NBSIR 81-2261

Review of Literature, Applicable Test Methods, and Incident Data for the Evaluation of the Fire Performance of Central Telephone Office Equipment

Emil Braun

Center for Fire Research
National Engineering Laboratory
U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

May 1981

Final Report

Prepared for:
ural Electrification Administration
.S. Department of Agriculture
/ashington, DC 20250

NBSIR 81-2261

REVIEW OF LITERATURE, APPLICABLE TEST METHODS, AND INCIDENT DATA FOR THE EVALUATION OF THE FIRE PERFORMANCE OF CENTRAL TELEPHONE OFFICE EQUIPMENT

Emil Braun

Center for Fire Research
National Engineering Laboratory
U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

May 1981

Final Report

Prepared for:
Rural Electrification Administration
U.S. Department of Agriculture
Washington, DC 20250

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

REVIEW OF LITERATURE, APPLICABLE TEST METHODS, AND INCIDENT DATA FOR THE EVALUATION OF THE FIRE PERFORMANCE OF CENTRAL TELEPHONE OFFICE EQUIPMENT

Emil Braun

Abstract

At the request of the Rural Electrification Administration, a program was initiated to evaluate the adequacy of current flammability specifications for electrical equipment used in telephone company central offices. The high reliance on telephone services for emergency communications necessitates that measures be considered to minimize the likelihood of fire related interruptions of service. This report provides a review of current test methods and specifications for central office equipment; a review of available fire test methods in various categories; a brief literature review of relevant fire research and fire testing of wiring, cables, and assemblies; and a review of fire incident data.

Key words: Central office equipment; electronic equipment; fire test methods; incident data; telecommunications; telephone exchanges.

1. INTRODUCTION

At the request of the Rural Electrification Administration (REA), United States Department of Agriculture, the Center for Fire Research (CFR) initiated a program to evaluate the adequacy of current flammability specifications for electrical equipment used in telephone company central offices. In addition to preventing personal injury, the primary concern regarding fire incidents in central telephone offices is the reduction of potential interruption of service to subscribers for an extended period of time. The high reliance on telephone services for emergency communications, particularly in rural areas, necessitates that measures be considered to minimize the likelihood of such an event.

The Rural Electrification Association has the federal authority to fund, via a financial loan program, the construction of telephone central offices. Along with this funding authority, REA has the obligation to ensure that standards and specifications for equipment and materials are met. Recent fire incidents which have occurred in central telephone offices have indicated that a need exists to review current flammability specifications for materials used in central office equipment.

The Center for Fire Research's objective is to review the potential fire problem associated with materials exposed to possible ignition sources in central offices and to determine whether existing specifications and accepted small-scale flammability test methods properly address these potential problems. At the conclusion of the program, recommendations will be made to REA concerning the viability of existing test methods to provide the necessary level of fire safety. If these test methods do not meet the minimum requirements for fire safety, alternative test methods will be recommended.

This report represents the completion of the first phase of a multiphase program. It provides a review of current Bell System test methods and specifications for central office equipment; a review of available fire test methods in various categories; a brief literature review of relevant fire research and fire testing of wiring, cables, and assemblies; and a review of fire incident data.

2. BELL SYSTEM FIRE PERFORMANCE REQUIREMENTS

The recognized authority in the field of telecommunications is AT&T's Bell Laboratories. Over the years they have developed a series of product material and purchase specifications that cover every aspect of telephone system design. Included in these specifications are test methods and criteria believed by Bell Laboratories to provide an adequate level of fire performance in the design and assembly of new equipment and cabling. Bell System specifications and procedures for qualification fire testing appear to be followed by all manufacturers of central office equipment.

Bell System specifications [1][1] are intended to provide a screening procedure that will result in the selection of polymeric materials for new equipment and cabling assemblies that exhibit fire retardant characteristics.

---

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

The desired end-point in this testing program is that a fire originating in the equipment racks of a central office be confined to the equipment rack of origin and not spread to adjacent frame assemblies. Furthermore, the fire's size should not grow beyond that which could be controlled by a hand-held fire extinguisher. This goal is presumably achieved either by performing several small-scale fire tests on equipment components or by conducting assembly fire tests that duplicate actual material configuration and operating conditions. Four small-scale fire tests are quoted by Bell System specifications. Table 1 is a list of these test methods. The acceptance criterion is also listed for each test method.

2.1 Bell System Protocol - Small-Scale Tests

The small-scale fire test protocol defined by the Bell System requires that all materials be tested by ASTM D 2863-70, "Flammability of Plastics Using the Oxygen Index Method" [2]. According to Bell System specifications, materials tested by this method must exhibit a minimum oxygen index of 28. The material must also meet the minimum requirements of one of the three remaining tests.

2.1.1 ASTM D 2863

This test method determines the minimum concentration of oxygen in a flowing mixture of O_2/N_2 necessary to support flaming combustion on a polymeric rod of prescribed size. Oxygen Index (OI) values can range from approximately 14 to 70. A large number of polymeric compounds are available that have OI values in excess of 28. Many, however, are not suitable for telecommunication applications. Table 2 lists several compounds that meet or exceed the minimum requirements and may be used in the assembly of electronics equipment. Two common compounds found routinely in electronic equipment are polyvinyl chloride and epoxy. Both compounds can be formulated to have an OI greater than 28.

2.1.2 ASTM E 136

This test method [4] defines noncombustibility of materials in terms of temperature rise, flaming, and weight loss criteria. Specimens of polymeric materials are inserted into a vertical tube furnace at 750°C. Two thermocouples are used to monitor the temperature response of the sample. A sample passes the test if at least three of the four specimens do not exhibit a temperature rise in excess of 30°C above the initial operating temperature of

Table 1. List of test methods used by Bell Systems for procurement of central office equipment and cables

Test Designation	Title	Acceptance Criterion
ASTM[a] D 2863-70	Flammability of Plastics Using the Oxygen Index Method	≥ 28
ASTM E 136-73	Test for Noncombustibility of Elementary Materials	Noncombustible
ASTM E 84-74	Surface Burning Characteristics of Building Materials	$I_S \leq 25$ $S_D \leq 50$
UL[b] 94	Test for Flammability of Plastic Materials	VE - 0 VE - 1

[a] American Society for Testing and Materials

[b] Underwriters Laboratories

Table 2. List of compounds and typical values for the oxygen index (based on reference 3)

Materials	Oxygen Index
Polyvinyl chloride	40
ABS	30
Teflon	95
Polyvinylidene fluoride	40
Polybenzimidazole	40
Aromatic polyamide	28
Nylon	28
Polyimide	36
Polycarbonate	30
Polysulfone	35
Phenolic	40
Epoxy	33
Alkyd	>29
Silicone rubber	>30

the furnace and there is no flaming from the specimen after the first 30 seconds. In addition, if the weight loss of the specimen exceeds 50 percent, then the specimen cannot flame or have a temperature rise above the initial furnace temperature.

2.1.3 ASTM E 84

This test method [5] measures the surface burning characteristics of a material by evaluating the flame spread over its surface when exposed to a test fire. Smoke density is also evaluated at the same time. Samples (7.3 m long) are mounted face down on the ceiling of the horizontal test chamber. A flame from the test fire is impinged on the specimen surface. The rate of flame spread and smoke evolution are recorded. Flame spread classification is proportional to the total area under the flame distance-time curve. For smoke evolution, the area under the smoke density-time curve is computed. This value is normalized by the smoke produced by red oak. Although E 84 is intended for building materials and not for cables, Bell System has modified the test and established acceptable fire performance for cables in this test to be a flame spread rating less than 25 and a smoke developed rating of not more than 50 (see section 4.2.2 and [4]). These are values commonly used in building codes to regulate interior finish materials in exitways and in critical areas of many types of occupancies.

2.1.4 UL 94

This standard [6] contains five test methods. The method cited in Bell System purchase specifications is the vertical burning test for classifying polymeric materials according to their ability to resist ignition -- 94V-0 and 94V-1. This test method exposes a vertically supported specimen to a bunsen burner type flame. Two successive 10-second exposures are applied to each 127 mm long specimen. A total of five specimens is tested. Dry absorbent surgical cotton is placed beneath the test specimen to determine the ignitability of molten drips. In order to receive a 94V-0 classification, a sample must not have a total afterflame time exceeding 50 seconds or an individual specimen afterflame time greater than 10 seconds. Glowing combustion is limited to 30 seconds or less for each specimen and no specimen can release flaming drips that ignite the surgical cotton.

A 94V-1 classification differs slightly from the preceding in that longer times are allowed for total afterflame, individual afterflame, and glowing combustion. They are 250, 30, and 60 seconds, respectively.

2.2 Bell System Protocol - Large-Scale Test

If materials are used that either have not been tested by the small-scale tests or have failed to meet the requirements of the small-scale protocol, large-scale fire tests are required on actual equipment and cable distribution assemblies. The assembly fire tests are intended to duplicate actual material configurations and operating conditions. The objective of the large-scale test is to ensure that if an ignition were to occur in a system, it would be confined to a vertical section of equipment delimited by the vertical frame supports. The assembly should also demonstrate that a large fire could not develop. A large fire is defined as one that could not be extinguished by a handheld fire extinguisher (Class 5B:C extinguisher, e.g., 10 lb. CO_2).

Communications cable and distribution assemblies have the added requirement that they must be able to limit flame spread to 6 inches horizontally and 4 feet vertically before self-extinguishing.

3. GENERAL FIRE TESTS

While no federal agency has adopted fire performance requirements for central telephone office equipment, there exists a large selection of test methods that may be appropriate for the evaluation of central office equipment. Many tests have been developed for electrical cable insulation. Fewer test methods exist for the characterization of fire properties of polymeric materials for electrical applications. The National Materials Advisory Board [7] has compiled a general list of fire test methods. They divided the various test methods into nine categories:

1. Ease of ignition;
2. Flame spread;
3. Rate of heat release;
4. Minimum oxygen requirement;
5. Smoke evolution;
6. Ease of extinguishment;
7. Toxic gas emissions;
8. Fire endurance;
9. Full-scale tests.

