Testing and Demonstrative Burns of Household Items, Appliances and Line Cords

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Our company performs fire investigations, fire performance analyses of products and fire reconstructions as well as process safety analyses and other non-fire related services. Over the past 3 years, we have performed a series of fire performance tests on appliances, electrical line cords and typical household items as part of ongoing work with the Consumer Electronics Association. To give some insight into our work and provide a contribution to inFIRE's available resources, I'm just going to briefly present the results of this work to you today. Full reports are available from CEA and have been published in Fire Technology[1].

The primary goals of these projects were to determine the ignition propensity of typical household items when exposed to nearby fires and document the damage to typical household items as a result of external fires, including the effects of external ignition on the electrical components of appliances and electronics.

The first round of tests involved television sets and small household devices such as telephones and radios in configurations with entertainment centers and, in some cases, upholstered chairs. In this performing these tests, our specific goals were to:

1. demonstrate the ignition and flame retardant characteristics of the materials used in the construction of televisions marketed in the United States (V0) as compared to a television set marketed in Europe (HB).
2. document the damage to television sets when exposed to nearby burning materials.
3. evaluate and compare the damage to television sets when subjected to different size, duration, and types of fires.
4. evaluate fire damage to television sets and other electronic devices when exposed to post flashover conditions.
5. evaluate electrical related damage to components of electronic devices, while they are operating and subjected to exposure fires.

In addition to two primary ignition tests, ten full-scale tests were performed at our burn facility. Six of these tests were in calibrated room calorimeter in accordance with ISO 9705 (Fire Tests-Full Scale Room Test for Surface Products, First Edition, 1993) and four in a room

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[1]Hoffmann, D.J., et. al. (2001). Electrical Power Cord Damage from Radiant Heat and Fire Exposure. *Fire Technology; 34:* 129-142.

Hoffmann, D.J., et. al. (2003). Full Scale Burn Tests of Television Sets and Electronic Appliances. *Fire Technology; 39:* 207-224.

without calorimetry in accordance with ASTM E603 (Standard Guide for Room Fire Experiments, 1998).

Here is a summary of the configurations for each of the tests. As you can see, test series one through three incorporated just the televisions and electrical devices - these were the tests performed in the calibrated room calorimeters. Test series four and five incorporated typical furnishings and multiple television sets and were performed according to the guide for room fire experiments.

The ignition tests and the demonstrations in which V0 and HB television cabinets were exposed to moderate exterior exposure fires were performed to demonstrate the ability of the V0 cabinets to resist attack by modest exterior fire ignition sources. In both ignition tests with V0 televisions, the cabinet did not sustain combustion and self extinguished. One V0 cabinet did not sustain combustion at all while the other V0 cabinet sustained combustion for approximately two minutes after the IPA fuel source was depleted. Damage, consisting of heat damage and some melting, to the V0 cabinets was localized to the area where flames from the ignition source impinged on the side of the cabinet.

When the HB cabinet was exposed to the same ignition source, the cabinet continued to burn freely and involved the combustible entertainment center. In demonstrations where the wooden/plastic entertainment center became involved, the fire continued to grow only after the plastic covered particle board of the entertainment center became fully involved. In Demonstrations 4A and 4B where a polyurethane foam upholstered chair was ignited, the television cabinet was only partially consumed and the picture tube remained intact even though the room approached flashover conditions in less than four minutes.

In Demonstrations 5A and 5B, the room contained four television sets, other plastic electronic devices and an upholstered chair. After ignition, the fire grew rapidly similar to Demonstrations 4A and 4B. In this instance, no extinguishing efforts were made until four minutes after flashover. At that time, all television sets were fully involved and all picture tubes had failed catastrophically. Observations of the fire through the door during the fire showed that the glass picture screen of the television will reflect the burning upholstered chair. Post fire examination showed that, even though the picture tubes had failed, the glass was generally contained on the set chassis and the yoke in each case was located on the chassis below its location at the back of the tube.

Electrical damage, on those television sets energized when exposed to a fire, was documented. There was no correlation found to the amount of electrical damage found on the television set and the damage to the fuse, line cord, or position of the over current protective device. In general, when the television was exposed to an external fire, and became involved, the circuit breaker protecting the device tripped. The condition of the fuses in the televisions did not show a trend when exposed to a fire and it was found that the element ceased to have continuity on some television sets and did not on others. When the element ceased to have continuity on the television sets, internal electrical damage was noted on wiring near the circuit board from the exposure fire. Visual inspection of the element showed that the element opened due to current and not heat from an exposure fire.

Based on the variation of damage to a television set from an exposure fire, the exposure fire (1) may or may not cause the circuit breaker protecting the device to trip, (2) can cause internal electrical activity on or near the circuit board of the television set, (3) can cause the internal fuse to open, and (4) can cause arcing on the power cord of the television set.

