UNITED STATES GOVERNMENT

Memorandum

U.S. CONSUMER PRODUCT
SAFETY COMMISSION
WASHINGTON, D.C. 20207

APR - 1 1988

TO : The Commission
THROUGH : Sadye E. Dunn, Office of the Secretary
THROUGH : James V. Lacy, Office of General Counsel
THROUGH : Leonard DeFiore, Executive Director
THROUGH : Douglas L. Noble, Director, Office of Program Management and Budget
THROUGH : Carl W. Blechschmidt, Program Manager, Office of Program Management and Budget

FROM : Linda L. Glatz, Project Manager, Electrical Hazards Program, OPMB LG

SUBJECT : Residential Electrical Distribution System Fires

Attached for your information is the final report on "Residential Electrical Distribution System Fires." This report, the result of the Fire Investigation Project in the Electrical Hazards Program, provides estimates of fires associated with residential electrical distribution systems and a detailed discussion of identified causes. It describes 149 investigations performed by local fire services in sixteen cities over the periods 1980-1981 and 1984-1985.

It was estimated that 56,300 residential fires involving the electrical distribution system, attended by the fire services, occurred annually during the period 1980-1985. These fires resulted in an estimated 410 deaths and 1,500 injuries annually. In addition, an estimated 890,000 residential fires involving the electrical distribution system, not attended by the fire services, occurred in 1984.

The conclusions of this report indicate that new initiatives will be needed to effect significant reduction of these residential electrical fires. The majority of fires studied involved one or more serious violations of the National Electrical Code. Typically, no electrical inspection had been made for several years. The report recommends several possible activities involving state and local authorities to address the sources of most fires reported in the study. The Electrical Hazards Program plans to submit a FY 1990 project to address these fires.

Two current Electrical Hazards Program projects focus on products, appliance cords and receptacles, that were involved in many of these fires. Both projects, however, are directed at improving voluntary standards for new products rather than replacing or identifying hazards involving older products that are already installed.

CPSA 6 (b)(1) Cleared lob 4/1/88
✓ No Mfrs/PrvtLblrs or Products Identified
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Comments Processed.

NOTE: This document has not been reviewed or accepted by the Commission.
Initial HK Date 4-1-88

This Electrical Distribution System Fires Report, along with other related project reports, will be provided to industry groups interested in electrical fire safety and will be used to support recommendations for standards changes and other action.

Pursuant to Section 5 of the Commission General Policies of March 18, 1987, the Executive Director indicates that he is reasonably unaware of any relevant and significant minority or dissenting views on this issue except for those contained in this package, if any.

82p.

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MEMORANDUM

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SAFETY COMMISSION
WASHINGTON,D.C. 20207

FEB 1 1988

TO : Carl Blechschmidt, EX-PB
Through: Dr. Robert D. Verhalen, AED, Epidemiology
Through: William W. Walton, AED, Engineering Sciences
FROM : Linda Smith, EPHA
FROM : Dennis McCoskrie, ESES

SUBJECT: Residential Electrical Distribution System Fires

This memorandum transmits a joint Epidemiology and Engineering Sciences report evaluating causes of fires in the residential electrical distribution system. It indicates that many fires are caused by lack of adherence to the National Electrical Code and suggests some actions that CPSC might take to reduce these fires.

Attachment

bcc:
Dr. Robert D. Verhalen
Robert E. Frye
Charles A. Nicholls
L. Smith
D. McCoskrie
W. Walton
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EPHA:L. Smith:rah:12/23/87

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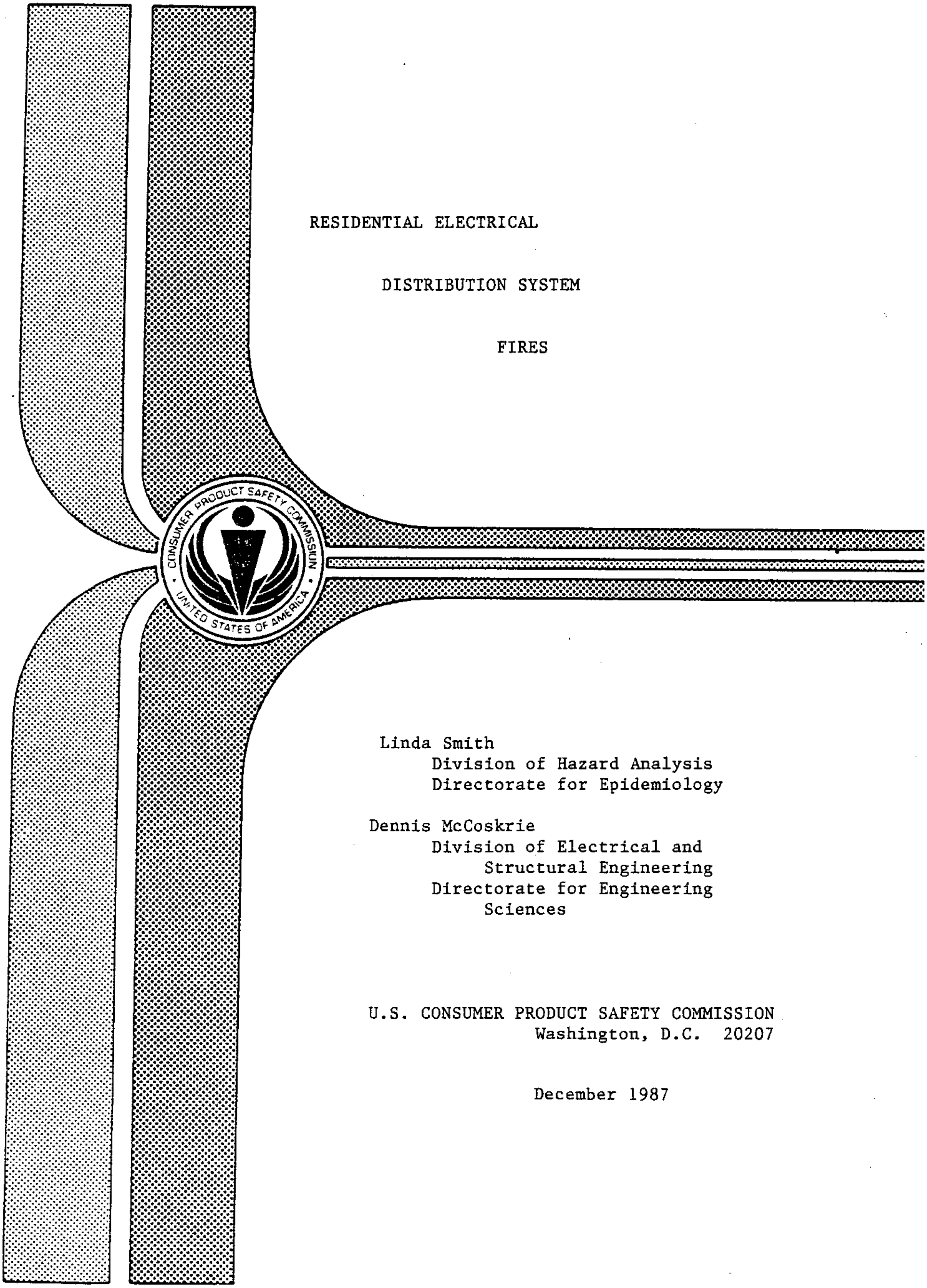

RESIDENTIAL ELECTRICAL
DISTRIBUTION SYSTEM
FIRES

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U.S. CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

December 1987

Acknowledgement

The authors acknowledge the essential contributions of the many firefighters, fire departments, and electrical inspectors who devoted their time and talents to completion of the fire investigations discussed in this report. Their participation in this fire research project, while also responding to many other competing demands, is greatly appreciated.

To summarize, these fire investigations indicated that CPSC may want to increase its efforts to develop and distribute informational materials to guide consumers in updating their electrical systems. Increased effectiveness might be achieved by seeking the active involvement of state and local jurisdictions as well as other federal agencies. The majority of the fires in this group probably would have been prevented if the installations and modifications had conformed to the current National Electrical Code. It is important, therefore, that CPSC continue its involvement in maintaining the effectiveness of the Code as the foundation for further efforts in preventing electrical fires.

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Introduction

A 1980 study prepared for the U.S. Fire Administration by Jerry Banks and Ronald L. Rardin1/ included the following observations on the U.S. fire problem:

> Based on 1975-1978 data, the U.S. had one of the highest fire death rates in the world--two to four times that of most European countries for which comparable data existed.2/ The U.S. also had one of the highest rates of fire per capita.
>
> In general, 75 percent of the fire deaths occurred in residential fires. (This was still true in the U.S. in 1985.)
>
> Compared to other countries studied, the U.S. had a larger component of residential compared to non-residential fires--about 25 percent residential. (Residential fires still accounted for 25 percent of all U.S. fires in 1985.)
>
> Banks and Rardin concluded that
>
> "... in almost every category (e.g. heating, electrical distribution, appliances, open flame, etc) the per capita rate of residential fire incidence in the U.S. and other developed countries will only be reduced if the elements of residential fire can be restricted."