Specific tests in each of the first seven categories are intended to determine a different material response under well defined exposure conditions. These measurements, however, do not necessarily represent fundamental material properties. The test results are affected by the geometry of the sample (e.g., specimen size, thickness, surface orientation, etc.) and changes in the sample's environment (e.g., airflow, humidity, etc.). The selection of appropriate test methods is governed by a need to maximize specific fire attributes of a material. Specific fire attributes are chosen for maximization based on a set of exposure conditions defined by a probable scenario for machine failures that could lead to ignition. At the present time, end-use conditions are ill-defined for most applications of these tests. The exception is the recent issuance of guidelines for conducting full-scale tests [8] and the development of several full-scale test methods [9,10] that are intended to evaluate wall-finish materials and furnishing for residential use.

Fire endurance tests are normally designed to evaluate structural components with regard to their ability to retain fire barrier integrity and load carrying capacity. With the exception of cable penetration tests, these tests will not be reviewed in this report.

The test methods reviewed in the following section represent those tests that are currently available to measure fire properties of materials for electrical applications. The minimum oxygen requirement test will not be discussed because only one exists and it has previously been described.

3.1 Ease of Ignition

The ignition of a material is the first stage in the development of a fire. The ease with which a material ignites when exposed to a source of energy typically encountered in end-use conditions may determine the appropriateness of a material for the stated application. Several tests exist for the measurement of the ease of ignition of materials used in electrical applications. Some are listed in table 3. Ease of ignition tests are used primarily to characterize the ignition times of sheet or rigid polymeric materials.

A test designed specifically for ignition measurements on insulated electric cables does not exist. Some flame spread tests expose electric cables to a standard heat source for fixed periods of time. These types of tests have an implicit minimum ignition time.

Table 3. Summary of ignition tests

Test Method	Sample Size	Sample Orientation	Ignition Source	Conditioning	Results
ASTM D 229					
Method II	13mm x 13mm x 254mm	vertical	heating coil & electric arc	168 hours @ 23°C, 50% RH	.ignition time .burning time
ASTM D 1929	3g	--	convective air furnace	--	.flash ignition temperature .self-ignition temperature
Federal Test Method Standard 406					
Method 2023	127mm x 13mm x 13mm	vertical	heating coil & spark plugs	--	.ignition time .distance of flame travel .burning time
Method 4011	flat sheet - 3.2mm thick	horizontal	electric arc (max. 40ma @ 15KV)	--	arc-resistance time
UL 746A					
Hot Wire	flat sheet >.25mm	horizontal	heater wire wrapped around sample	.7 days @ 70°C forced-draft oven .4 hours cooled over silica gel	time to ignition
High-Current Arc	127mm x 13mm x sample thickness	horizontal	electric arc (32.5 amp @ 240V)	--	number of arc exposures to ignition
High-Voltage Arc	127mm x 13mm x sample thickness	vertical	electric arc (5.2KV @ 2.36ma)	--	time to ignition
Hot Bar	730mm x 730mm x sample thickness	vertical	hot bar @ 650°C	.7 days @ 70°C forced-draft oven .40 hours @ 23°C, 50% RH	time to ignition
UL Ignition Temperature Test	maximum size: 6.4mm x 3.2mm	--	heated flask	--	temperature of flask at ignition

ASTM D 229 Method II [11] and Federal Test Method Standard Number 406, Method 2023 [12] describe comparable test procedures for testing the ignition resistance time of rigid sheet polymers. The specimen is vertically centered in a heating coil and, during the heating process, it is exposed to an electrical arc until ignition of the core material occurs. The length of time of exposure is reported as the mean of five specimens. ASTM D 229 Method I also tests for ignition resistance using a flaming exposure.

Underwriters Laboratories (UL) also has a heated coil ignition test [13]. In this method, however, the test material is wrapped with an electrically heated wire and observed until visible flaming occurs on the test specimen. This is taken as the ignition time. The physical contact made between the heated wire and the test material and the lack of a secondary ignition source distinguishes this method from the preceding two methods.

An alternative approach for measuring ignition resistance is to determine the self-ignition temperature of a material that may be used in electrical appliances. ASTM D 1929 [14] measures the minimum furnace temperature necessary to cause a specimen to release combustible gases which will ignite at the furnace outlet either in the presence or absence of a small pilot flame (flash ignition or self-ignition). Electrical appliance designs could then be reviewed to ensure that these temperatures are not exceeded under worst-case conditions. UL [15] employs a similar type of test as part of their appliance certification program. The major difference is in how the sample is heated. The ASTM test uses a controlled airflow while the UL test provides for natural convection within the flask and conduction through the flask to heat the specimen to ignition. This can, generally, be used to account for differences in test results on similar materials.

In addition to the preceding ignition tests, there are so-called "arc tracking tests" [15] listed in table 3. These tests subject a specimen to either a high-current arc or a high-voltage arc. The high-current arc exposes a specimen to repeated applications of a 32.7 amp electric arc. The high-voltage arc test is a low-current 5200 volt source. The length of damage (e.g., charring) that an applied voltage and current will induce in an insulator is called the tracking distance. Maximum tracking distance is 50.8 mm or a 5-minute exposure for high-current arcs and a 2-minute exposure for high-voltage. Federal Test Method Standard 406 Method 4011 [16] applies a stepwise increasing current to 40 ma at approximately 15 KV. The time to initiate tracking and the current setting are reported. This measurement may be an indicator of dielectric performance under fault conditions.

3.2 Flame Spread

Flame spread tests, which measure the rate of flame propagation or the extent of burning, can be divided into tests that measure flame spread on polymeric sheet materials and tests that measure flame spread on wire and cables. In either case, the intent is to design a test method that would characterize materials to the extent they could contribute to the growth of a fire. Any flame spread test presupposes the existence of a fire. The size of the ignition source used in these tests is an indication of which stage in a fire's development the test is measuring material performance. With the exception of ASTM E 84, the tests summarized in table 4 measure material fire performance at an early stage of fire development.

3.2.1 Sheet Materials

UL 94 [6] previously described represents one of the most complete schemes for the small-scale testing of polymeric materials. The test methods outlined in UL 94 measure burning rate in the vertical and horizontal configuration. The rating system developed by UL also recognizes a material's self-extinguishing characteristics. Analogous test methods are ASTM D 635 [17] and Method 2021 [18]. They measure flame spread rate in a horizontal configuration, while ASTM D 568 [19] and Method 2022 [20] measure a vertical flame spread rate. While no longer in use for cellular plastics, ASTM D 1692 [21] is comparable to ASTM D 568 except that a larger specimen is tested.

3.2.2 Wire and Cables

There are two types of wire and cable flammability tests. IEEE 383 [22] represents a large-scale test protocol, while ASTM D 470 [23] is typical of a small-scale test. The large-scale tests are conducted with multiple lengths of cable distributed in a holder in a manner that represents actual end-use configurations. The fire performance of the entire system of wires and cables is evaluated. In addition to flame spread, these tests evaluate a cable's circuit integrity during flaming conditions. Small-scale tests evaluate the fire performance of a single cable assembly or wire.

Single cable tests such as MSHA 18.64 [24], ASTM D 470, and portions of UL 44 [25] and JIS C 3005 [26] expose a small section of cable to a bunsen type burner for a predetermined time period. Either a flame spread rate is determined or the time to self-extinguish is measured. UL 83 [27], BSI 4066 [28], BSI 6977 [29], and portions of UL 44 use a vertical configuration and a bunsen type burner to evaluate single cables.

Table 4. Summary of flame spread tests

Test Method	Intended Use	Sample Size	Sample Orientation	Ignition Source	Conditioning	Results
ASTM E 84	cable tray	cable rack - 30cm x 594cm	horizontal	88 KW burner (20 minutes)	--	.flame spread .smoke generation
ASTM D 568	sheet polymer	45cm x 2.5cm x sample thickness	vertical	bunsen burner	40 hrs @ 23°C, 50% RH or 88 hrs @ 23°C 50% RH	.burn rate .extent of burning
ASTM D 635	sheet polymer	12.5cm x 1.3cm x sample thickness	horizontal	bunsen burner	--	.burn rate .extent of burning
ASTM D 1692	sheet polymer	15cm x 5cm x ≤1.3cm thick	horizontal	bunsen burner	24 hrs @ 23°C, 50% RH	.burn rate
BSI	cable (dia <5cm) cable (dia >5cm)	60cm long	vertical	bunsen burner two bunsen burners	4 hrs @ 60°C	.burn rate .exposure time a function of sample weight
BSI 6977	cables	60cm long	vertical	bunsen burner (60 seconds)	4 hrs @ 60°C	.burn rate .extent of burning
Federal Test Method Standard 406						
Method 2021	sheet polymer	13cm x 1.3cm x 1.3cm	horizontal	bunsen burner (30 seconds)	--	.burn rate
Method 2022	sheet polymer	46cm x 2.5cm x sample thickness	vertical	.pyroxylin fuse .Benzene drop	2 hrs @ 23°C	.time to burn specimen .extent of burning
IEEE 383	cable tray	244cm x ≥15cm multi-cables with 1/2 diameter space	vertical	.ribbon gas burner (20 minutes) .oil soaked burlap	--	.extent of burning .time of burning .circuit integrity
JIS C 3005	cable	30cm long	horizontal	bunsen burner (30 seconds)	--	.extent of burning
MSHA 30:18.64	cable	91cm long	horizontal	Tirrill burner (60 seconds after conductor is heated to 204°C)	--	.extent of burning .burn rate
UL 44	cable	25cm long	horizontal	Tirrill burner (30 seconds)	--	.extent of burning .combustible drops
	cable	46cm long	vertical	Tirrill burner (5-15 second exposures; wait for extinguishment)	--	.time of burning .charring of indicator
	cable tray	244cm long, 6 sample lengths	vertical	ribbon gas burner (20KW - 20 minutes)	--	.time of burning .extent of burning
UL 83	cable	46cm long	vertical	Tirrill burner (5-15 second exposures)	--	.time of burning .charring of indicator
UL 94	sheet polymer	12.7cm x 1.3cm x ≤1.3cm	horizontal	bunsen burner	48 hrs @ 23°C, 50% RH	.burn rate
			vertical	bunsen burner (repeated 10-second exposure)	.48 hrs @ 23°C 50% RH .168 hrs @ 70°C cooled 4 hrs in desiccator	.time of burning .time of glowing .combustible drops

There is a Japanese standard [26] that measures the tracking resistance for a vertically configured cable sample. A 4 KV sinusodal test voltage is applied between the center core and a helically wound outer conductor.