Analysis of the fire patterns from the exposure fires showed that fire damage that occurs prior to flashover is indicative to a general area of origin. Fire patterns were often misleading and the post fire damage made it difficult to assess the location of the origin of the fire. Without prior knowledge of the test protocol, post fire condition of the demonstrations illustrates the difficulty for an untrained fire investigator to ascertain the cause and origin of the fire.

The second round of testing performed by SEL was to expose energized line cords from electronic devices and appliances to simulated fire environments. In performing these tests, our specific goals were:

1. To evaluate the performance of line cords in fire environments.
2. To characterize the electrical activity and damage sustained by the line cords.

A total of 728 line cords were exposed to radiant heat and fire under the six different test configurations, described in this table) in order to determine if there was a positive correlation between the fire environment, line cord type, single or double jacketed insulation, line cord behavior and/or damage caused by electrical activity.

Based on the Test Series, the following conclusions were reached regarding the exposure of electrical line cords to radiant heat and flame:

In Series A, the line cord was suspended horizontally between two ceramic mandrels with a ½ inch sag in the cord midway between mandrels. Here, the test light circuit was interrupted but the circuit breaker was not tripped despite arcing and spattering of the copper conductor.

In Series B, the line cord was draped over a ceramic mandrel with radiant heat oriented at 45 degrees to the vertical. In this particular test, the radiant cone ignites the insulation of the line cord. The cord is severed and the circuit interrupted and the energized section of cord arcs while the breaker remains in the on position.

In Series C, a ½ inch flame from a gas burner impinged on the natural bend in a cord plugged into a duplex outlet. Here, flame impingement interrupts the circuit and trips the breaker.

In Series D, the line cord was placed on carpet, and in Series E on untreated parquet wood flooring both with radiant heat source directly above. In both test series D & E, combustible material caused the test light circuit to be interrupted but the breaker did not trip despite arcing.

In Series F, the power cord was suspended over a wood crib fire. The wood arch fire ignited both line cords suspended above. This caused only one circuit to be interrupted, and the breaker remained open.

Energized line cords do not always produce evidence of electrical faults when exposed to radiant heat sources that char or ignite the cord insulation. This was demonstrated by tests A and B, wherein lines continued to perform even after insulation was burned charred and/or decomposed. Therefore the charred insulation did not provide a path for current to flow.

Line cords in contact with combustible surfaces ignited by radiant heat always produced evidence of electrical faults. This was demonstrated by tests C, D, E and F, wherein line cords always failed when the surface below them was ignited.

The physical appearance of electrical faults in line cords produced when exposed to radiant heat or flame does not depend upon the:

1. Magnitude of the fault current - the available fault current during testing was 300 AMPs. The damage to the conductors, however, varied and was not related to the tripping of the circuit breaker;
2. The conditions of fire exposure - comparison of cords faulted by radiant exposure to that of flame exposure, showed no considerable difference in damage.; or
3. The type of insulating material and construction of a electrical line cord.

Electrically caused damage to power cord conductors produced under controlled laboratory fire conditions does not differ from the damage previously observed by SEL under field fire conditions. When line cords subjected to laboratory tests were compared with those in actual fires, the damage evidenced was very similar.

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Television Burn Demonstrations

Summary of Television Burn Demonstrations

Demo.		TV Type	Screen Size	Electronic Devices	Energized	Configuration
Ignition 1		V0	20”	Telephone	No	Videocart under hood
Ignition 2		V0	20”	None	No	Videocart under hood
1	1A	V0	20”	1 Cordless Phone 1 Small Radio	No	Entertainment Center
	1B	V0	20”	1 Cordless Phone 1 Small Radio	Yes	Entertainment Center
2	2A	V0	20”	Telephone	No	Entertainment Center
	2B	V0	20”	Telephone	Yes	Entertainment Center
3	3A	HB	19”	None	No	Entertainment Center
	3B	V0	20”	None	Yes	Videocart under hood
4	4A	V0	27”	Radio	No	On tables beside upholstered chair
	4B	V0	27”	Radio	Yes	On tables beside upholstered chair
5	5A	V0	36”, 30”, 2 x 27”	4 Radios 4 Telephones 1 Ans. Machine	No	In burn room with upholstered chair and rug
	5B	V0	36”, 31”, 27”, 25”	4 Radios 4 Telephones 1 Ans. Machine	Yes	In burn room with upholstered chair and rug