Fires in residential electrical distribution systems are an important contributor to this problem. We estimate that electrical distribution system fires accounted for 8 percent of all residential fires in the U.S. in 1985. They resulted in 8 percent of the residential fire deaths, 7 percent of the injuries and 16 percent of property losses.

1/ Jerry Banks and Ronald L. Rardin, "Selected International Comparisons of Fire Loss", Georgia Institute of Technology, December 1980.

2/ This comparative difference occurred in more recent years also, in a 1981-1984 comparison of fire rates presented in "International Fire Losses, 1981-1984, Fire Protection, September 1986, pp. 21-24.

Executive Summary

This report presents an evaluation of the scope and characteristics of the fire problem associated with residential electrical distribution systems. Major elements of systems include distribution panels, branch circuits, receptacle outlets, light fixtures, and cords and plugs.

The report is divided into two main sections. The first presents national estimates of fires attended by the fire service. These estimates are based on data collected by the U.S. Fire Administration and the National Fire Protection Association. This section also includes estimates of fires not attended by the fire service based on a 1984 national survey. Both sets of estimates identify the involvement of specific electrical components.

Major findings based on these data follow:

o An estimated 56,300 fires that involved residential electrical distribution systems occurred annually during the years 1980-1985. This estimate includes only fires attended by the fire service.

o These fires resulted in an estimated 410 deaths and 1,500 injuries annually, reflecting rates of 7.3 deaths and 26.6 injuries per 1,000 fires occurring. For comparison residential fires overall had about 32 injuries and 8 deaths per 1,000 fires in 1985.

o These fires also resulted in $489.6 million in property loss annually, an average $8,700 per fire.

o The components most often involved in attended fires were installed wiring, cords/plugs, switches/receptacle outlets, light fixtures, lamps/light bulbs, and overcurrent protection devices in that order.

o In addition to the attended fires, an estimated 890,000 residential fires that involved electrical distribution systems occurred in 1984 but were not attended by the fire service. These fires were not reported to have resulted in any deaths or injuries and, on the whole, caused minor property loss.

o Among unattended fires, appliance cord involvement was reported most often followed by installed wiring, fuses/ circuit breakers, extension cords, light fixtures, and switches/receptacles.

The second half of the report discusses the results of 149 CPSC-sponsored investigations of fires that started in residential electrical distribution systems. These investigations followed 3 days of specialized training given to fire service personnel in the investigation of such fires and included considerable detail. The fires occurred in 16 cities over the periods 1980-1981 and 1984-1985 and included only fires that supported a conclusion of electrical fire origin.

Characteristics of these 149 investigated fires follow:

o Fires appeared to occur at the highest rates among dwellings over 40 years old.

o Branch circuit wiring fires occurred most often (50 fires), followed by fires in receptacle outlets (26 fires), extension cords (17 fires), and light fixtures (13 fires).

o Fires in service entrance equipment and branch circuit wiring predominantly occurred in dwellings over 20 years old.

o Fires at splices, connections, and terminations were reported in 58 of 149 fires. They occurred among all equipment groups except the one transformer fire.

o Improper alterations that adversely affected the system were involved in 55 fires and were the contributing factor found to be involved most frequently.

o Other contributing factors were: improper initial installation (30 fires), deterioration due to ageing and environmental factors (25 fires), improper use (23 fires), inadequate electrical capacity (22 fires), and faulty products (17 fires). Some fires involved more than one of these factors.

Overall, the presence of an inadequate electrical system and consumer actions to modify or accommodate that system were involved in some manner in 103 of the 149 fires.

When researchers try to pinpoint the causes of these fires they quickly confront a multitude of reports citing merely "failure of electrical wiring", a phrase which could apply to any of the components that make up this system--service entrance wiring, meter boxes, distribution panels, branch circuits, receptacle outlets, light fixtures and extension cords. (See Appendix A for a Glossary of specialized terms).

For several years, CPSC sponsored investigative efforts to identify the causes of these fires. We involved the U.S. Fire Administration in training selected fire departments to conduct detailed investigations of fires ignited by components of the residential electrical distribution system. These investigations subsequently were analyzed by the National Bureau of Standards in their report "Analysis of Electrical Fire Investigations in Ten Cities," Final Report, December 1983. To augment this effort, CPSC sponsored a second phase of data collection in additional cities in 1984-1985.

This report is based on the results of these two efforts. Section I presents a general picture of the scope of the fire problem in the electrical distribution system as exhibited by national fire statistics. Section II identifies the characteristics of the systems involved in the fires investigated and evaluates them for underlying contributing factors. It is essential to understand that the investigated fires are not part of a randomly drawn probability sample, either in terms of the cities selected for participation or the fires selected for investigation by a fire department. Nevertheless, we believe that they provide valuable information about commonly involved causal mechanisms.

I. National Estimates of Fire Losses

A. Fires Attended by the Fire Service

We estimate that over the six year period 1980 - 1985, the fire service attended an average of 56,300 residential structural fires annually that originated in some part of the electrical distribution system (Table 1). These fires resulted in an estimated 410 civilian deaths, 1,500 civilian injuries, and $489.6 million in property loss each year.1/ Deaths occurred at a rate of 7.3 per 1,000 fires, injuries at a rate of 26.6 per 1,000 fires. An estimated 58 percent of those injured were hospitalized.

The number of fires occurring has followed a general downward trend, from 64,600 fires in 1980 to 52,200 in 1985--a decrease of 19 percent since 1980.2/ To a large extent, this change tracks an 18 percent decrease in the total number of residential structural fires attended by the fires service. This is consistent with the finding that fires in the electric distribution system constituted a very stable percentage of all residential structural fires over these years -- 9 percent in 1980, 8 percent each year in 1981-1985. These fires also accounted for about 8 percent of all residential civilian deaths and injuries each year.

They contributed a greater percentage of all residential structural property loss, about 15 percent annually. For 1985, these fires resulted in an average loss of $11,900 per fire compared to $6,100 per fire for all residential structural fires. See Appendix D.

1/ These estimates were derived by applying proportions observed in National Fire Incident Reporting System (NFIRS) data from the U.S. Fire Administration, to aggregate national estimates from a survey conducted by the National Fire Protection Association (NFPA). See Appendix B. It is important to note that NFPA believes that their estimates of civilian injuries (and therefore any estimates based on them) are on the low side because many are not reported to the fire service. Firefighter casualties are not included in these estimates.

2/ Estimates of fires, deaths, and injuries by year are included in Appendix B.

Fixed wiring contributed the largest number of fires, nearly one of every three fires (20,500 of 56,300 annually).[3] Fixed wiring also contributed the greatest number of deaths, (160 annually). These fires had the highest average property loss when the component (equipment) causing the fire could be singled out ($10,200 per fire). It may be that the hidden location of these fires within the wall contributed to late recognition and, therefore, greater damage.

Cord and plug fires, i.e., extension cords and appliance cords, were involved in about 10,600 fires annually, accounting for about one of every five electrical system fires.[4] Although they were involved in fewer fires, they accounted for the highest death and injury rates per fire. They resulted in 12.3 deaths and 44.3 injuries per 1,000 fires compared to 7.3 deaths and 26.6 injuries per 1,000 fires for the system as a whole. Resulting property loss also was high, $10,000 per fire.

The group of switches/outlets and light fixtures were involved in about equal number of fires, 6,600 [5] and 6,500 respectively. Fires related to lamps/light bulbs and overcurrent protection devices occurred less frequently, about 3,900 and 3,300 annual fires respectively.[6]

3/ This group consisted mainly of the branch circuit wiring, but also included service entrance cable and wiring and service drop wire.

4/ Based on a special CPSC data collection for 1985, we estimated that about half of the attended cord and plug fires that occurred in 1985 involved extension cords and the other half involved appliance cords, about 5,000 each. Appendix B provides detail of this analysis.

5/ Based on the 1985 special study we estimated that about 80 percent of the switch/outlet fires in 1985 involved receptacle outlets and 20 percent involved switches with additional fires coded in other equipment codes. (5,400 receptacle outlet fires and 1,300 switch fires in 1985).

6/ Based on the 1985 special study, we estimated that about 40 percent of the overcurrent protection device fires involved fuses and 60 percent involved circuit breakers (an estimated 1,300 fuse fires and 2,000 circuit breaker fires in 1985).