UL 44, UL 83, and IEEE 383 all represent vertical cable tray tests. A ribbon burner releasing approximately 74 MJ/hr is used as the ignition source. Recently, Underwriters Laboratory has modified ASTM E 84 for cable testing [30]. A horizontal cable tray assembly is inserted into the E 84 tunnel. Modifications were made to the original burner to allow for proper flame impingement on the underside of the cable tray. Test results are reported for flame spread and smoke evolution.

3.3 Rate of Heat Release

A rate of heat release calorimeter defines the rate at which a material contributes heat to a fire when exposed to carefully controlled fire conditions. If an ignition has occurred, this property of a material characterizes its contribution to the rate of fire growth and thus is a good indication of the hazard represented. There are several attempts currently underway at NBS and elsewhere to develop a standard test apparatus and procedure for the measurement of heat release rate. However, no standards organization has yet formally adopted any of the several test methods being developed. As of November 1980, a heat release rate test method was tentatively included in the gray pages of the 1980 Edition of Annual Standards of ASTM.

3.4 Ease of Extinguishment

While the Bell System large-scale test protocol makes provision for determining that a system assembly will not quickly develop a large fire that cannot be readily extinguished with a small fire extinguisher, no standard test method exists to measure quantitatively the ease of extinguishment characteristics of a material.

3.5 Smoke Evolution and Toxic Gas Production

Hazards due to smoke and toxic gas production have normally been confined to considerations of occupant egress potential. Current test methods [5,32, 33] for smoke evolution measure either the optical density or the percent light absorption for smoke produced by a material upon exposure to a standard energy source. No standard protocol exists for determining the toxicity of combustion products. Protocols are under development which evaluate animal responses to the evolved combustion products. In addition, the problem at hand may require the development of an evaluation scheme for determining the deleterious effects combustion products have on electrical contacts as well as people. If such a test could be developed for materials manufactured to meet other test requirements, service interruption could be minimized.

3.6 Fire Endurance

Building codes across the country require that specific barriers within a building be rated as fire resistive barriers. Barriers (walls, floors, or ceiling assemblies) are rated without regard to the effects of openings such as pipes, electrical outlets, or cable penetrations. Central telephone offices routinely penetrate rated and nonrated barriers with cable "poke-thru." Communication cables are passed through barriers that separate the cable vault from the main distribution and switching facility. Within the main distribution facility cables are passed through interior barriers that may not be fire rated. Power cables also penetrate some of the same barriers.

In an effort to ensure that rated barriers are not compromised by cable penetrations, IEEE issued a standard test [21] to qualify cable penetration fire stops. This standard attempts to rate cable penetrations installed in rated barriers. Cable penetrations in the test are constructed with the intended barrier in the end-use configuration. Cable penetration fire stops are not acceptable if the specified temperature limits are exceeded on the unexposed side or ignition of the cable or fire stop materials occurs. The presence of visible flame on the unexposed side within the fire rating time also constitutes a failure. Ratings are given in terms of hours (or fraction of hours) of endurance under a standard time-temperature exposure.

4. LITERATURE

The fire performance evaluation of electrical systems has generally been confined to small-scale tests of polymeric components used in the construction of these systems. A greater research and development effort has been directed towards improving the fire performance of wires and cables as compared to other polymeric components. Generally, wire and cable insulation has not been identified as the cause of a fire. Insulation has been cited, however, as the means for fire propagation once a fire has begun. The greatest effort has, therefore, been directed to developing test methods to evaluate flame propagation potential along a wire or cable assembly. Methods have also been developed to evaluate installation techniques that would limit flame propagation. The following sections represent a brief review of some of the pertinent literature on fire performance testing; it is recognized that such a review cannot be complete or exhaustive.

4.1 Polymeric Materials

The literature appears to be devoid of comparisons between full-scale assembly tests of electrical equipment and small-scale tests conducted in the laboratory. Thus, leaving the choice of distinguishing acceptable from non-acceptable performance in a small-scale test to extrapolations from other fire scenarios.

Miner [34] in reviewing several test methods used to evaluate polymeric materials noted that a material which exhibited superior fire performance in one test method would not necessarily perform as well in another test method. Since material performance is dependent on the test method, the selection of appropriate test methods must be guided by an understanding of potential failure modes of the finished product.

Wiktorek [35] characterized the flammability of polymeric materials for computer application using four different flammability test methods. The tests were: hot wire ignition test, radiant panel test, oxygen index test, an IBM in-house test similar to ASTM D 568. He found that, with the exception of the hot wire ignition test, materials maintained their ranking in the other three tests.

Recent tests on television receivers [36] showed that overload failures, while producing hot spots in excess of 500°C, did not result in any ignitions. Fire tests on the enclosure materials, printed circuit boards, or wires were not conducted.

4.2 Wire and Cables

The research associated with wire and cable fire performance has been divided into two parts. First, consideration of flame propagation along wires and cables, both individually and in bundles. Second, the performance of a firestop (e.g., concrete wall or floor) penetrated by wires and cables.

4.2.1 Cable "Poke Thru"

Cable penetration of a wall is a necessary requirement for moving power and information from one location to another. Numerous methods have been used for sealing penetrations in walls and floors. Although sealing with concrete appears to provide an excellent fire barrier, expansion of services and cable replacement becomes difficult and costly. Work has been conducted on alternate means of sealing "poke thru" holes around cables. Quigg and Orals [37] performed fire tests on 4-inch and 6-inch thick floor slabs. Using different hole and slot sizes, they evaluated different sealing methods. They found that a 1-hour floor rating could be obtained using a gypsum concrete and mineral fiber insulation combination or a Silicone, granular gypsum, and mineral fiber insulation combination.

McGuire [38,39] found that a small-scale test furnace could be used to evaluate various penetration schemes for a 6-inch concrete wall. He found that sleeving cables with thin steel (26-gage) provided better resistance to heat transfer to the unexposed surface than a 2-inch thick electrical conduit. It was also noted that the fire performance of larger cables was not as good as the smaller cables for a 2-hour exposure.

Kita, et al. [40], describe two sealing methods for cable penetrations in telephone office buildings. The sandwich sealing tests and the box sealing tests both proved effective in providing a 2-hour rating in floor furnace tests. Both methods appear to have the disadvantages of high installation costs and lack of flexibility.

Kruczek and Cascio [41] developed alternative design standards for cable vaults that would limit fire and smoke movement. The design standards are intended for new installations. Fire protection is provided by a perforated underframe block cast into the floor under the main frame. Each block contains 10 small holes that permit passage of one cable assembly. Because the smaller holes are limited to one cable, sealing around the cable is easier and cable bundles are minimized. In addition, shafts, ducts, or sleeves are recommended for riser cables.

An alternative to standard wall penetrations by cables is suggested by Peverill [42]. His work involved the evaluation of electrical connectors installed in a fire wall of an aircraft. He showed that a 20-minute fire resistance connector could be developed with existing technology. These connectors did not degrade the wall's fire stopping capabilities. More improvements in connector design would be necessary before this concept could be implemented in central office applications.

4.2.2 Flame Propagation

The majority of recent research attention has been directed to developing improved polymers and cable assemblies. These materials and assemblies have been evaluated by several of the tests previously described. Investigations of the usefulness of modifications or appropriateness of some test methods have been conducted as well. Woolerton's [43] work on the use of a heat release rate test to evaluate the flammability of communications cable is an example of the latter type of work. Woolerton found that the Ohio State University Release Rate Apparatus could be modified to measure circuit integrity under fire exposure conditions. Using a mathematical simulation of the ASTM E 84 test, flammability performance of cables in the tunnel could be predicted from rate of heat release data.

Beyreis, et al. [44], have modified ASTM E 84 to allow for the characterization of flame spread and smoke production of cables in a horizontal rack configuration. A cable rack is mounted in the upper part of the tunnel and exposed to the test burner for 20 minutes. The test sample was a uniform single layer of cable filling the tray width. Klevan, et al. [45], discusses the difference between a fully loaded cable tray and a single layer of cables. Klevan concludes that the rate of flame propagation would be much greater for the fully loaded tray.

Clarke [46] presented an analytical model for cable tray fires. He concluded that the current tray separation criteria of 5 feet vertical and 3 feet horizontal [22] are marginal for local fires and too small to prevent fire spread for extended tray fires. Klamerus [47] verified this finding when he conducted cable tray fire tests using a multiple tray configuration. He found a fully developed cable fire could propagate across the vertical separation distance between trays and that installing a shield between trays effectively reduced the burn area in the upper tray to zero.

Most of the cable and wire flammability tests previously cited are conducted with no current flowing in the wire or a minimal current for those cases in which circuit integrity is of concern. (The MSHA cable test is performed with the conducting core at 204°C.) Lupton, et al. [48], demonstrated that flame propagation and char zone as well as flame time increase with increasing cable temperature. They suggested that end-use temperature conditions be simulated in any evaluation of cable fire performance.

Reports of the development of improved polymers and cable assemblies are periodically published. New PVC cable systems [49,50] as well as other cross-linked polymers [51] and fluoropolymers [52] have been evaluated. Numerous test procedures are used to evaluate specific products. Maezawa, et al. [53], affixed cables to a heat-resistant board and exposed the reverse side of the board to a standard heating curve. Matsubara, et al. [54], employ a similar test procedure to evaluate a 0.6 KV and a 6.6 KV cable assembly. Kaufman and Laudreth [55] used a modified E 84 test to evaluate a flexible PVC cable jacket.

In 1972, the Electrical Research Association [56] reviewed the cable fire problem and concluded that a set of small-scale fire test methods that are correlated to full-scale fire performance is required by manufacturers of materials and cables to assess their progress in developing flame-resistant wires and cables. ERA determined that three aspects of a wire or cable relate to fire safety: First, the ease with which fire propagates through an installation; second, the production of smoke, corrosive, and toxic fumes; and, third, the integrity of the circuit. Few wire and cable fire tests measure circuit integrity. Circuit integrity has been a critical evaluation criterion for nuclear power plants [45,47]. Nuclear power plants require a minimum time to sequentially shut down in the event of an emergency. Control circuit integrity must be maintained throughout this process. The Nuclear Regulatory Commission has adopted test methods [22] that measure circuit integrity.

