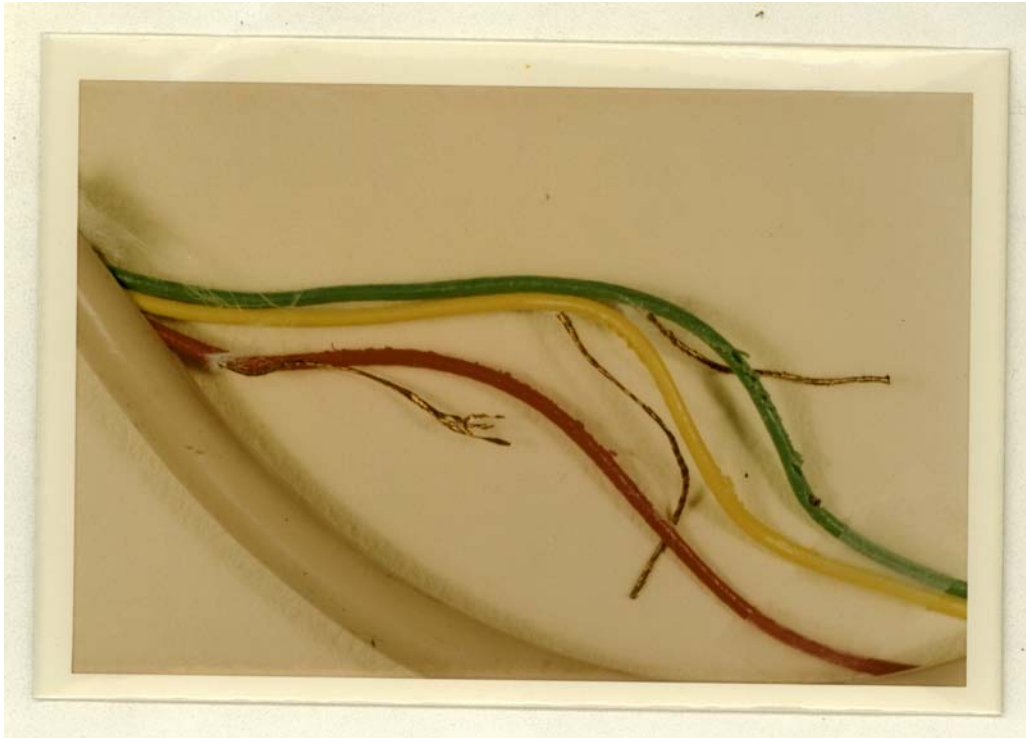


Figure 3: Shows wires and insulation in good order.



Figure 4: Shows heat damage to wires and surrounding fibers in yellow and red sheaths.