Table 1

Estimated Annual Losses from Fires Attended by the Fire Service Involving Residential Electrical Distribution Systems, by Component, 1980-1985

	Estimated Fires		Estimated Deaths		Estimated Injuries		Estimated Loss	
mponent	Annual Average	%	Annual Average	Rate Per 1,000 Fires	Annual Average	Rate Per 1,000 Fires	Annual Average	$ Loss Per Fire
							($ mill)	
TOTAL	56,300	100	410	7.3	1,500	26.6	489.6	8,700
xed Wiring	20,500	36	160	7.8	410	20.0	209.7	10,200
rds, Plugs 1/	10,600	19	130	12.3	470	44.3	106.5	10,000
itches, Outlets	6,600	12	30	4.5	130	19.7	36.0	5,500
ght Fixtures	6,500	12	30	4.6	160	24.6	44.9	6,900
mps, Light Bulbs	3,900	7	20	5.1	140	35.9	22.0	5,600
ercurrent rotection	3,300	6	20	6.1	60	18.2	21.8	6,600
ter Boxes	800	1	*		10	12.5	5.8	7,200
ansformers	600	1	*		20	33.3	5.2	8,700
her	1,800	3	*		30	16.7	12.9	7,200
known	1,700	3	20	11.8	70	41.2	24.8	14,600

Includes extension cords and appliance cords.

stimates round to less than 10 deaths annually.

timates were derived by applying proportions observed in National Fire Incident Reporting System data FIRS) from the U.S. Fire Administration, to aggregate national estimates from a survey conducted by e National Fire Protection Association (NFPA).

urce: Consumer Product Safety Commission/EPHA

B. Fires Not Attended by the Fire Service

In addition to fires attended by the fire service, a 1984 survey sponsored by CPSC indicated that during a one year period there were 890,000 fires involving electrical distribution systems that were not attended by the fire service.[7] (A fire was defined as an incident that resulted in flames or smoke.) No injuries or deaths were reported for these fires. They resulted in generally small amounts of property damage. Sixty-eight percent were said to have caused property damage of $100 or less, two percent reported property damage between $100 and $1,000. Seventeen percent reported no property damage. The remainder did not provide information on property loss. Table 2 presents fire estimates by component.

The rank order of components reported were different than in the attended fires. Among attended fires, installed (fixed) wiring was reported most often and comprised 36 percent of all electrical distribution system fires. In the unreported fires, installed wiring ranked second, after appliance cords, and constituted about 12 percent of these fires.

As shown in Table 3, an estimated 5 percent of all electrical distribution system fires were attended by the fire service.[8] An estimated 15 percent of the fires involving installed wiring were attended by the fire service, the highest percentage of attended fires of any component group. This is consistent with the hypothesis that these fires were more often detected at later stages of progression and, therefore, on the whole more serious once ignited. The group of switches and outlets also had a higher than average percentage of fires attended by the fire service (11 percent).

The number of appliance cord and extension cord fires relative to each other appeared to be quite different in the attended and unattended fires. Data on attended fires indicated that fires originating with appliance cords and extension cords occurred in about equal numbers. Data on unattended fires indicated that appliance cord fires occurred about 4 times as often as extension cord fires.

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[7] "1984 National Sample Survey of Unreported Residential Fires," Audits and Surveys-Government Research Division, prepared under contract for the U.S. Consumer Product Safety Commission, June 13, 1985.

[8] The 1984 survey estimated that, overall, about 4 percent of residential fires were attended by the fire service.

Table 2

Estimated Residential Electrical Distribution System Fires Not Attended by the Fire Service, by Component, 1984 1/

Component	Number of Fires	Percent
TOTAL	890,000	100.0
Appliance Cords	371,000	41.7
Installed Wiring	105,000	11.8
Fuses, Circuit Breakers	94,000	10.6
Extension Cords	90,000	10.1
Light Fixtures	73,000	8.2
Switches, Receptacles	51,000	5.7
Other	80,000	9.0
Don't Know, Refused	26,000	2.9

1/ "1984 National Sample Survey of Unreported, Residential Fires", Audits & Surveys Government Research Division, prepared under contract for U.S. Consumer Product Safety Commission, June 13, 1985.

Source: Consumer Product Safety Commission/EPHA

Table 3
Estimated Fires Involving the Residential Electrical Distribution System, Attended and Unattended by The Fire Service, by Component, 1984

COMPONENT	TOTAL No.	TOTAL %	ATTENDED[1] No.	ATTENDED[1] %	UNATTENDED[2] No.	UNATTENDED[2] %
Total	940,900[3]	100	50,900[3]	5	890,000	95
Installed(fixed) Wiring	124,100	100	19,100	15	105,000	85
Appliance Cords	376,000	100	5,000	1	371,000	99
Extension Cords	95,000	100	5,000	5	90,000	95
Fuses, Circuit Breakers	97,200	100	3,200	3	94,000	97
Light Fixtures	78,800	100	5,800	7	73,000	93
Switches, Receptacles	57,200	100	6,200	11	51,000	89
Other	86,600	100	6,600	8	80,000	92
Unknown	26,900	100	900	3	26,000	97

1) Estimates are based on National Fire Incident Reporting System (NFIRS) data, extrapolated to National Fire Protection Association estimates of national fire losses.

2) "1984 National Sample Survey of Unreported, Residential Fires," Audits & Surveys, prepared under contract to the U.S. Consumer Product Safety Commission, June 13, 1985

3) Fires do not add to the total due to substitution of adjusted 1985 estimates for appliance cords and extension cords.

Source: Consumer Product Safety Commission/EPHA

II. Investigated Fire Incidents

The remainder of this report describes the characteristics of 149 fires originating in components of residential electrical distribution systems. These fires were investigated by local fire services in 16 cities after a preparatory 3 day training course on electrical systems that was sponsored by CPSC. These fire investigations were conducted during two time periods, 1980-1981 and 1984-1985. Appendix C includes a list of the cities participating in each time period along with a further description of the training and data collection phase of the project. The results of the first phase of data collection were given in a 1983 report that covered a broad range of system characteristics and findings.[9] This CPSC report will update findings of most interest and focus on underlying factors that contributed to these fires.

It is important to recognize that individual case selection was made by the local fire departments. This selection involved a number of factors, including whether fire investigators were available when needed, a matter of timing within the department. The effect of these factors on proportions of specific case scenarios in the study was not clear.

A. Comparison with NFIRS

Fixed Property Use

Ninety-four percent of the 149 investigated fires in this project occurred in single family homes (including row houses and townhouses), and 6 percent occurred in apartments. In comparison, NFIRS-reported fires had a distribution of 86 percent one or two family dwellings (including duplexes and some types of row houses and townhouses), 11 percent apartments and 2 percent hotel or other structures. Fewer apartments among the investigated fires and more single family dwellings may reflect the study case selection criteria which excluded all hotels and allowed inclusion of apartments only if they had their own meter boxes.

9/ John R. Hall, Jr. et al., "Analysis of Electrical Fire Investigations in Ten Cities", U.S. Department of Commerce, Center for Fire Research, December 1983.

Area of Origin

Table 4 presents a comparison of the area of origin distributions of the 149 investigated fires with the NFIRS-reported fires. Of the investigated fires, roughly half occurred in functional areas (within rooms), and half occurred in structural areas such as concealed wall or floor spaces. Of those occurring within functional areas, bedroom fires were reported most frequently, followed by living room, closet, and kitchen fires in that order. The ranking of NFIRS fires occurring in functional areas was similar. Bedroom fires were reported most frequently, followed by living room, kitchen, and closet fires in that order.

Rankings within type of structural area were somewhat different. In the investigated fires, wallspace and attic fires were reported most frequently. In the NFIRS fires, attic fires and basement/crawl space (substructure) fires were reported most often.

Property Loss

A comparison of flame damage indicated that the investigated fires in general resulted in lower amounts of property damage than did NFIRS fires (Table 5). Flame damage was confined to the object of origin in 39 percent of the investigated fires but only 30 percent of the NFIRS fires. At the other extreme, damage extended beyond the room of origin in 15 percent of the investigated fires but 29 percent of the NFIRS fires. Using another measure of damage, the investigated fires had a mean estimated loss of about $6,400 while the NFIRS fires had a mean estimated loss of $11,900.[10]

It is believed that this difference stemmed primarily from the requirements of the study which, in effect, excluded fires with damage so extensive that physical evidence was no longer available. It is not known whether this resulted in a different distribution of fire causes than would have been found if every fire had been included.

Components Involved in Ignition

As shown in Table 6, based on rankings, the distributions of components (equipment involved in these fires) were very similar in the two data bases. Fires originating in fixed wiring appeared most frequently in each. Also, fires in cords/plugs, switches/outlets, and light fixtures occurred roughly in the same order in both data bases.

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[10] Based on 1985 NFIRS data.

Table 4
Comparative Distribution Of Area Of Origin In Residential Electrical Distribution System Fires, NFIRS versus CPSC

Area of Origin	NFIRS[1]			CPSC [2]		
	No.	%	Rank	No.	%	Rank
TOTAL	13,275	100		149	100%	
Functional	8,618	65		74	50	
Bedroom	2,590		1	21		1
Living room	1,632		2	13		2
Kitchen	1,494		3	11		4
Closet,Storage	682		4	12		3
Garage	529		5	5		5
Bathroom	475		6	-		9
Laundry	453		7	4		6
Hall	232		8	3		7
Dining Room	221		9	2		8
Other	310			3		
Structural	3,767	28		75	50	
Attic	974		1	23		2
Basement/Crawl Space	804		2	4		5
Wall Space	651		3	27		1
Exterior Wall Surfaces	531		4	11		3
Between Floors	344		5	10		4
Exterior Roof	143		6	-		
Other	320					
Other	890	7				

[1] National Fire Incident Reporting System, U.S. Fire Administration, 1980-1985 mean

[2] Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a controlled sample. The results, therefore, must be viewed with caution.