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	2B	V0	20”	Telephone	Yes	Entertainment Center
3	3A	HB	19”	None	No	Entertainment Center
	3B	V0	20”	None	Yes	Videocart under hood
4	4A	V0	27”	Radio	No	On tables beside upholstered chair
	4B	V0	27”	Radio	Yes	On tables beside upholstered chair
5	5A	V0	36”, 30”, 2 x 27”	4 Radios 4 Telephones 1 Ans. Machine	No	In burn room with upholstered chair and rug
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	2B	V0	20”	Telephone	Yes	Entertainment Center
3	3A	HB	19”	None	No	Entertainment Center
	3B	V0	20”	None	Yes	Videocart under hood
4	4A	V0	27”	Radio	No	On tables beside upholstered chair
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V0 Television Cabinet

V0 Television Cabinet

HB Television Cabinet

HB Television Cabinet

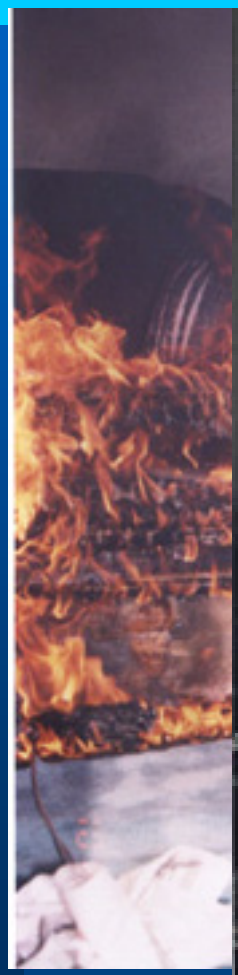
HB Television Cabinet

Demos with Upholstered Chair

Demos with Upholstered Chair

Demos with Upholstered Chair and Multiple Televisions