Circuit integrity during a fire exposure has also been the concern of transportation system designers [57]. In an effort to measure and rate electrical wires and cables for circuit integrity, recommendations [58] have been made to the Department of Transportation that IEEE 383 be modified and used to evaluate wires and cables for use in rapid transit systems. Circuit integrity is also of concern in central telephone stations due to the strategic importance of maintaining communications links in the event of an emergency.

5. FIRE SCENARIOS

Appropriate test methods are best determined after an analysis of incident data and the development of fire scenarios. A fire scenario is a sequence of critical events (e.g., component failure, ignition, growth, and spread of a fire) that can result in a fire loss. Fire scenarios are generally but not exclusively developed after an analysis of incident data. While currently available sources of incident data are incomplete for a detailed description of a fire scenario, approximate models can be developed.

The primary source of the following information on fire incidents in telephone exchanges was the National Fire Data Center of the U.S. Fire Administration. Additional information was obtained from a review of fire reports in various fire journals and from previously mentioned reviews of fire incidents in telephone related buildings.

5.1 Incident Data

The U.S. Fire Administration maintains the National Fire Incident Reporting System (NFIRS). NFIRS collects its information from numerous fire departments throughout the country. While not a statistical sampling, the data system contains information on various details of a fire's origin and growth. Data such as the point of origin, the type of materials and equipment involved, and the form of energy that caused the ignition are collected as well as the type of property and the number of deaths and injuries. The data reviewed in this report were obtained from NFIRS for calendar years 1976 through 1979.

A total of 189 telephone exchange fires were reported to NFIRS during this time period. These include central offices, telephone exchanges, communications cable sites with associated repeater and terminal facilities. The incidents can be divided into five categories, figure 1. It was found that nearly 41 percent of the fires occurred within a building. Trash fires accounted for 17 percent of the total incidents, while 24 percent involved materials located outside of a building.

The distribution of the incidents by space utilization of the area of fire origin is shown in figure 2. The data show that 35 percent of the fires occurred in electrical or electronic related facilities: 24 percent in electronic equipment rooms, and 12 percent in service facilities (i.e., transformer vaults, repair shops).

Figure 3 describes the distribution of telephone exchange fires by the type of equipment initially involved in the ignition. While 46 percent of the incidents did not involve equipment, 23 percent could be directly attributed to electronic or electrical equipment failures.

Figures 4 and 5 describe the extent of flame damage and of smoke damage, respectively. There were nine reported cases of smoke damage beyond the room of origin and six of flame damage. Generally, smoke damage extended far beyond the zone of damage caused by fire. In 54 percent of the reported cases, flame damage was limited to the object initially ignited. In 30 out

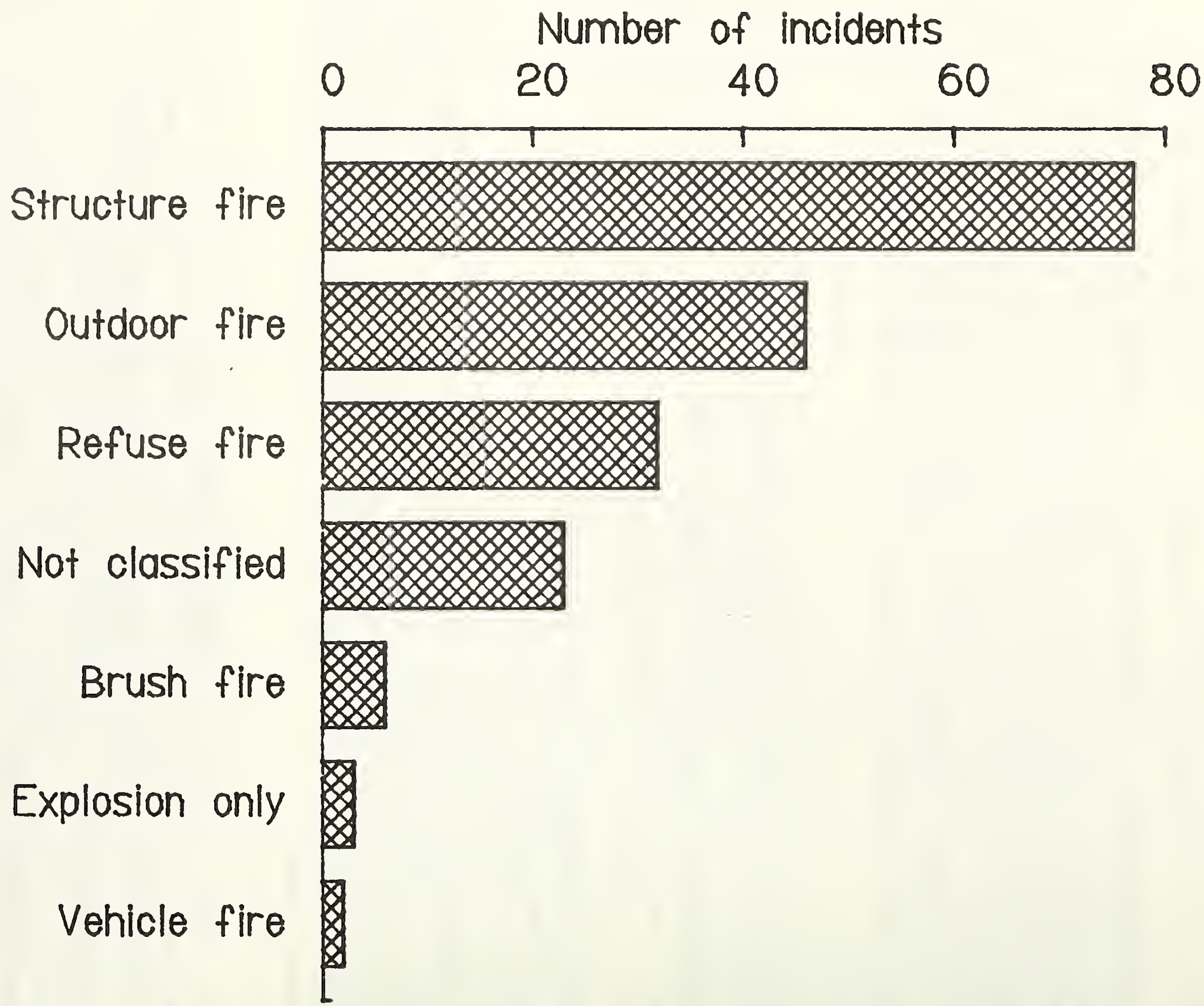

Figure 1 – NFIRS classification of telephone exchange fires

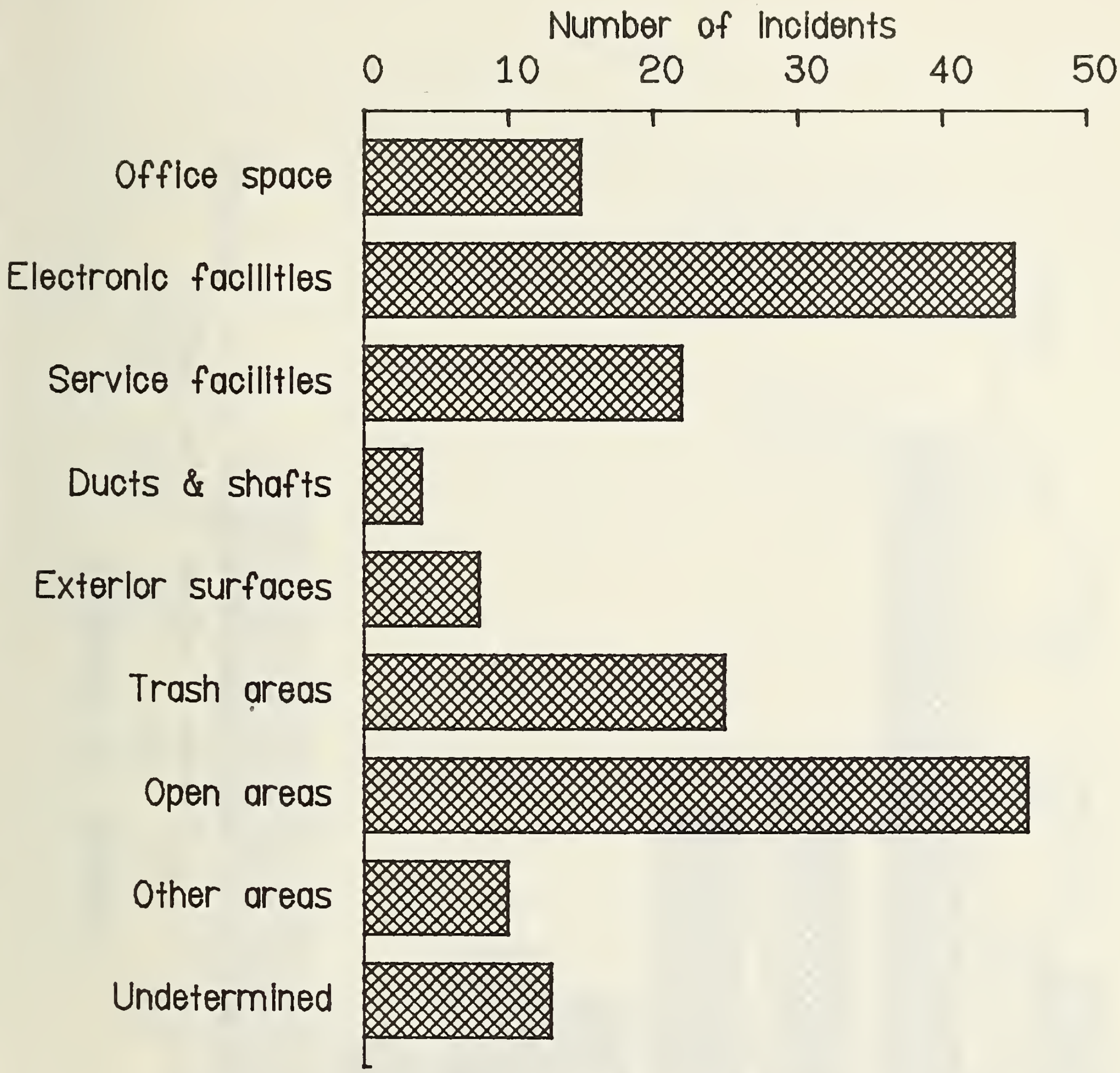

Figure 2 - Classification of telephone fires as reported in NFIRS by area of origin