Source: Consumer Product Safety Commission/EPHA

Table 5
Comparative Distributions Of Extent Of Flame Damage in Residential Electrical Distribution System Fires, NFIRS Versus CPSC

Extent of Flame Damage	NFIRS 1/ n=13,204 Percent Total	 Cumulative	CPSC 2/ n=149 Percent Total	 Cumulative
TOTAL	100	--	100	--
Confined to Object of Origin	30	30	39	39
Confined to Part of Room of Origin	22	52	34	73
Confined to Room of Origin	18	70	10	83
Confined to Floor of Origin	6	76	7	90
Confined to Structure of Origin	21	97	8	98
Extended Beyond Structure	2	99	-	98
Other	1	100	2	100

1) National Fire Incident Reporting System, U.S. Fire Administration, 1980-1985 mean

2) Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a controlled sample. The results, therefore, must be viewed with caution.

Source: Consumer Product Safety Commission/EPHA

Table 6
Comparative Distributions of Components Involved in Residential Electrical Distribution System Fires, NFIRS versus CPSC

	NFIRS 1/ n=13,444		CPSC 2/ n=149	
Component	Percent	Rank	Percent	Rank
Total	100*		100	
Fixed Wiring	38	1	42	1
Cord, Plug	19	2	19	2.5
Switch, Outlet	12	3.5	19	2.5
Light Fixtures	12	3.5	11	4
Lamp, Light Bulb	7	5	2	6
Overcurrent Protection	6	6	5	5
Transformer	1	7.5	1	7.5
Meter box	1	7.5	1	7.5
Other	3	-	-	-

* Column does not add to total due to rounding.

1/ National Fire Incident Reporting System, U.S. Fire Administration, 1980-1985 mean.

2/ CPSC special study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a controlled sample. The results, therefore must be viewed with caution.

Source: Consumer Product Safety Commission/EPHA

B. Dwelling/System Characteristics

A comparison of ages of the 149 dwellings involved in fires with the dwelling populations in the study cities indicated that the fire rate increased with dwelling age. The index-ratio of fires to housing units shown in Table 7 indicates the relative fire rate for particular housing age groups compared to the overall fire rate. The rate of fire in dwellings over 40 years old was 1 1/2 times that of dwellings 21-40 years old and about 3 times that of dwellings 11-20 years old.

Older dwellings, however, also exhibited different electrical system characteristics than newer dwellings. For example, circuit breakers protected all the study dwellings that were 20 years old or less (Table 8).[11] In comparison, circuit breakers protected about half the dwellings that were over 20 years old. Fuses protected the remainder. Similarly, none of the dwellings 20 years old or newer had knob and tube or armored cable wiring systems (Table 9). Knob and tube was common among those over 40 years old.

C. Component Involved In Ignition

Table 10 presents the distribution of electrical system components involved by age of the dwelling. Excluding those of unknown age, the fires involving service equipment and branch circuit wiring occurred almost exclusively in dwellings over 20 years old--18 of 19 service equipment fires (95 percent) and 44 of 48 branch circuit fires (92 percent). Among fires in receptacle outlets and switches, 20 of 28 fires (71 percent) occurred in dwellings over 20 years old.

[11] Those incidents citing protection only by a power company fuse involved either situations where the panel box (and the overcurrent protection) was bypassed or where the fire occurred between the panel box and the street lines.

Table 7
Ratio of Residential Electrical Distribution System Fires to Housing Population, by Age of Dwelling

Age of Dwelling	Percentage of All 1/ Dwellings in Study Areas	Percentage of Investigated 2/ Electrical Distribution System Fires	Index-Ratio 3/ Of Fires To Dwellings
Total	100.0	100.0	1.00
≤ 10 Years	19.8	6.4	.32
11-20 Years	17.3	8.5	.49
21-40 Years	28.7	29.1	1.01
Over 40 Years	34.2	56.0	1.64

1/ Distributions of occupied housing units are based on 1980 Census figures. For the cities included in Phase II (1984), the distributions have been adjusted to include housing units built between 1980 and 1984 based on a survey of 1986 occupied housing units by Donnelly Demographics. Excludes cities that reported only one study fire during a time period.

2/ Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a controlled sample. The results, therefore, must be viewed with caution.

This distribution is based on 141 fires. It excludes 5 fires where age of dwelling was unknown and 3 fires in cities where only one fire was submitted in a study period. The latter were excluded on the theory that it would not be appropriate to include all housing units in an area to accomodate one fire.

3/ This index indicates how much higher or lower than the overall fire rate was the fire rate for a particular building age group.

Source: Consumer Product Safety Commission/EPHA

Table 8
Type of Overcurrent Protection Device Protecting the Involved Branch Circuit in Residential Electrical Distribution System Fires, by Age of Dwelling

Type Overcurrent Protection Device	Total	Age Of Dwelling in Years				
		≤10	11-20	21-40	Over 40	Unk.
TOTAL	149	9	12	43	80	5
Circuit Breakers	75	8	12	21	33	1
Edison Base Fuses	50	--	--	17	32	1
Type S Fuses	4	--	--	1	2	1
Cartridge Fuses	1	--	--	1	--	--
Power Company Fuses	14	1	--	2	10	1
Unknown	5	--	--	1	3	1

Source: Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore, must be viewed with caution.

Consumer Product Safety Commission/EPHA

Table 9
Wiring Method of Involved Branch Circuit in Residential Electrical Distribution System Fires, by Age of Dwelling

Wiring Method		Age Of Dwelling in Years				
	Total	≤10	11-20	21-40	Over 40	Unk.
Total	149	9	12	43	80	5
Non-Metallic Sheathed Cable	60	8	8	21	23	--
Knob & Tube	26	--	--	3	23	--
Armored Cable	9	--	--	3	6	--
Electric Metallic Tubing	8	--	2	4	2	--
Combinations	10	--	--	2	8	--
Other	18	--	2	6	7	3
Unknown	18	1	--	4	11	2

Source: Consumer Product Safety Commission special study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore, must be viewed with caution.

Consumer Product Safety Commission/EPHA

Table 10
Electrical Component Involved in Residential Electrical Distribution System Fires, by Age of Dwelling

Component	Total	≤10	11-20	21-40	Over 40
		Age Of Dwelling In Years			
TOTAL	144 1/	9	12	43	80
Service Equipment	19	1	--	7	11
Branch Circuit Wiring	48	1	3	19	25
Cords/Plugs	29	2	2	7	18
Receptacles/Switches	28	2	6	7	13
Lamps/Light Fixtures	19	3	1	3	12
Low Voltage Transformer	1	--	--	--	1

1/ Includes only fires where age of the dwelling was known.

Source: Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore must be viewed with caution.

Consumer Product Safety Commission/EPHA

As will be discussed later, the occurrence of some fires was related to recent alteration to the system that involved a component newer than the dwelling. Even in such cases, however, the interaction with the remaining, older, electrical system generally was of critical importance.

Table 11 presents a more detailed description of the types of components involved in the origination of these fires. Among fires originating in branch circuit wiring, non-metallic sheathed cable was reported most frequently. Adequate information was not available to evaluate whether this distribution might indicate a greater failure rate for certain types of wiring. Among the other equipment groups, receptacle outlets accounted for 26 of 29 fires in the receptacle outlet/switch group. Incandescent lighting fixtures accounted for 12 of 19 fires in the lighting fixture/lamp group.

In order to conserve scarce resources during the second phase of data collection we discouraged reporting of fires involving extension cords. (Extension cord fires are being addressed separately by CPSC.) Therefore, few fires were added to this group during the second phase.

Table 11
Specific Components Involved in Residential Electrical Distribution System Fires

Component	Number
TOTAL	149
Service Equipment	21
Distribution Panel	8
Utility Supply Conductors	7
Service Entrance Cable	5
Meter	1
Branch Circuit Wiring	50
Non-Metallic Sheathed Cable	26
Knob and Tube	10
Armored Cable	6
Wire in Metallic Conduit	2
Other	6
Receptacle Outlets and Switches	29
Receptacle Outlet	26
Wall - Type Switch	2
Thermostat	1
Cords and Plugs	29
Extension Cords	17
Cords on Lamps & Appliances	9
Christmas Tree Wiring	1
Other	2
Lighting Fixture, Lamp	19
Incandescent Fixture	12
Lampholder	3
Portable Lamp	3
Fluorescent Fixture	1
Low Voltage Transformer	1
Transformer	1

Source: CPSC study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore, must be viewed with caution.

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Failure Modes, Components, and System Areas

Table 12 contains the reported frequencies of the various types of failures observed during the analyses of these fires. Tracing through the residential electrical system, starting from the power company connection, this section identifies the system components that initiated ignition and explains some of the particular mechanisms, as well as circumstances and history that may have been involved.

During the history of residential electrical services, a technical vocabulary has been established that may not be familiar to many readers. This vocabulary is not particularly self-explanatory. A Glossary section has been added as Appendix A of this report,to provide definitions for specialized terms that may be used in this and other parts of this report.

a. Service Equipment

Accounting for 21 fires, this category includes the electric lines and other equipment that convey and distribute power from the electric utility local distribution to the individual branch circuits of the residence.