Demos with Upholstered Chair and Multiple Televisions

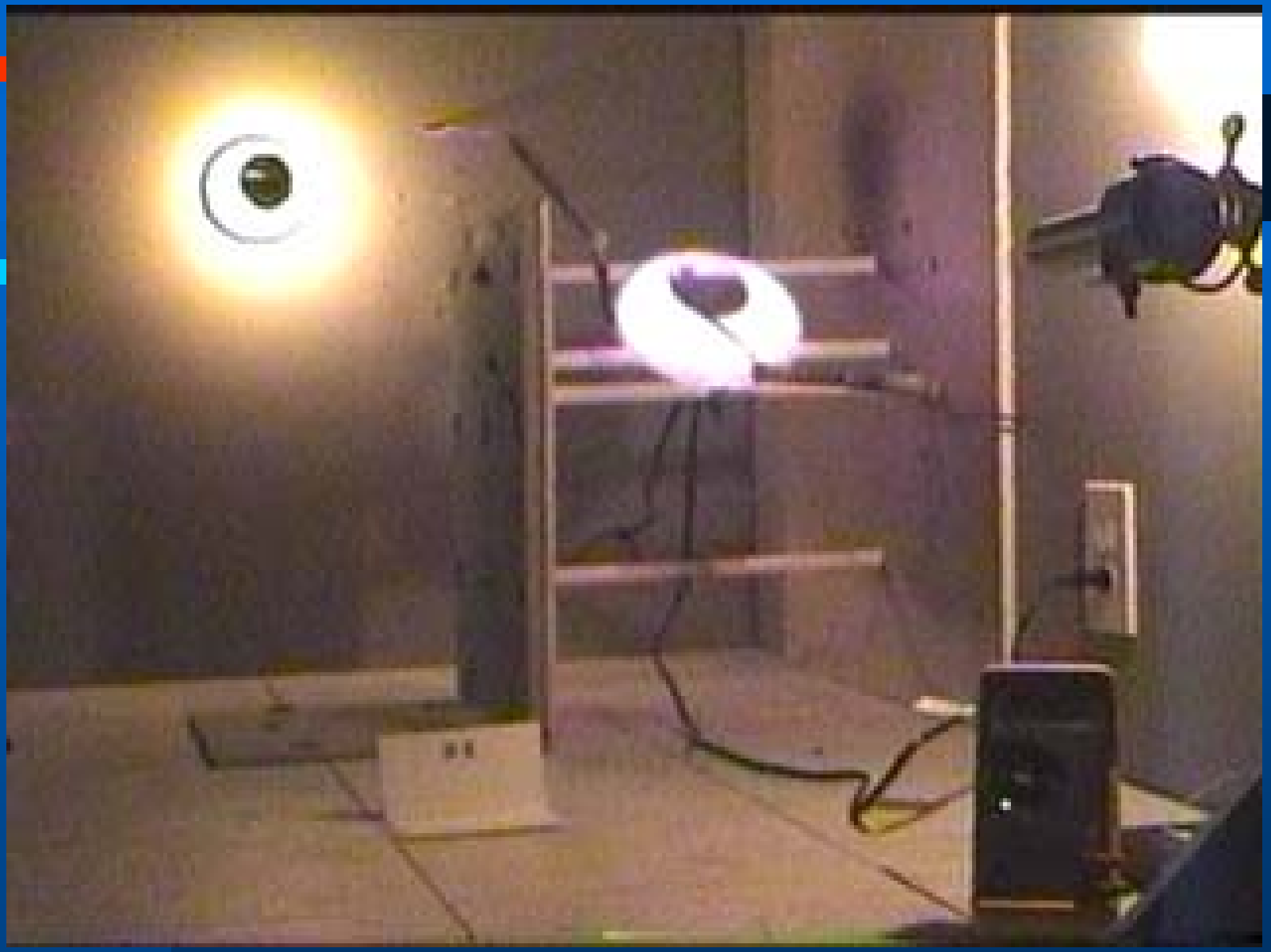


Electric Line Cord Testing

Summary of Line Cord Testing

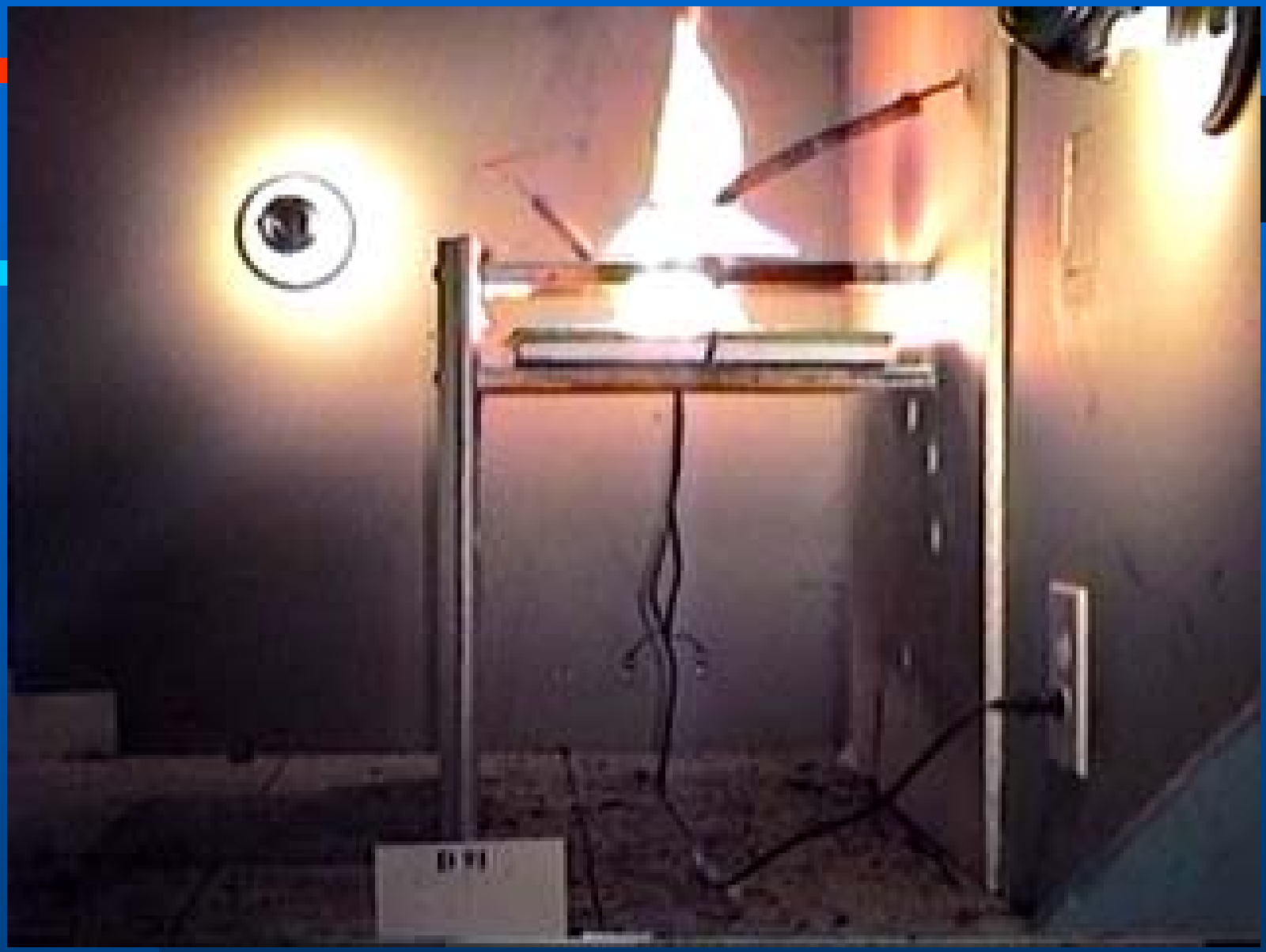
Test Series	Type of Exposure	Exposure Conditions	Configuration
A	Radiant Heat	Horizontal Exposure	Line cord suspended horizontal between two ceramic mandrels with a ½" sag in cord midway between mandrels
B	Radiant Heat	Exposure at 45 Degrees	Line cord draped over a ceramic mandrel with radiant heat oriented at 45 degrees to the vertical
C	Flame Impingement	Gas Flame	½" flame from gas burner impinging on the natural bend in cord plugged into duplex outlet
D	Radiant Exposure	Horizontal Exposure Over Carpet	Line cord place on carpet with radiant heat directly above
E	Radiant Exposure	Horizontal Exposure Over Parquet Floor	Line cord placed on untreated parquet wood flooring with radiant heat source directly above
F	Flame Impingement	Wood Crib	Power cord suspended over wood crib fire