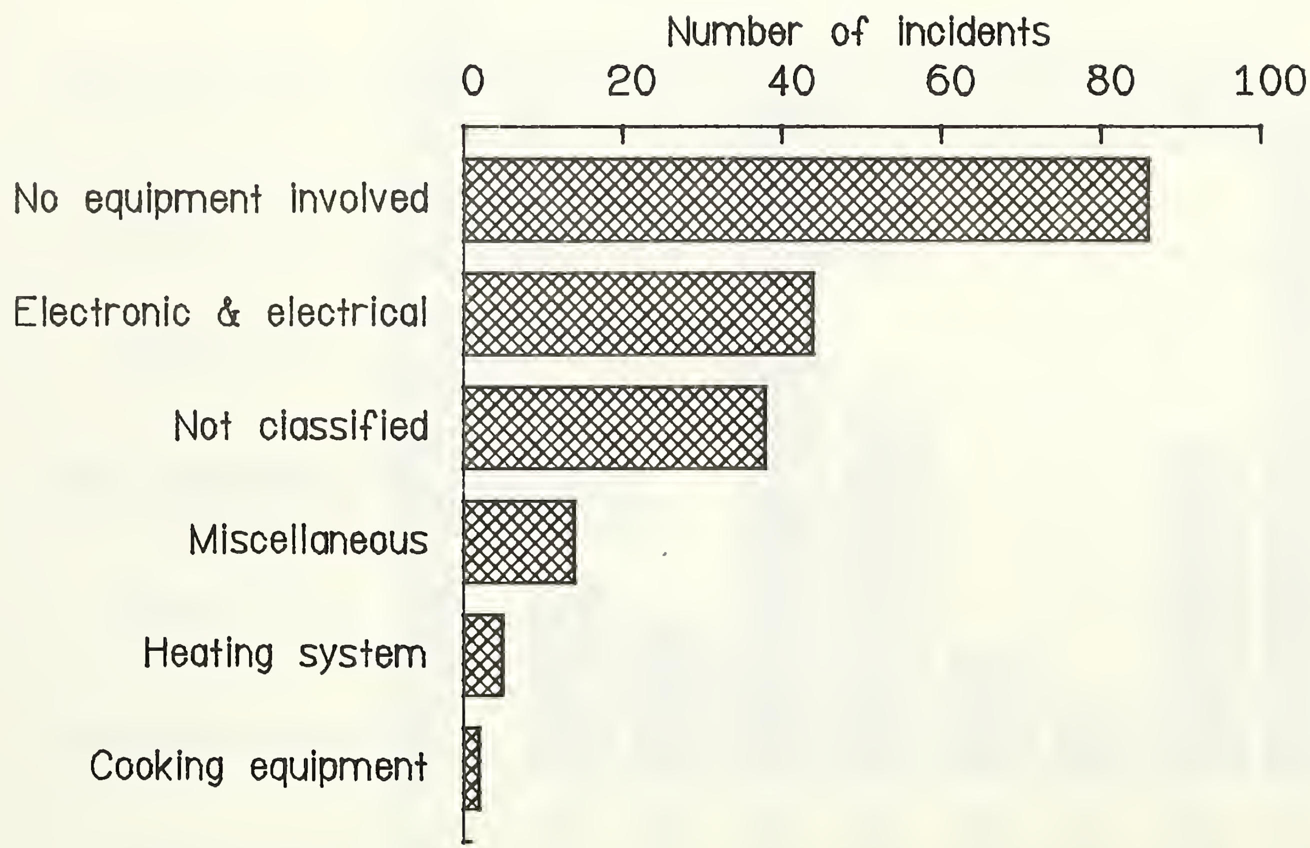

Figure 3 – Distribution of telephone exchange fires as reported to NFIRS by the equipment involved in the ignition

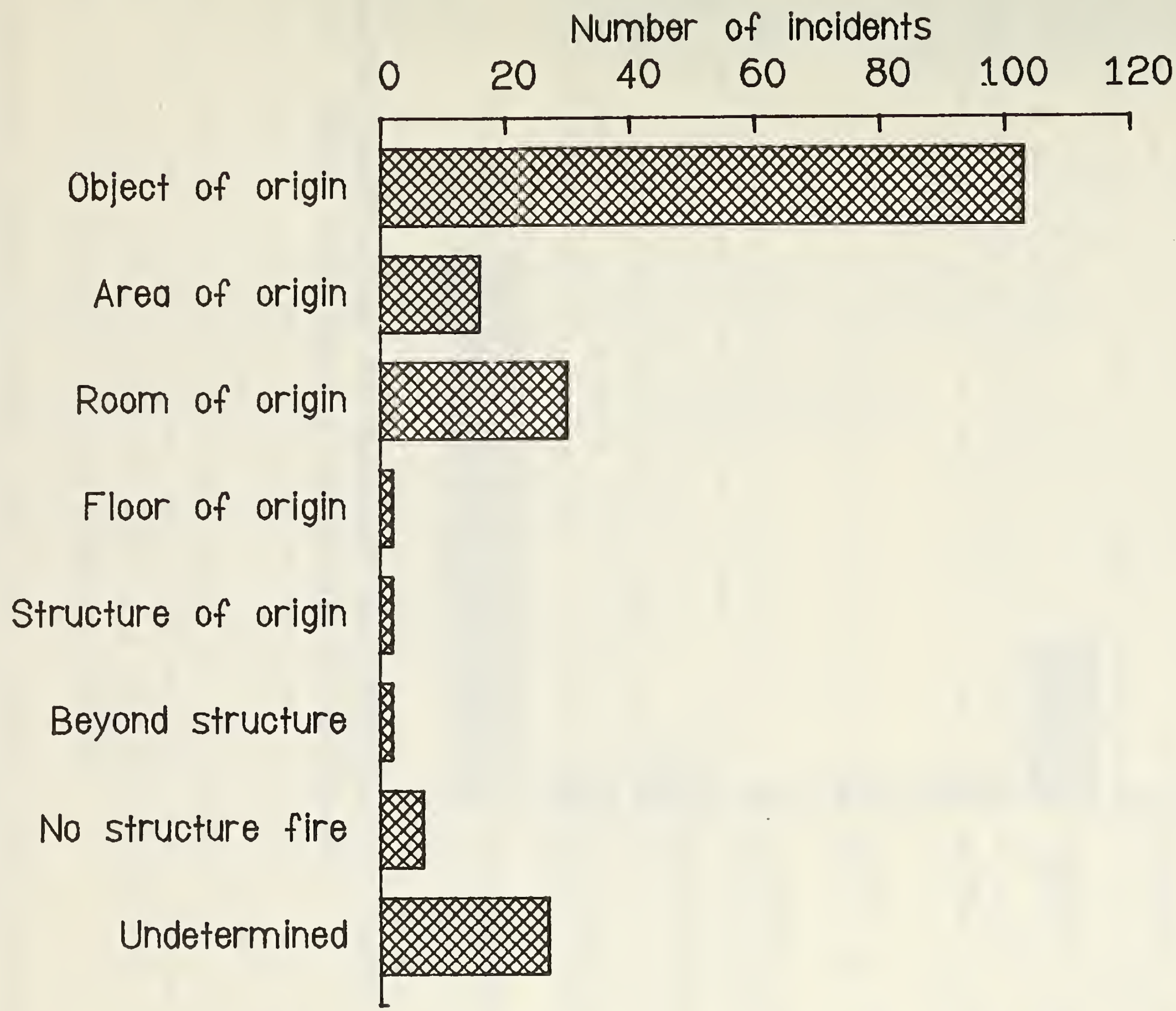

Figure 4 – Description of the extent of flame damage caused by telephone exchange fires as reported in NFIRS

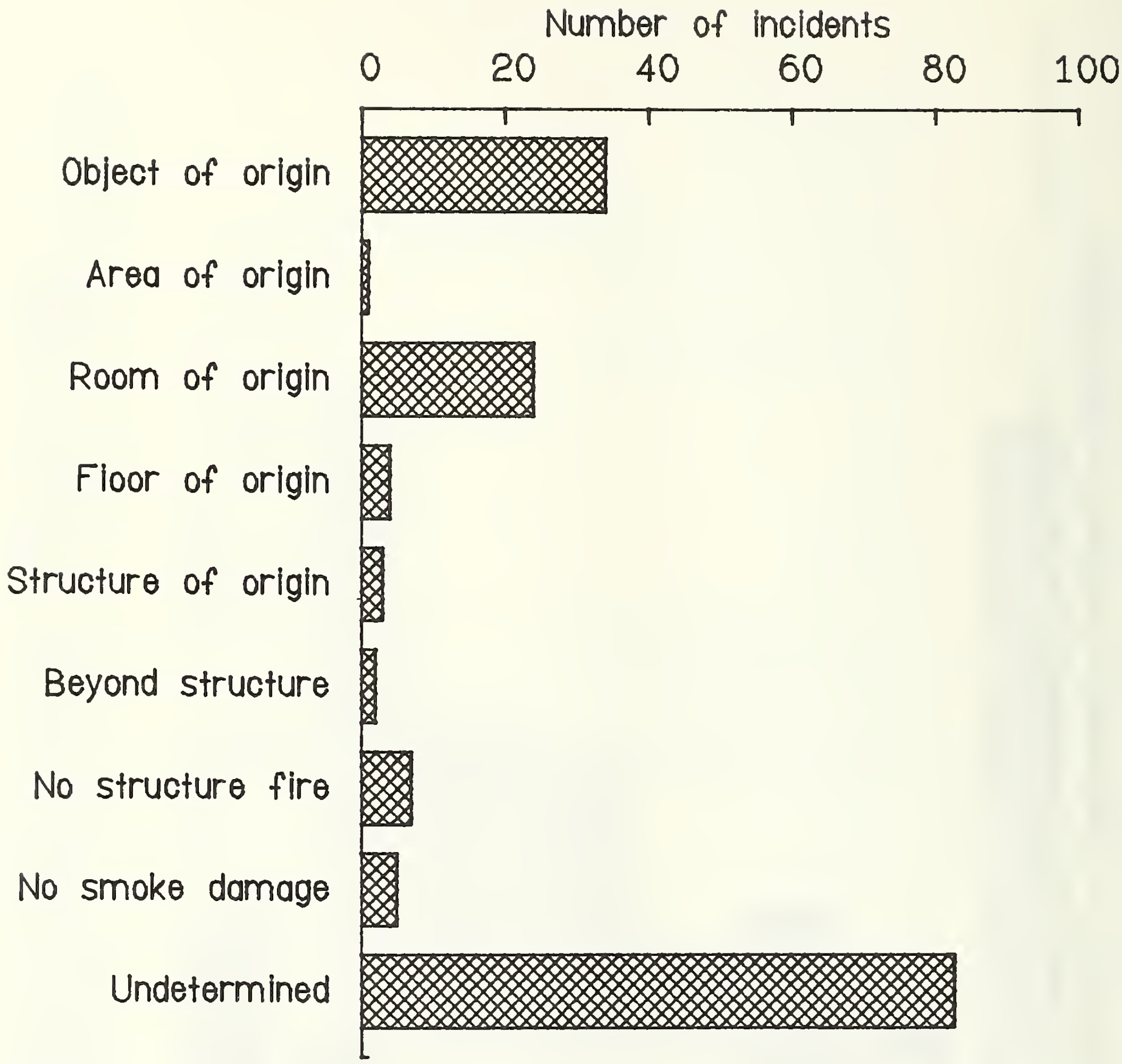

Figure 5 – Description of the extent of smoke damage caused by telephone exchange fires as reported in NFIRS

of 68 cases involving structure fires where smoke damage was reported, the damage extended beyond the initial item involved.