Starting at the utility lines that provide the 120/240-V electric power needed for residential service, the **utility supply conductors** (service drop) typically carry electrical power to the "weather head", or some other supporting structure where the **service entrance conductors** or **service entrance cable** (SEC) are connected to the conductors of the service drop.

Typical fire situations involve a **ground fault,** i. e., contact between one of the "live" (ungrounded) service drop conductors and some grounded metal part of the residence. The damage can be extensive, because the only effective overcurrent protection for these conductors is the power utility equipment, which is rated to protect the power company distribution system, rather than individual service drops.

The electrical wires that connect the service drop to the distribution system of an individual residential occupancy --**service entrance cable**, or, in older homes, **service entrance conductors** -- must be heavy-guage wire rated to carry the current load of the complete residential system. Electrical faults that involve the service entrance conductors also can be very destructive because the fault current is only limited by the utility equipment.

A prominent characteristic of component failures in the **service-**

Table 12
Failure Modes Involved in Residential Electrical Distribution System Fires, by Component

Component	Number
Total	149
Service Equipment	21
Ground Fault (Water Deteriorated Insulation)	8
Mechanical Damage or Improper Installation	4
Gutter Touching Bare S.E. Conductors	2
Loose Connection	1
Equipment Overload	1
Miscellaneous Failures at Distribution Box	5
Branch Circuit Wiring	50
Mechanical Damage/Improper Installation	15
Poor or Loose Splice	11
Ground Fault	6
Use of Improper Wiring in Circuit	3
Knob and Tube Encapsulated	3
Miscellaneous Overload	6
Failure of Twist-On Connector	1
Unknown	5
Receptacle Outlets and Switches	29
Loose or Poor Connection	17
Mechanical Damage	3
Overloaded	1
Failure of Neutral Connector	1
Malfunction of Switch	1
Miscellaneous	2
Unknown	4
Cords and Plugs	29
Mechanical Damage/Poor Splice	10
Overloaded Extension Cord	7
Overloaded Plug	2
Damaged plug	2
Miscellaneous - plug	3
Miscellaneous - cord	4
Unknown	1
Lighting Fixtures and Lamps	19
Loose or Poor Connection	7
Combustibles Too Close	7
Overlamped	3
Switch Failure	1
Miscellaneous	1
Transformer	1
Improperly installed	1

Source: Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore, must be viewed with caution.

Consumer Product Safety Commission/EPHA

equipment area is the apparent suddenness of failure after years or months of seemingly satisfactory service. Failure modes such as friction wear of SEC insulation by the edge of aluminum siding or the gradual loosening of the connecting clamps for the SEC on the distribution panel usually are not observed until the final increment of failure produces heavy ground-fault currents, arcing, and fire. This delayed action type of failure is typical also of some branch-circuit component failures such as the overdriven staple finally interconnecting neutral and "hot" conductors of plastic-jacketed cable after years of gradual deterioration of the insulation under the staple.

Service entrance cables may be exposed to **mechanical damage** caused by **improper installation** or by impact or friction during service life, because of their exposed locations in some residences. This can lead to "short-circuits" to ground through gutters or metal siding or to internal "shorting" between the cable conductors. Moisture that penetrates the cable through breaks in the outer covering can contribute to **water deteriorated insulation** external to the cable conductors and between them. Exposure to severe weather conditions, including sunlight, can also contribute to deterioration and breakdown of the SEC insulation.

The **distribution panel** or service panelboard or service box, is the equipment that interconnects the electric utility system to the residential branch circuits. The panelboard should be fully enclosed by metal and the enclosure should be grounded.

One variety of problem experienced with distribution panels is associated with the extensive use of aluminum conductors in SEC cables. Because the thermal expansion of aluminum differs from that of other materials (steel, brass) commonly used in the service panel clamp connections to the service-entrance conductors, there is a tendency for the connection to become loose as the panel responds to temperature and power load variations. This is particularly apt to happen if the connection was not very carefully secured initially. A loosened connection can lead to corrosion, contact resistance and severe overheating, even melting, to the point that the mechanical connector presents a fire hazard. Deteriorated insulation could result in the live parts contacting the panel cover or some other grounded metal part to create a "short-circuit" to ground. Several examples of this kind of service distribution panel fire are found in this group of fire incidents.

Distribution panels, particularly older versions, were misused in many of the residences in these reports so as to contribute to ignition of fires elsewhere in the electrical system. In homes where the fusepanel is fitted for the original Edison-base plug fuses, the fuse protection can be defeated by overfusing the circuits. This is possible because the fuses are mechanically interchangeable without regard to the current rating of the fuse. A branch circuit that should be protected against current levels greater than 15 amperes may be exposed to currents as great as 25 or 30 amperes, because higher-rated fuses have been substituted in the panel. Usually this occurs because constant overloading of the branch circuits had resulted in frequent blowing of the 15-ampere fuses and loss of service on that circuit. The extreme degree of this misuse is the insertion of a copper penny under the fuse, which essentially leaves the branch circuit unprotected. In some installations there are "main" fuses between the service connections and the busses that will provide backup protection at levels such as 60 or 100 amperes.

Several other varieties of misuse were observed at or near the service box or panel in these fire reports. Only one branch circuit is supposed to be connected to one branch-overcurrent protector. There were cases in which two or more branch wires were secured under the same screw terminal -- in one case an aluminum wire and a copper wire had been combined under the same terminal and caused overheating of the contact. In other instances, additional branch circuits were connected to service panel busses without any overcurrent protection in that branch or to service entrance conductors on the utility side of the meter (thus bypassing both the overcurrent protection and the power company meter).

b. Branch Circuit Wiring

Branch circuit wiring is the system of electrical conductors that connects the receptacle outlets, switches, lighting fixtures and directly wired appliances in the residence to the branch-circuit overcurrent protection devices of the distribution panel. The causes of the 50 fires attributed to the several varieties of branch circuit wiring are discussed below. In older homes it is not unusual to find two or more varieties interconnected in the system.

Most often found to be involved in electrical fires was **non-metallic-sheathed cable** (NM), which employs a fabric or plastic jacket to bind and protect the individual insulated branch-circuit conductors.

Some of the problems found to have occurred in NM wiring were initiated by **improper installation.** Typically, the final failure occurred in months or years after the installation was made. In some instances, additional stresses such as overloading contributed to the final failure; in others, only the original misapplication was involved.

Mechanical damage of the insulation in places where it had been injured by overdriven metal staples or misplaced hammer blows led to overheating caused by high-impedance "short-circuit" currents between the cable conductors. In other cases, installation of

NM cable in contact with vibrating metal ducts or fan housings resulted in **ground faults** from the branch-circuit conductor to a grounded metal edge or surface. In time, rubbing of the insulation by the vibrating metal part wore through the insulating material. Other instances were found where sharp bending or kinking of the wire before or during installation created weaknesses in the wire insulation or in the metal conductor that later caused overheating and fire.

In some older installations, **overloading** of the branch wiring was made possible by overfusing of an Edison-base fuse panel. Long-term continued overloading of electrical cable causes overheating and gradual deterioration of the electrical and mechanical properties of the wire insulation. As the electrical insulation fails, leakage currents between the conductors in the cable produce even greater overheating that can result in failure of the cable and ignition at some point. In other cases, cable failure and ignition did not occur until after the addition of thermal insulation over the overloaded conductors. This traps the heat generated by overloading and leakage current in the cable, so as to produce excessively high temperatures of the cable, which was originally rated for operation in "free air". Home additions and remodelling caused other damage to NM, as, for instance, when a nail driven through new panelling penetrated a hidden branch circuit cable.

The oldest type of branch-circuit wiring found in homes in this group of fire reports is **knob and tube** wiring, which employs individual conductors without any protective cover over the wire insulation, for branch-circuit distribution

Overfusing and **overloading** contributed to several knob-and-tube branch circuit failures that caused fires. Typically, homes more than forty years old, and which had not received upgrading of the electrical system to provide greater capacity, had unsafe extensions of the wiring connected to the original knob-and-tube network. That the extensions were unsafe was not obvious to most householders. Wire conductors incorporated in knob-and-tube systems are rated to carry greater currents than the same gauge wire in an NM or BX cable (because knob-and-tube conductors are run as single wires and, as a result, can dissipate heat more efficiently than a conductor in a two- or three-conductor cable). Extensions of the original knob-and-tube wiring by means of BX or NM cables and subsequent defeating of the overcurrent protection made it possible to overload the knob-and-tube conductors to cause overheating and fire. There were also instances where **encapsulation**, thermal insulation of **knob-and-tube** wiring and/or enclosure of the wiring during structural remodelling of the home contributed to overheating and ignition.

Some examples were found where **poor or loose splices** were made by occupants of the home, to existing knob-and-tube wiring, in order to provide electricity in areas beyond the original wiring. The splices were poorly executed and caused resistive overheating when heavy electrical demand was connected to the extension circuit. Connections were made without either soldering of the splice or use of a twist-on connector and without any insulation of the splice or protective enclosure in a junction box.