Series A

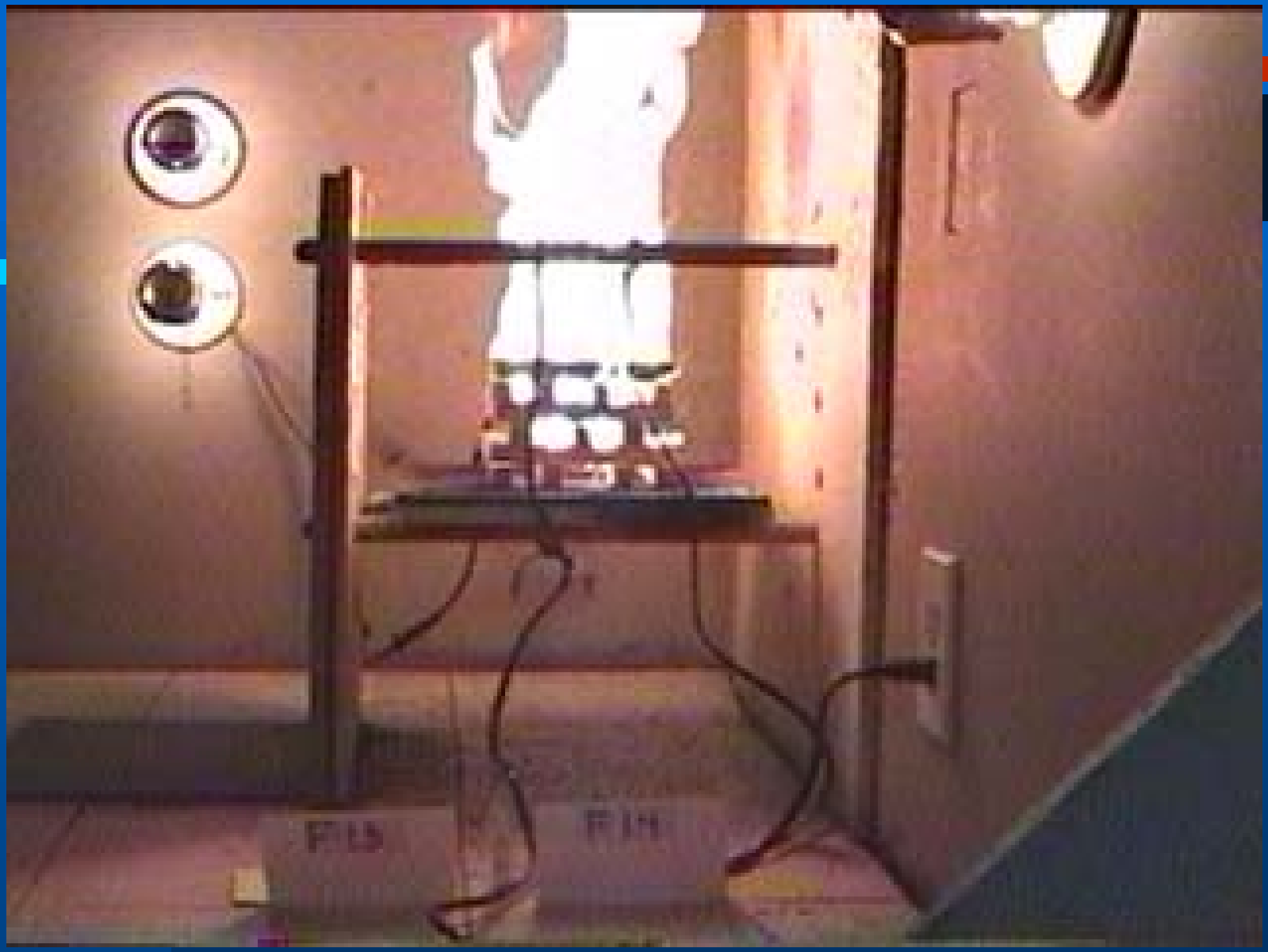


Series B

Series C



Series D&E



Series F

Total Cords Exhibiting Electrical Activity for Test Configurations

Cord Type	Series A	Series B	Series C	Series D	Series E	Series F	TOTAL (%)
01-I	5/20	4/20	8/10	20/20	15/15	2/2	62
02-I	4/20	6/20	4/10	20/20	15/15	2/2	59
03-I	17/20	6/10	10/10	20/20	15/15	2/2	91
04-I	10/20	4/10	8/10	20/20	15/15	2/2	76