The 71 incidents occurring in electronic equipment rooms, service facilities, and ducts are analyzed in figures 6 through 8. Figure 6 is a breakdown of the incidents by the type of equipment involved in the ignition. Only eight reported incidents involved the electronic telecommunications equipment. Electrical distribution equipment accounted for 53 percent of the incidents. Lighting accounted for eight of these incidents. Two were caused by failing transformers and one was caused by a misplaced tarpaulin igniting from contact with a light bulb. The others appear to have been caused by overheating light fixtures. Figure 7 describes the form of heat of ignition and figure 8 shows the distribution of initial materials ignited. Thirty incidents were caused by electrical shorts or overloaded circuits. Electrical wire failures appear to be the major form of electrical failure representing 31 percent of all failures.

5.2 National Fire Protection Association

The Fire Record Department of the National Fire Protection Association (NFPA) publishes reports on selected groups of typical fires reported to them. These fire reports are descriptions of causes of fires and fire department responses. Since January 1960, five telephone exchange fires are described. While the data does not represent a statistical data base, it provides additional information that can be utilized in the development of a fire scenario.

One fire, occurring in Pusan, Korea [55], was caused by careless smoking and will not be discussed. The four remaining fire reports describe fires caused by equipment failures. Two fires [60,61] were caused by ignition of power supply cables. One fire [62] was caused by an electrical fault in an equipment control board and one [63] was the result of a short in a battery providing power to operate the telephone exchange. Because of the presence of a detection and suppression system, the battery failure caused only minor damage to the building and switching equipment. The other fires had flame propagation along cable ways that penetrated interior walls, floors, or ceilings. In one case, the ceiling was made of a combustible material. In other cases barrier penetrations were not completely sealed.

The 1975 telephone exchange fire in New York City [64] is an example of the dangers of an incomplete seal of a cableway penetration of a barrier. In this case, the fire originated in a basement cable vault. The fire spread

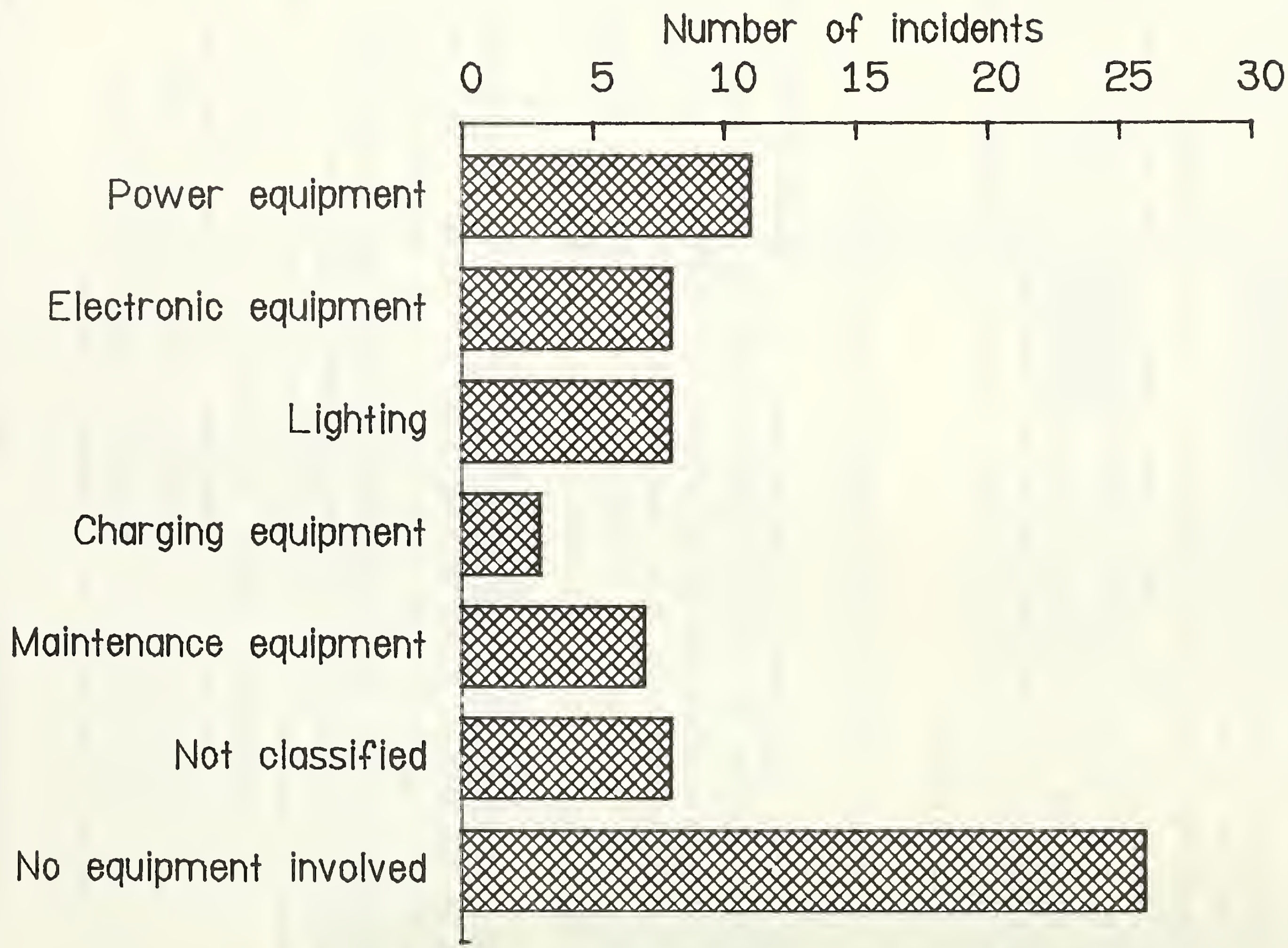

Figure 6 - Type of equipment failures in electronic rooms, service facilities, and ducts as reported by NFIRS

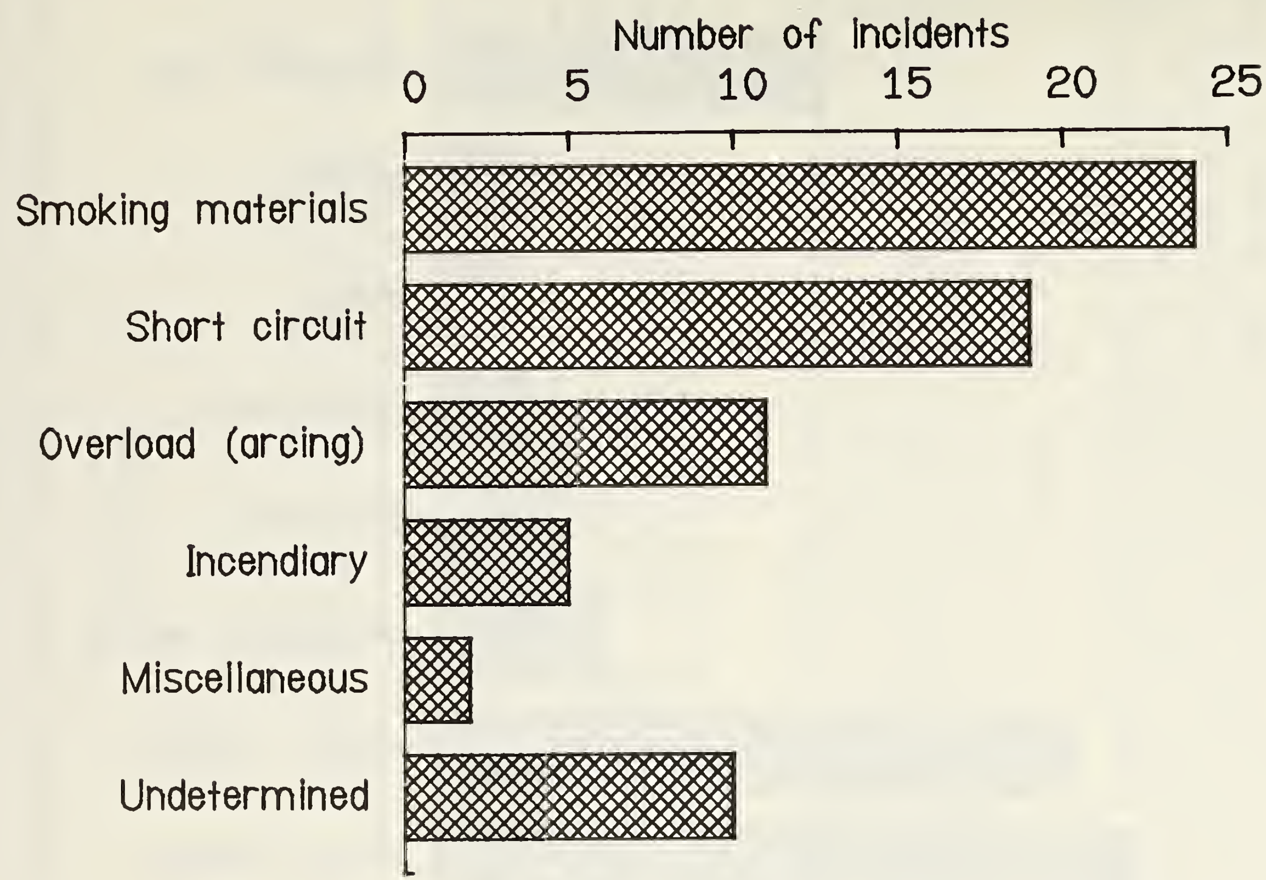

Figure 7 – NFIRS data on the form of energy release causing ignition in electronic and electrical facilities of telephone exchanges