The type of branch-circuit wiring most often used to supersede knob-and-tube was **armored cable** -- commonly called "BX", a trademark that came to be used as a generic name for this material. It consists of insulated conductors, and sometimes a bare bonding strip of copper or aluminum, enclosed in a flexible metal enclosure (tube).

Among the fire incidents discussed here are examples of **ground faults in armored cable** that caused overheating and ignition but did not actuate the overcurrent protection on the branch circuit. The fire safety protection provided by overcurrent limiting is only effective if the circuit from the "hot" conductor back to the system ground through the neutral line or the cable armor is low enough in resistance to permit current flow that exceeds the overcurrent limit. If this does not happen, because of a high resistance fault, or resistance in the grounding system, the fault current can still cause heating that leads to ignition.

There were one or two incidents where the connection between the neutral and earth-ground at the service entrance was inadvertently opened in such a way that substantial currents were passed through the cable armor to other household equipment that was grounded. The resultant overheating of the armor ignited combustible materials in contact with the cable. There were a few reports, also, of overheating faults between a conductor and the armor jacket, after the branch circuit cable had been functioning without incident for a number of years. No full explanation was determined for these failures, but deterioration of the insulation from long-term overloading may have contributed to them.

One or two fire-incident failures involved other forms of **wire in metallic conduit,** such as electrical metallic tubing (EMT) and flexible conduit. A typical example was arc damage between the flexible conduit and one conductor, after severe overloading of the circuit had damaged the wire insulation.

c. Receptacles, Outlets, and Switches

Among the 29 fires attributed to this group of electrical system components, the great majority, 26, involved **receptacle outlets** as the apparent source of fires in these reports. The most common failure mechanism associated with the receptacle was found to be overheating resulting from **loose or poor connections** to the terminals of the receptacle, or between the receptacle contacts and the mating plug.

Many fire incidents that involved obvious overheating of receptacle outlets also provided evidence of overheating of the mating plug. In some cases, the problem seems to have been a loose fit between the plug blades and the receptacle contacts, so that substantial current conduction through the loose contact caused resistive heating to the point of igniting nearby materials. The basic cause can be non-standard sizing of the metal parts, wear, distortion of the plug and blades by **mechanical damage**, or breakdown of the plastic body of the receptacle by arcing or carbon tracking. In most cases where substantial ignition at the receptacle has occurred, it is very difficult to determine which component overheated first.

Several reports refer to **poor connections** involving aluminum wire attached to receptacle outlets. These connections tend to loosen because of the thermal and mechanical properties of aluminum and then experience additional overheating from contact resistance of the corrosion products that can build up between aluminum wire and receptacle fittings of brass or steel.

In other instances, it appeared that **loose connections** had become a problem when copper conductors had not been secured properly when the receptacle was installed. Continued overheating from high loading continued to cause deterioration of the contact and overheating that caused ignition.

Only one fire report in this group cites **overloaded receptacle** as the failure mode responsible for the fire. Considering the numbers of lights and appliances plugged into some of the failing receptacles,it seems likely that overloading contributed to overheating and deterioration of other receptacles, even if the fire investigation found that the receptacle was stated not to be overloaded at the time of ignition.

d. Cords and Plugs

Connecting devices that convey electricity from outlet receptacle or other a-c receptacles to lights, appliances, etc. accounted for 29 of the fires. **Cords and plugs** include **extension cords** (identified as "cord sets" in the pertinent Underwriters Laboratories standard) and **cords on lamps and appliances** ("power supply cords" in the UL standard).

Many of the largest category of cord failures involved **mechanical damage**, usually caused, at least in part, by misuse of the cords. **Extension cords** were run in stairways and hallways, pinched in doorways, nailed to walls and moldings, and otherwise misapplied in ways that crushed and scuffed the insulation. **Cords on appliances and lamps** experienced similar misuse. The results were that the wire conductors were able to establish enough electrical current between them to cause severe overheating and ignition, but not enough to activate the overcurrent protection fuse or circuit breaker to open the supply circuit.

Most **poor splices** referred to in many of these fire reports were splices that never should have been connected in the first place. **Extension cords** had the plug end cut off and the conductors separated with the insulation stripped off the wire ends. These cords then were attached to existing permanent wiring, such as knob-and-tube or NM by means of open splices. The stranded wire of the extension cord was wrapped around the solid wire of the branch circuit without soldering the connection or using any kind of pressure device, such as a twist-on connector, to secure the splice. Some of these splices were left bare, others were taped.

These splices were not mechanically secure to begin with and tended to overheat while conducting current, so that the splices tended to loosen further and allow increasing resistance to develop at the electrical connection. This process may have caused overheating to the point of ignition, in some cases. In others, overloading of the extension cord, burial of the splices in thermal insulation, or encapsulation of the splices in a hollow wall may have accelerated the process.

Overloaded extension cords contributed to a significant number of fires. The descriptions provided in the reports indicate that most, if not all, of the cords involved were the #18 AWG light indoor cords that constituted the majority of indoor cords sold for many years. The established ampacity of these cords was 10 amperes, so that they were not protected by the most prevalent 15- and 20-ampere limits of common household branch circuits.

In many homes where these fires occurred, even greater overloads of 10-ampere cords could occur, because 25- or 30-ampere fuses had been substituted for fuses of the correct ratings. Apparently, the current ratings of the extension cords were not considered, because combinations of lights and appliances were found plugged into the three outlets of cords that could combine to demand much more current than the cord's rating. To make matters worse, some cords were buried in combustible materials that inhibited the transfer of heat from the overloaded cord, as well as providing fuel for the ignition.

The incidents cited here as **overloaded plugs** refer to separate household devices that can contribute to overloading circuits and which tend to become overloaded when users fail to determine and observe their ratings. One device cited in these reports is a light-socket adapter that is usually rated to transfer a total of 660 watts, of which 60 would be assigned to a 60-watt bulb in its lamp socket. (660 watts is approximately equivalent to a current rating of 5.5 amperes; 60 watts, 0.5 amperes.) Instances were reported where much larger total electrical loads were plugged into the two sockets of the adapter so as to cause severe overheating of the adapter and the light fixture where it was installed.

e. Lighting Fixtures and Lamps

Of the 19 fires associated with lighting devices, 12 involved **incandescent fixtures,** permanently mounted lighting devices fitted with incandescent lamb bulbs. The most common problems in these fixture fires were **loose and poor connections**, which seemed to have been caused by poor workmanship both in original installations and in modifications to the system. Poorly made hand crimps and twisted wire connections made without solder or pressure connectors caused overheating at the contact junctions. This heat was conducted away from the junctions by the metal wire so as to overheat the wire and its insulation close to the contact. This led to deterioration of the insulation and the onset of leakage current between the cable conductors which, in turn, caused greater overheating. Ultimately this process caused ignition of nearby materials. Some of these failures may have been accelerated because the fixtures were **overlamped** and/or covered with thermal insulation. Almost all the fixtures involved in these fires were intended to be operated with clear space behind the wall or ceiling, so that the heat from the lamp can be dissipated through this air space. One exception was a recessed type fixture that was installed by an occupant. He apparently threw away the junction box and the thermal insulation supplied with the fixture for the purpose of shielding the structural wood from the heat of the lamp. Overlamping probably also contributed to this fire.

Fire incidents characterized as **combustibles too close** usually involved **portable lamps.** A home-crafted hanging lamp produced one ignition because the untreated cotton macreme used to suspend the lamp was too close to the lamp bulb. In other instances, towels and bedding were ignited because they came in direct contact with portable lamps.

Overall, 58 of 149 fires occurred at splices, connections or terminations. Table 13 presents the frequencies of these fires by component.

The involvement of aluminum wiring in electrical distribution system fires continues to be of interest. Fourteen of these 149 fires involved the use of aluminum conductors--5 distribution panel fires, 4 branch circuit fires (three non-metallic sheathed cable and one that involved a combination of wiring methods) and five fires at a receptacle outlet.

D. Contributing Factors

Even after identifying the equipment and characteristics involved in these fires, the question of how they came about and how they might be prevented remained. In-depth review indicated that they exhibited common underlying factors. For purposes of analysis and with the intent of providing direction to addressing such fires, we developed the following classifications.

A. Improper Alterations - included fires that resulted from changes made to the system after initial installation, sometimes by other construction, that adversely affected its operation.

B. Improper Initial Installation - included fires that resulted from failure of an improperly executed installation.

C. Deterioration Due to Ageing - included fires that stemmed from a component that failed with the passage of time. In some but not all cases, deterioration appeared to have been enhanced by environmental factors such as high temperature, exposure to moisture, or sunshine.

D. Improper Use - included fires that resulted from the consumer using the equipment in a way it was not intended to be used.

E. Inadequate Electrical Capacity - included fires that resulted from the effects of overloading the equipment.

F. Faulty Product - included fires involving equipment that failed in a manner indicating a defect.

These groups reflect our evaluation of major precipitating factors even though other factors may have been present in some degree.12/ Figure 1 presents the results of this classification.

12/ Multiple factors were cited in 31 fires, when each was considered an essential element of equal importance in precipitating the fire. For example, 12 fires involved both Improper Use and Inadequate Electrical Capacity.