05-I	8/20	2/10	10/10	20/20	15/15	2/2	74
06-I	12/20	5/10	7/10	20/20	15/15	2/2	79
07-NI	4/20	0/10	10/10	20/20	20/20	2/2	68
08-NI	6/20	0/10	10/10	20/20	20/20	2/2	71
09-NI	10/20	0/10	10/10	20/20	20/20	2/2	76
TOTAL (%)	42	25	86	100	100	100	

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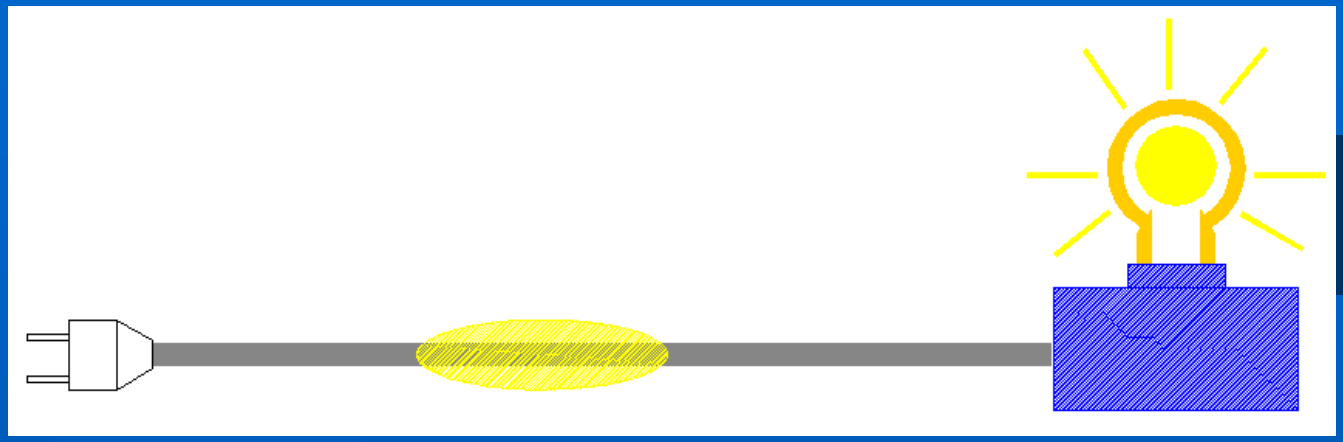
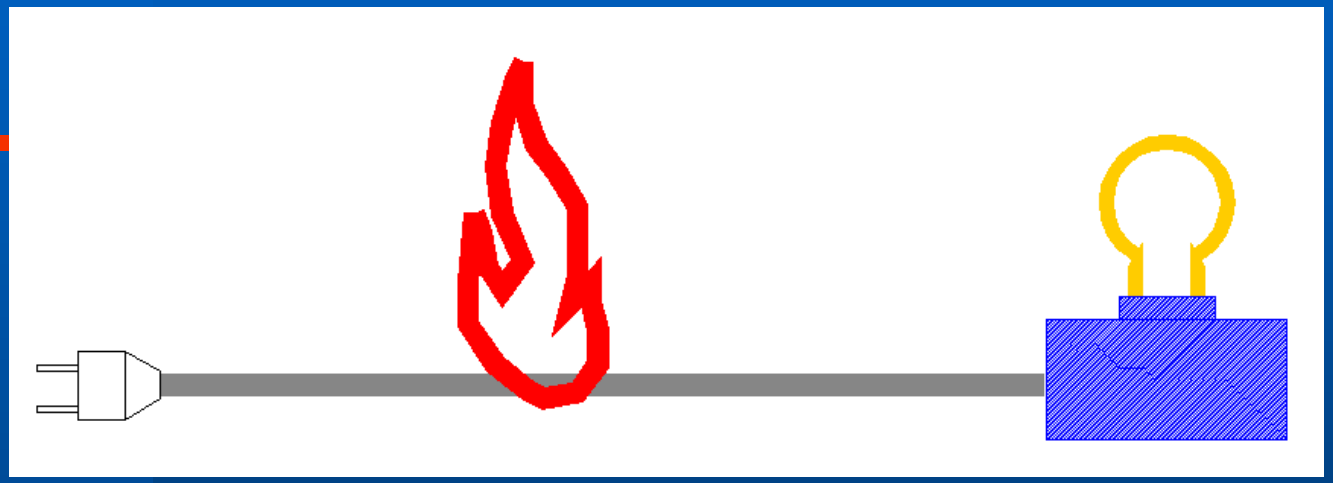
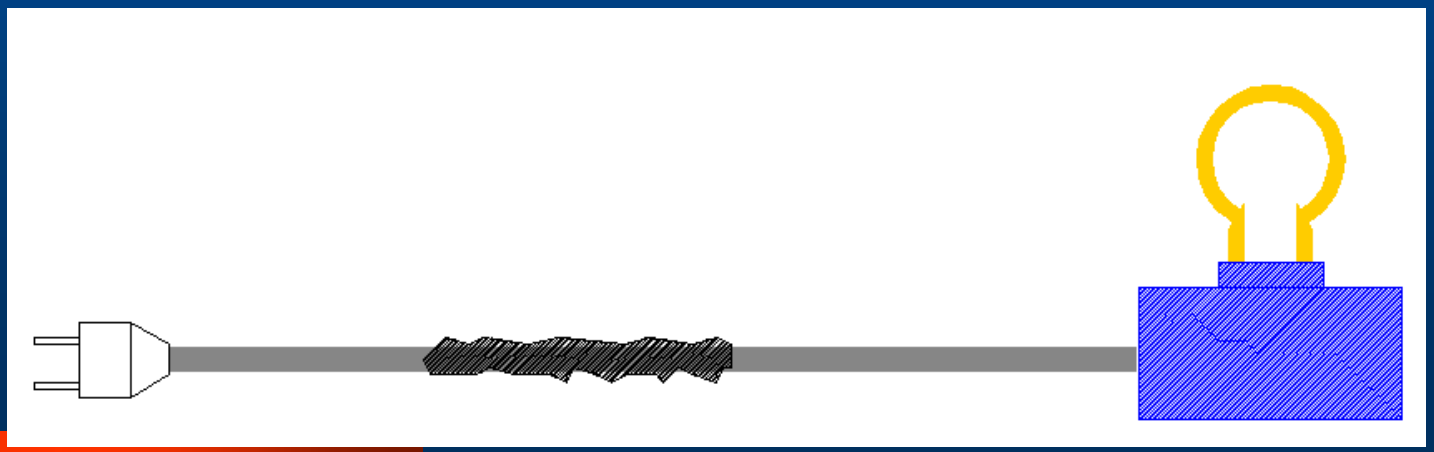
01-I	5/20	4/20	8/10	20/20	15/15	2/2	62
02-I	4/20	6/20	4/10	20/20	15/15	2/2	59
03-I	17/20	6/10	10/10	20/20	15/15	2/2	91
04-I	10/20	4/10	8/10	20/20	15/15	2/2	76
05-I	8/20	2/10	10/10	20/20	15/15	2/2	74
06-I	12/20	5/10	7/10	20/20	15/15	2/2	79
07-NI	4/20	0/10	10/10	20/20	20/20	2/2	68
08-NI	6/20	0/10	10/10	20/20	20/20	2/2	71
09-NI	10/20	0/10	10/10	20/20	20/20	2/2	76
TOTAL (%)	42	25	86	100	100	100	