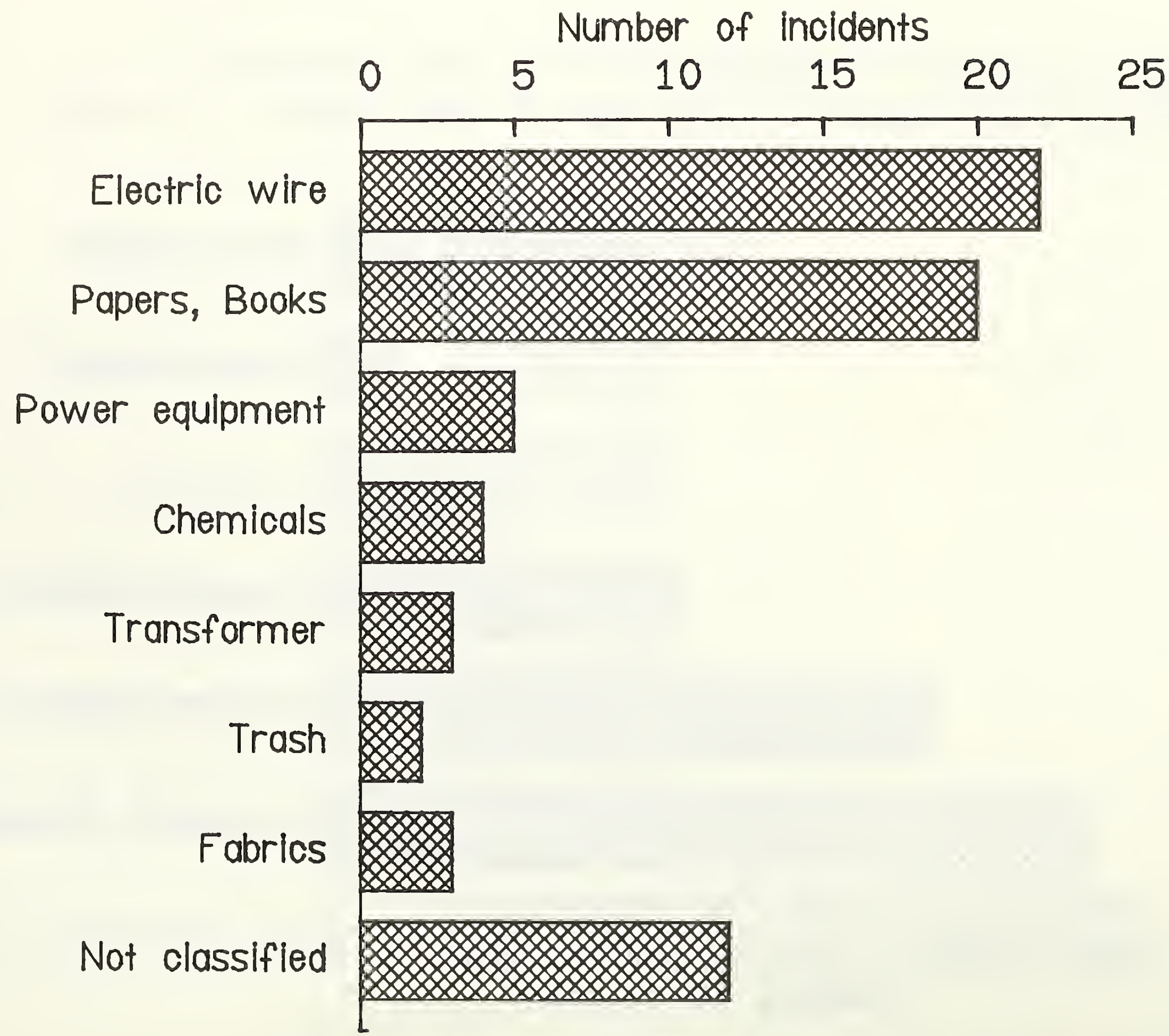

Figure 8 – NFIRS data on the form of material initially ignited in electrical and electronic facilities of telephone exchanges

to the first and second floors of the building by way of telephone cableways penetrating the floors.

A typical occurrence of an equipment failure took place at Colton, Oregon, in August 1979. The fire was most probably caused by an electronic component failure on one of the circuit boards. The flames extended across frames. The resulting smoke and heat virtually destroyed the telephone exchange. The major flame path was the rows of printed circuit boards and not the wires and cables. A similar type of circuit failure is reported by Harrison and Lewoc [65] to have occurred in a computer system at Goddard Space Flight Center. The fire had originated on a printed circuit board in an electronic clock. A carbon resistor on the board failed and, because of the close spacing of circuit boards, the fire propagated to several other cards. The fire was readily extinguished by personnel at the facility before excessive damage occurred.

5.3 Bell System Statistics

Eckler [66] analyzed 1500 fire reports occurring in Bell System buildings from 1971 through 1977. While the data as presented by Eckler cannot be used to determine the number of fires that occur in a given type of Bell System space, general information is available relating to fire frequency in telephone buildings.

In general, Eckler found that the frequency of fire occurrence increased with the number of people occupying a building. However, as the staff was decreased the cost of a fire increased apparently because of a delay in detecting the fire. The data show that the median damage of a fire in an unoccupied building is approximately 10 times as large as the median damage of a fire in an occupied building.

In analyzing the various methods people use to extinguish a fire, Eckler shows that in 58 percent of the fires the fire department is not even notified of a fire occurrence. These fires would, therefore, not be included in the NFIRS data base.

6. CONCLUSIONS

A review of applicable test methods, relevant literature, and incident data has been conducted. It has been shown that many test methods exist for measuring the flammability characteristics of polymers used in electrical applications. Test methods used to evaluate the fire performance of grouped (bunched) wire and cables have been limited to comparative flame propagation measurements except for IEEE 383, which can measure circuit integrity, and a modified ASTM E 84, which measures smoke density.

Large-scale tests of central office equipment have been limited to evaluations of fire propagation along wires and cables. The interaction of system components in a fire environment has not been reported.

A review of NFIRS fire incident data on telephone exchanges has shown that:

- A third of the fire incidents reported occurred in electrical or electronic related facilities;

- A major cause of fire incidents in electrical or electronic related facilities was the power distribution system in a building;

- Smoke related damage extended over a larger volume of space than fire related damage;

- Electrical wire failures appear to be the major form of electrical failure.

Based on Eckler's data, fire reports to NFIRS may underrepresent the extent of telecommunication equipment failures. These fires may be successfully extinguished by telephone personnel before extensive damage occurred in which case local fire departments are not notified.

The major path of flame spread from the source of ignition appears to be cableways.

A single test method to assess the suitability of materials intended for central office equipment does not exist. There appears to be appropriate test methods that with some modification could be used to measure critical fire properties. These results could be combined to reduce the likelihood of ignition and flame spread. A vertical self-extinguishing test may be suitable for the evaluation of printed circuit boards and back planes. Cables could be evaluated using IEEE 383 and barrier penetrations could be tested according to IEEE 634. Materials used in power branch circuit may also have to be evaluated to ensure that fire safety requirements which may be promulgated by REA for telecommunications equipment are not compromised. However, additional full-scale test verification would be necessary.

7. REFERENCES

[1] Bell System Purchase Products Specifications, New Jersey (1977).

[2] Standard Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index), D 2863, American Society for Testing and Materials, Philadelphia, Pennsylvania (1977).

[3] Hilado, C. J., Flammability Handbook for Plastics, Technomic Publishing Company, Incorporated, Westport, Connecticut (1974).

[4] Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C, E 136, American Society for Testing and Materials, Philadelphia, Pennsylvania (1979).

[5] Standard Test Method for Surface Burning Characteristics of Building Materials, E 84, American Society for Testing and Materials, Philadelphia, Pennsylvania (1979).

[6] Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, Underwriters Laboratories, Incorporated, Northbrook, Illinois (1980).

[7] National Material Advisory Board, Fire Safety Aspects of Polymeric Materials, Vol. 2, Test Methods, Specifications, and Standards, Technomic Publishing Company, Incorporated, Westport, Connecticut (1979).

[8] Guide for Room Fire Experiment, American Society for Testing and Materials, E 603, Philadelphia, Pennsylvania (1977).

[9] Maroni, W. F., Rigid Cellular Wall Insulations, Fire Journal, Vol. 67, No. 6 (1972).

[10] Williamson, R. B. and Baron, F. M., A Corner Fire Test to Simulate Residential Fires, Journal of Fire and Flammability, Vol. 4 (April 1973).

[11] Standard Method of Testing Rigid Sheet and Plate Materials Used for Electrical Insulation, D 229, American Society for Testing and Materials, Philadelphia, Pennsylvania (1977).

[12] Federal Test Method Standard 406, Method 2023, Plastics: Methods of Testing, U.S. General Services Administration, Washington, D.C. (1961).

[13] Polymeric Materials - Short Term Property Evaluations, UL 746A, Underwriters Laboratories, Incorporated, Northbrook, Illinois (1978).

[14] Standard Test for Ignition Properties of Plastics, D 1929, American Society for Testing and Materials, Philadelphia, Pennsylvania (1978).

[15] Kline, L. M., Burning, Arcing, Ignition, and Tracking of Plastics Used in Electrical Appliances, Underwriters Laboratories Research Bulletin, No. 55 (February 1964).

[16] Federal Test Method Standard 406, Method 4011, Plastics: Methods of Testing, U.S. General Services Administration, Washington, D.C. (1961).