Table 13
Residential Electrical Distribution System Fires Involving Splices, Connections or Terminations, by Component.

Component Connection	Number of Total Fires	Number of Fires At Splices, Connections, Or Terminations
Total	149	58
Service Components	21	6
Branch Circuit Wiring	50	18
Cords and Plugs	29	8
Receptacles Outlets /Switches	29	19
Light Fixtures, Lamps	19	7
Transformers	1	0

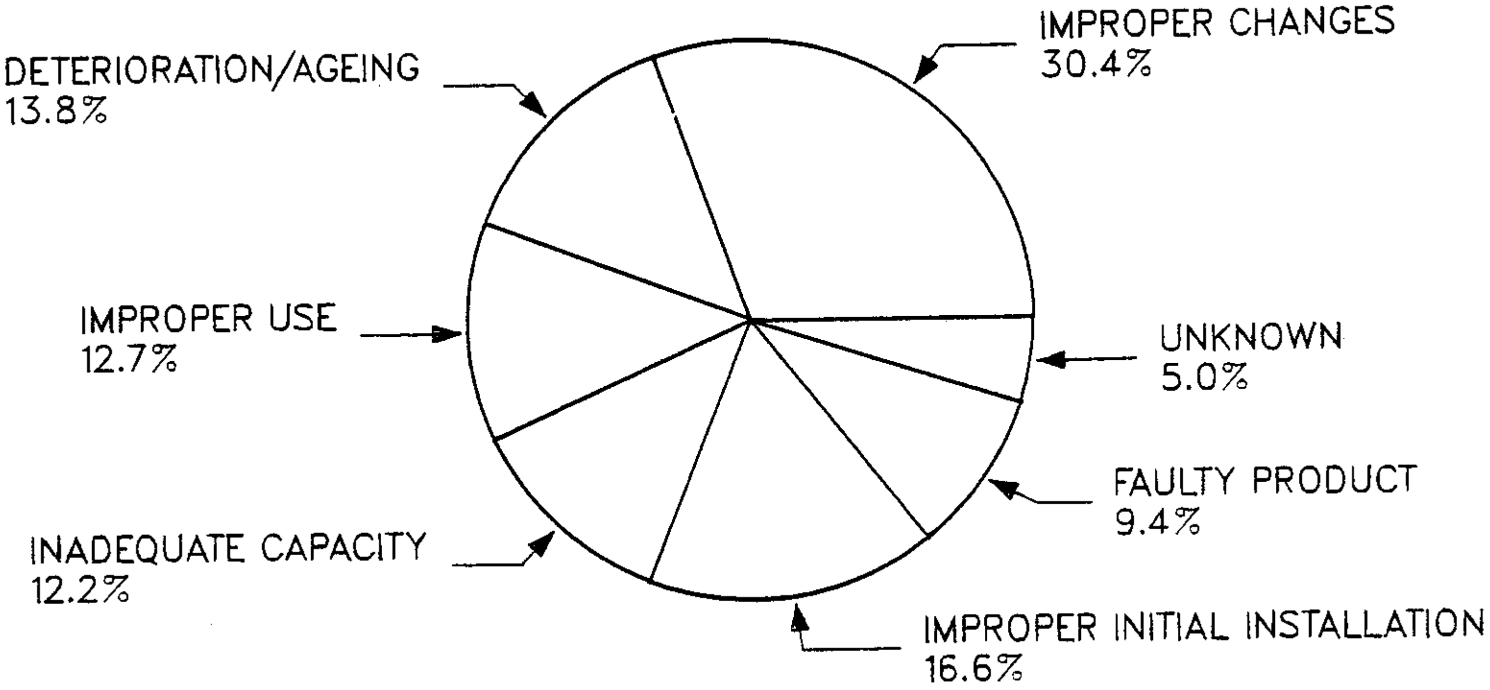
Source: Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore, must be viewed with caution.

Consumer Product Safety Commission/EPHA

FIGURE 1

**

CONTRIBUTING FACTORS INVOLVED IN RESIDENTIAL ELECTRICAL DISTRIBUTION SYSTEM FIRES



Source: Consumer Product Safety Commission special study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore, must be viewed with caution.

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The presence of an older, inadequate electrical system was a factor in several of these groups, which to a large extent reflected the ways consumers reacted to meet their electrical needs (Table 14). In simplified terms, some consumers attempted to modify the system in a manner that resulted in fires (improper changes - 55 fires). Others chose to use extension cords to extend the system without changing its capacity (improper use - 23 fires). Some overloaded the system by placing increased demands upon it (inadequate capacity - 22 fires). Still others merely continued to use a system that had deteriorated to the point that it would not safely handle its usual load (deterioration due to ageing--25 fires). As a combined group, these incidents accounted for 125 of the 181 factors cited (103 of the 149 fires).

The involvement of older dwellings is shown in each of these four groups in Table 14. Dwellings over 40 years old were involved in 67 of 125 factors identified (53 of 103 fires). Dwellings over 30 years old were involved in 85 of 125 factors identified (67 of 103 fires).

Of the remaining factors, 30 fires exhibited evidence of improper installation. Sixteen of these involved branch circuit wiring but service equipment and receptacles were involved in 6 fires each (Table 15).

Faulty products were believed to be the cause of 17 fires. Most often these involved cords to various appliances, though several faulty receptacles were identified.

It is essential to understand that we categorized these fires on the basis of the total mix of information available on each incident. Consequently, each group contains a variety of details and situations. A more detailed description follows of the essential elements and type of incidents within each group.

Table 14
Contributing Factors Involved in Residential Electrical Distribution System Fires, by Age of Dwelling

Contributing Factors	TOTAL		Age Of Dwelling(Years)					
	No.	%	≤10	11-20	21-30	31-40	Over 40	Unk.
Total	181	100	10	13	25	24	86	23
Improper Changes	55	30	1	2	9	7	29	7
Deterioration Due To Aging	25	14	2	3	-	5	9	6
Improper Use	23	13	1	1	2	5	13	1
Inadequate Electrical Capacity Alone	22	12	-	-	4	1	16	1
Improper Initial Installation	30	17	4	4	8	3	7	4
Faulty Product	17	9	2	3	2	1	8	1
Unknown	9	5	-	-	-	2	4	3

Note: Frequencies add to more than number of investigations since multiple factors were coded for 31 cases.

Source: Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore, must be viewed with caution.

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Table 15

Contributing Factors Involved in Residential Electrical Distribution System Fires, by Component

Contributing Factor	Total	Service Equipment	Branch Circuit Wiring	Cords/ Plugs	Receptacles/ Switches	Lamps/Light Fixtures
TOTAL	181*	25	59	44	32	20
Improper Changes	55*	10	25	2	8	9
Deterioration Due To Ageing	25	5	5	5	9	1
Improper Use	23	--	--	17	1	5
Inadequate Electrical Capacity Alone	22	2	7	12	1	-
Improper Initial Installation	30	6	16	--	6	2
Faulty Product	17	1	3	6	5	2
Unknown	9	1	3	2	2	1

Note: Frequencies add to more than the number of investigations since multiple factors were coded for 31 cases.

*Includes 1 Transformer incident

Source: Consumer Product Safety Commission study of 149 investigated fires in the residential electrical distribution system, 16 cities. These fires do not constitute a probability sample. The results, therefore, must be viewed with caution.

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E. Technical Description

1. Improper Alterations

a. Definition

This category, the one most frequently cited in classifying causes of these fires, is composed principally of instances where an existing residential wiring system was altered in such a way as to establish a potential fire hazard. In almost all cases, the work seems to have been performed by an unlicensed, untrained person who was unaware of National Electrical Code (NEC) requirements, or who ignored them while making the alteration. There were also some examples of non-electrical changes to residences, such as adding thermal insulation in walls and ceilings or adding aluminum siding close to the utility service drop or the service entrance cable, that resulted in damage to the electrical system and a resultant fire hazard.

b. Characteristic Examples

A new heat pump was installed in the crawl-space under a single family dwelling originally built in 1955. Several hours after the installer left (he needed an additional switch to complete the installation.) an occupant of the house smelled smoke. A fire was discovered in the basement crawl space. Investigation by fire authorities and an electrician determined that the fire was electrical and had been initiated by heavy overcurrents in the feeder cable to the heat pump and in other electrical cables fastened to the bottom of the floor. The investigation established that incorrect wiring to the heat pump caused the current overloads, overheating, and ignition of wiring and cardboard boxes stored in the crawlspace.

In a house built approximately in 1920, a #16 AWG flat two-conductor extension cord was spliced (open twisted wires, no solder, no twist-on connectors) to original #14 AWG knob-and-tube conductors. These splices were hidden in wall cavities. This branch was protected by means of a 20-ampere circuit breaker, whereas the #16 stranded cord is nominally rated at 13 amperes. This cord normally supplied a refrigerator and a window fan. During the day of the fire (in June, 1980), the circuit breaker tripped and was switched back to "ON". When a fire company responded to a telephoned report of a fire, they found evidence of overheating at loose splices within the wall.