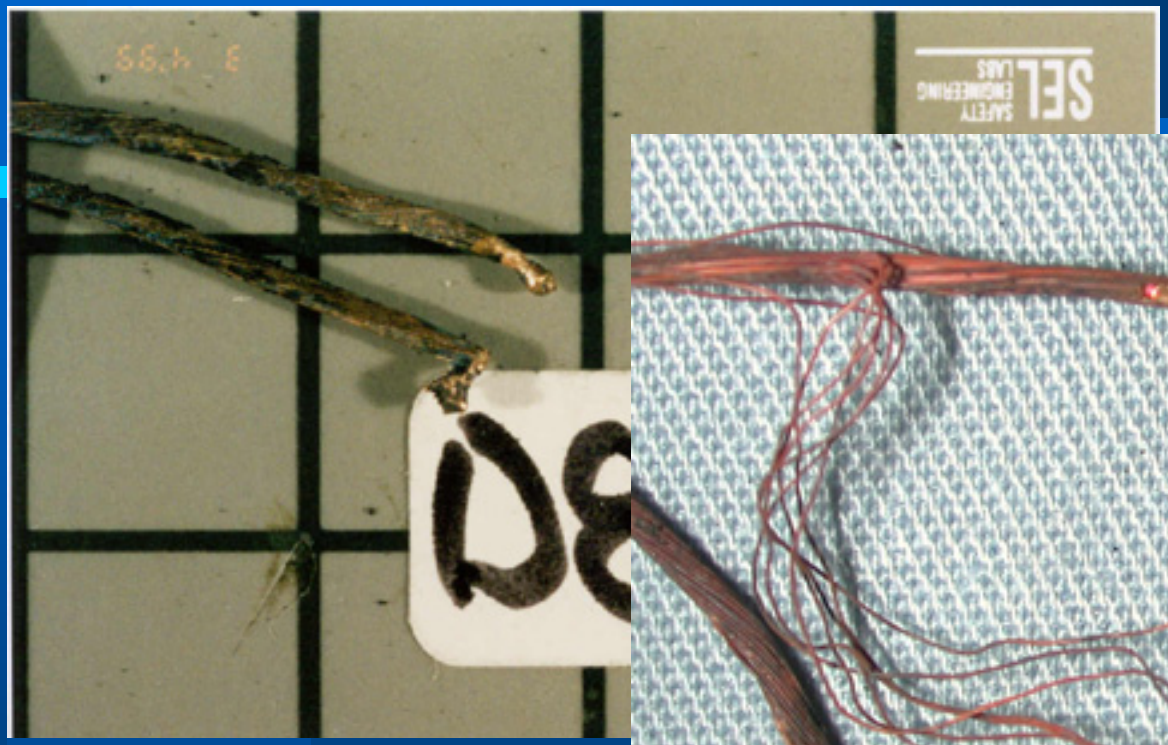


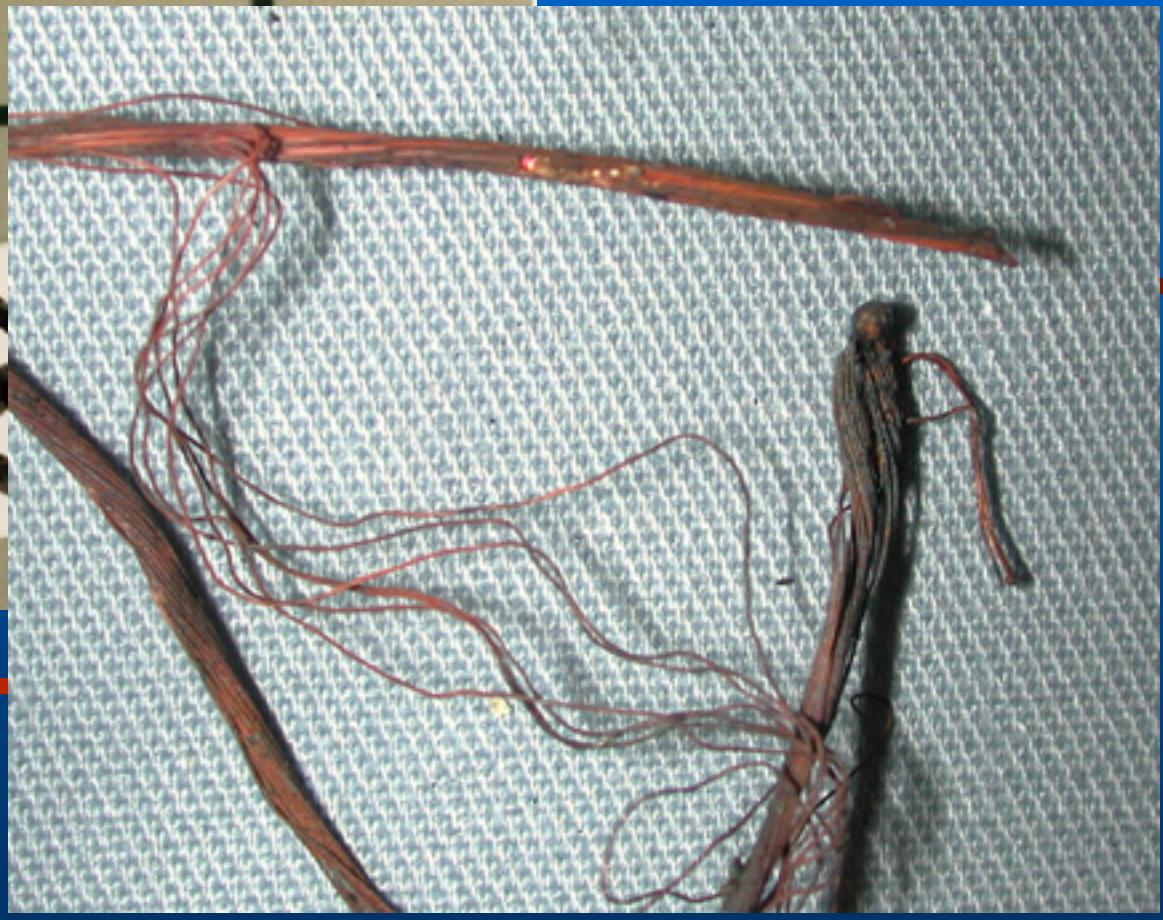


Test Cord

Incident Cord

Test Cord





Incident Cord