[17] Standard Method of Test for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position, D 635, American Society for Testing and Materials, Philadelphia, Pennsylvania (1977).

[18] Federal Test Method Standard 406, Method 2021, Plastics: Methods of Testing, U.S. General Services Administration, Washington, D.C. (1961).

[19] Standard Method of Test for Rate of Burning and/or Extent and Time of Burning of Flexible Plastics in a Vertical Position, D 568, American Society for Testing and Materials, Philadelphia, Pennsylvania (1977).

[20] Federal Test Method Standard 406, Method 2022, Plastics: Methods of Testing, U.S. General Services Administration, Washington, D.C. (1961).

[21] Standard Method of Test for Rate of Burning and/or Extent and Time of Burning of Cellular Plastics Using a Specimen Supported by a Horizontal Screen, D 1692, American Society for Testing and Materials, Philadelphia, Pennsylvania (1976).

[22] IEEE Standard for Type Test of Class IE Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations, IEEE 383, Institute of Electrical and Electronics Engineers, Incorporated, New York (1974).

[23] Standard Method for Testing, Thermosetting Insulated and Jacketed Wire and Cable, D 470, American Society for Testing and Materials, Philadelphia, Pennsylvania (1975).

[24] Tests for Flame Resistance of Cables, Title 30 Part 18.64, Code of Federal Regulations, Washington, D.C. (1979).

[25] Standard for Rubber-Insulated Wires and Cables, UL 44, Underwriters Laboratories, Incorporated, Northbrook, Illinois (1977).

[26] Testing Methods for Plastic Insulated Wires and Cables, JIS C 3005, Japanese Standards Association, Japan (1977).

[27] Thermoplastic Insulated Wires, UL 83, Underwriters Laboratories, Incorporated, Northbrook, Illinois (1979).

[28] Specification for Flame-Retardant Characteristics of Electric Cables, BSI 4066, British Standards Institution, London, England (1969).

[29] Specification for Braided Travelling Cables for Electric and Hydraulic Lifts, BSI 6977, British Standards Institution, London, England (1969).

[30] Underwriters Laboratories, Incorporated, Report on Telephone Cable, Northbrook, Illinois (1978).

[31] IEEE Standard Cable Penetration Fire Stop Qualification Test, IEEE 634, Institute of Electrical and Electronic Engineers, Incorporated, New York (1978).

[32] Standard Test Method for Measuring the Smoke Generated by Solid Materials, NFPA 258, National Fire Codes, Vol. 10, National Fire Protection Association, Boston, Massachusetts (1977).

[33] Standard Test Method for Density of Smoke From the Burning or Decomposition of Plastics, D 2843, American Society for Testing and Materials, Philadelphia, Pennsylvania (1977).

[34] Miner, R. J., Flammability Tests and Smoke Generation, "Flammability and Safety," Society of Plastics Engineers, Incorporated, Regional Technical Conference, Newark Section, Newark, New Jersey (1971).

[35] Wiktorek, R. J., Technical Evaluation of Various Test Procedures as Applied to Materials for Computer Applications, Flammability and Safety Conference, Society of Plastics Engineers, Incorporated, Regional Technical Conference, Newark Section, Newark, New Jersey (1971).

[36] Rogers, G. J. and Evans, D. D., Characterization of Electrical Ignition Sources Within Television Receivers, Nat. Bur. Stand. (U.S.), Tech. Note 1109 (1975).

[37] Quigg, P. S. and Orals, D. L., Communication Cable "Poke Thru" Floor Fire Test, Building Standards, Vol. 46, No. 2 (1977).

[38] McGuire, J. H., Small-Scale Fire Tests of Walls Penetrated by Telephone Cables, Fire Technology, Vol. 11, No. 2 (1975).

[39] McGuire, J. H., Small-Scale Fire Tests of Six-Inch Wall Penetrated by Telephone Cables, National Research Council of Canada, No. 116 (1976).

[40] Kita, K., Suyama, N., and Kawabara, S., New Sealing Method on Cable in Telephone Office Building, CIB, Systems Approach to Fire Safety in Buildings, Proc., Vol. 2, Session 4, Japan (August 1979).

[41] Kruczek, F. W. and Cascio, C. R., The Cable Vault Goes Modern, Bell Laboratories Record (January 1978).

[42] Peverill, W. L., Engineering a Fireproof Test for Conductors, Insulation Circuits, Vol. 16, No. 8 (1970).

[43] Woolerton, G. R., The Use of Release Rate Tests to Evaluate Flammability of Communications Cable, J. Fire and Flammability, Vol. 9 (July 1978).

[44] Beyreis, J. R., Skjordahl, J. W., Kaufman, S., and Yocum, M. M., A Test Method for Measuring and Classifying the Flame Spread and Smoke Generating Characteristics of Communications Cable, Proceedings of the 25th International Wire and Cable Symposium, Cherry Hill, New Jersey (November 16-18, 1976).

[45] Klevan, J., MacDougall, E., and Hall, A., Fire Damage Data Analysis as Related to Current Testing Practices for Nuclear Power Applications, Brookhaven National Laboratory, BNL-NUREG 23364, Informal Report (October 1977).

[46] Clarke, R. K., An Analytical Model for Cable Tray Fires, Sandia Laboratories, SAND 75-0288 (September 1975).

[47] Klamerus, L. J., Cable Tray Fire Tests, IEEE Power Engineering Society, Winter Meeting, New York (February 4-9, 1979).

[48] Lupton, E. C., Tahlmore, C. D., and Obsasnik, J., Some Differences Noted in the Flammability of Wire Constructions Between Testing at Room Temperature and at Elevated Conductor Temperature, Proceedings of the 24th International Wire and Cable Symposium (AD-A017787) (November 18-20, 1975).

[49] Augustyn, E. J. and White, E. L., New High Temperature, Flame Resistant, Thermoplastic PVC Wire Insulations, Proceedings of the 21st International Wire and Cable Symposium, AD752908 (December 1972).

[50] Bilow, N. and Lehn, W. L., High Temperature Electrical Wire Insulation Development, Proceedings of the 21st International Wire and Cable Symposium, AD752908 (December 1972).

[51] Hildreth, N. and Brooks, J., EXAR: A Flame-Resistant, High Temperature, Cross-Linked Wire Insulation System, Proceedings of the 21st International Wire and Cable Symposium, AD752908 (December 1972).

[52] Reed, J. C. and Perkins, J. R., Tefzel ETFE Fluoropolymer: Temperature Rating and Functional Characterization, Proceedings of the 21st International Wire and Cable Symposium, AD752908 (December 1972).

[53] Maezawa, T., Murayama, V., and Yoshizawa, A., Heat Resistant Cables for Fire-Prevention Systems, Proceedings of the 24th International Wire and Cable Symposium (AD-A017787) (November 1975).

[54] Matsubara, H., Matsunaga, C., Inoue, A., and Yasuda, N., The Development of New Fireproof Wire and Cable, Proceedings of the 24th International Wire and Cable Symposium (AD-A017787) (November 1975).

[55] Kaufman, S. and Laudreth, C. A., Development of Improved Flame-Retardant Interior Wiring Cables, Proceedings of the 24th International Wire and Cable Symposium (AD-A017787) (November 1975).

[56] Electrical Research Association, Cables, and Fire, A Review of Some Recent Literature With Commentary, The Electrical Research Association (December 1972).

[57] Meyer, L. E., Taylor, A. M., and York, J. A., Electrical Insulation Fire Characteristics - Volume I: Flammability Tests, U.S. Department of Transportation, UMTA-MA-06-0025-79-1, I (December 1978).

[58] Taylor, A. M., Wire and Cable Insulation for Rapid Transit Systems, Am. Chem. Soc., National Symposium on Fire Safety of Polymeric Materials, Washington, D.C. (June 6-8, 1977).

[59] Telephone Exchange Fire, Pusan, Korea, March 18, 1968, Fire Journal, Vol. 62, No. 6, p. 60 (1968).

[60] Telephone Exchange Fire, Mebane, North Carolina, August 23, 1976, Fire Journal, Vol. 71, No. 1, p. 42 (1977).

[61] Telephone Exchange Fire, Marshfield, Massachusetts, October 21, 1979, Fire Journal, Vol. 74, No. 2, p. 21 (1980).

[62] Telephone Exchange Fire, Garland, Washington, December 3, 1968, Fire Journal, Vol. 63, No. 3, p. 53 (1969).

[63] Telephone Exchange Fire, Granda Hills, California, August 3, 1975, Fire Journal, Vol. 70, No. 5, p. 45 (1976).

[64] Lathrop, J. K., Telephone Exchange Fire, New York, New York, Fire Journal, Vol. 69. No. 4 (1975).

[65] Harrison, G. A. and Lewoc, D. G., Computer Fire and Resultant Circuit Card Fire Tests, Fire Journal, Vol. 63, No. 2 (1969).

[66] Eckler, A. R., A Statistical Analysis of Bell System Building Fires, 1971-1977, The Bell System Technical Journal, Vol. 57, No. 8 (1978).

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET *(See instructions)*	1. PUBLICATION OR REPORT NO. NBSIR 81-2261	2. Performing Organ. Report No.	3. Publication Date May 1981

4. TITLE AND SUBTITLE

REVIEW OF LITERATURE, APPLICABLE TEST METHODS, AND INCIDENT DATA FOR THE EVALUATION OF THE FIRE PERFORMANCE OF CENTRAL TELEPHONE OFFICE EQUIPMENT

5. AUTHOR(S)

Emil Braun

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

Final Report

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Rural Electrification Administration
U.S. Department of Agriculture
Washington, D.C. 20250

10. SUPPLEMENTARY NOTES

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

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

At the request of the Rural Electrification Administration, a program was initiated to evaluate the adequacy of current flammability specifications for electrical equipment used in telephone company central offices. The high reliance on telephone services for emergency communications necessitates that measures be considered to minimize the likelihood of fire related interruptions of service. This report provides a review of current test methods and specifications for central office equipment; a review of available fire test methods in various categories; a brief literature review of relevant fire research and fire testing of wiring, cables, and assemblies; and a review of fire incident data.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Central office equipment; electronic equipment; fire test methods; incident data; telecommunications; telephone exchanges.

13. AVAILABILITY

[XX] Unlimited
☐ For Official Distribution. Do Not Release to NTIS
☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
[XX] Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

40

15. Price

$6.50