Six months before the fire incident an occupant of a home estimated to have been built in 1906 installed a 50-ampere two-pole range receptacle on the wall that was subject to vibration from the air bubbler of a spa. A faulty connection inside the receptacle subsequently caused glowing or arcing inside the receptacle that burned through the plastic cover. The wall vibration was believed to have contributed to the arcing or glowing failure of the receptacle connection. This receptacle fire ignited the wood siding and sheathing so as to cause the fire incident of December 19, 1980.

June 30, 1984, an electrical fire caused extensive damage to the second floor and attic of a frame house that was more than fifty years old. Investigation of this fire indicated that it originated in a closed space above a shower stall that had been added to a first-floor bathroom. The recessed light installed in the closed space had been encapsulated in cellulose insulation so as to become severely overheated when the light was turned on. This overheating was the source of ignition of the fire. While the wiring system of this house was not the direct cause of this fire, inadequate over-current protection may have contributed to its severity.

An electrical fire November 12, 1980, in the ceiling-crawl-space of a brick-veneer home built in 1910 was determined to have been started by resistance heating or arcing. This had occurred at a location where a staple had been over-driven so as to cut through the insulation of a section of NM cable. This cable had been spliced into the original knob-and-tube wiring by wrapping the new conductors around the old but without soldering the splices. The whole area was covered with several inches of cellulose-fiber insulation. While the rated allowable current (in free air, not covered with insulation) for the #14 AWG cable was 15 amperes, the original 25-ampere fuse apparently had been left in this branch-circuit. (#14 AWG knob-and-tube conductors were rated at 25 amperes.)

c. Common Characteristics

The fires in this category originated from a variety of components of home wiring systems and from currently-used as well as outdated components and materials. Defects and failures in the branch-circuit wiring were more frequent than in any other component of the wiring system. Some common characteristics were observed in failures in all the wiring system components, however.

Extension of the Original System -- The great majority of these fires resulted from efforts to extend the electrical systems of older homes. They had been built when the use of electricity was much less than in recent years. Improvised system extensions were added to provide apparent increases in capacity, without also increasing the capacity of the system starting at, or including, the service drop.

"Do-it-yourself" Electrical Installation -- With very few exceptions, the electrical installation that contributed to the fire was performed by untrained personnel who either did not know good electrical wiring practice or did not follow it if they knew it. In a few cases, carelessness of workmen or occupants while performing other types of work on the house injured the electrical system in such a way as to initiate a fire (e.g., a nail was driven through NM cable behind wall panelling as the panelling was being installed.)

Non-observance of NEC -- Very few of the homes involved exhibited any evidence of electrical inspection beyond that conducted when the house was built. Almost all of them were found to have multiple serious violations of the National Electrical Code. Many of these violations did not contribute directly to the fire, but some of them contributed electrical stresses that contributed to the primary failure. Competently installed wiring that conformed to the National Electrical Code would have prevented the great majority of these fires.

Bad Connections -- Most of the fires in this group started at some point in the electrical system where connections between metallic conductors failed. Examples are found starting with the connections of the branch-circuit cable (especially with aluminum conductors) to the service panel bus bars, with splices of various kinds in the home distribution system, with wire connector connections to lamps and receptacles and between receptacles and plugs. The prevalence of overloading and overfusing in most of these homes added abnormal stresses on the electrical connections.

d. Reasons and Remedies

These fire investigation records do not include information from the owners or occupants stating their reasons for introducing the changes in their wiring systems that eventually caused ignition. Some reports reflect low economic status of the homes involved so that it is probable that they believed that they could not afford to have a skilled electrician perform improvement of their system. Also, for them to have decided to make these improper changes it seems that they underestimated the danger, or were unaware of it.

Based upon this group of fire investigations, further improvements of voluntary standards for electrical products or of the NEC will not do much to reduce the incidence of electrical fires. Most of these fires resulted from conditions, components, and user practices that violate one or more of these voluntary standards.

Smoke alarms and other fire detectors can reduce damage and injuries from these fires, but prevention and subsequent reduction of the incidence of these fires will require upgrading of home electrical systems and of the workmanship and safety practices employed in electrical alterations and additions.

2. Deterioration

a. Definition

This category includes fire incidents where gradual deterioration of an electrical system component was believed to be the predominant cause of the failure that caused ignition. In almost all cases failure occurred in basic materials such as electrical insulation or conductive materials of the system. Deterioration can occur simply with age; in many cases it is accelerated by increased temperature; electrical insulation can be degraded by the presence of water or other contaminants and also by exposure to sunlight (ultraviolet radiation); mechanical stresses such as abrasion or repeated bending are often factors in deterioration of electrical components.

b. Characteristic Examples

An unoccupied wood residence, more that fifty years old, was observed to have a serious fire in an outside wall, June 21, 1985. After extinguishing this fire, investigators found that ignition had been initiated by high-current conduction through the #14 wire that connected the residence telephone system to ground. Current had been transferred to this wire from a downspout which had contacted a service-entrance conductor through its deteriorated insulation. This conductor was in a location exposed to weather and, probably, abrasion by motion of the downspout. The investigators suggested that rain, before and during this fire, may have helped to increase the current flow to the grounding wire.

In December of 1980, an electrical fire occurred in a wood frame house that was approximately thirty years old. Ignition occurred in a duplex outlet receptacle which was not in use at the time. The insulation of the outlet appeared to have broken down because of previous overheating. Smoke and overheating had been observed about five days previously while a water-bed heater had been plugged into this outlet. Apparently gradual deterioration by electrical conduction within the receptacle continued until obvious (overheating) occurred. (There is no report that there was any electrical load "downstream" of this outlet.)

January 15, 1981, an electrical fire occurred in a basement bedroom of a home that was built in 1940. Investigation of this fire revealed that the ignition source was a lamp plug connected to an extension cord receptacle. It appeared that continuing insertion and withdrawal of this plug had gradually weakened the plastic body that contained the blades of this plug until the plastic failed, permitting arcing between the blades that resulted in overheating and ignition.

A two-story brick dwelling, at least forty years old, experienced a fire in a wall switch, June 11, 1985. The occupants had observed flickering of the light controlled by the switch for several weeks, but thought that the bulb was failing. It was found that the contact stop may have been weak to begin with, so that it deteriorated relatively quickly in continued use and fractured in such a way that no solid mechanical or electrical contact could be made. This caused overheating and ignition of the plastic body of the switch.

In December of 1980, substantial damage to a second-floor bedroom occurred because of a fire in a twelve-year-old home.The fire and electrical investigators determined that the source of ignition was the control cord of an electric blanket. During continual use of the blanket, the cord sustained mechanical wear and damage to its insulation. Probably this deterioration was accelerated by the cord being covered with bedding when it was in use.

c. **Common Characteristics**

Many of the failures cited here did not provide much warning to untrained or uninformed users of the electrical system. Frequently no problem became apparent until some extra stress, such as rain, combined with deterioration to cause a fault. Electrical testing with appropriate instruments by an experienced electrician would have been required to detect some of them because they would not have been detected beforehand by visual inspection.

While some failures, such as a fault to ground in a run of flexible armored (BX) cable that had been installed years ago, seem to be simply deterioration with age, many more failures seem to involve factors in addition to simple deterioration.

d. **Reasons and Remedies**

The materials and components employed in residential wiring were developed under strong pressures to minimize cost. There is not much evidence, in some cases, that strong efforts were made to predict effective life and control failure modes so as to be safe, rather than unsafe. When the expected life of components is measured in decades, real-time life testing is not practicable; laboratory simulations of high-stress environments and accelerated life testing must be employed in the testing of new electrical system components. It appears that some test evaluations used in the past did not predict actual life accurately.

Many of the failures in these fires are "end-of-life" phenomena. There is a conceptual problem that homeowners may have with this, because they do not think in terms of their electrical system having a finite life.

One helpful activity to reduce future problems is technical study of failure modes (e.g., the current CPSC Electrical Outlets project) to guide upgrading of standards and products to reduce the likelihood of these failures.

Another possible effort suggested by our analysis of these fire reports would be to develop a specific set of guidelines for the inspection and analysis of electrical systems in older homes, where the aging of materials and components is of most concern.

3. Improper Use

a. Definition

This category includes those where some electrical device or component was used well outside its ratings or was misused in some other seemingly obvious fashion, so as to lead to ignition of some part of the residence or its contents. The basic cause of the resultant fire was found to be the original improper use.

b. Characteristic Examples

A single-family frame house experienced a fire in an upstairs bedroom. At the time of the fire, a thirteen-year-old boy was asleep in the room with a radio and an incandescent lamp plugged into a receptacle outlet. The fire pattern indicated that the lamp had been left on and that the material that was ignited first was bedding that was in contact with the electric lamp while the boy was sleeping.

A three-story frame residence, believed to have been built about 1880, evidenced substantial reworking of the electrical system in 1949 and again in 1978. In July, 1981, a window air-conditioner was installed in a second-floor bedroom. It was connected to a receptacle outlet on the third floor by means of a spliced extension cord more than 50 feet long. The spliced sections of this cord exhibited damage to the insulation such as cuts and cracks. After the air-conditioner was first turned on and had been operating for about an hour, an occupant of the house, while checking the bedroom to see if the air-conditioner had cooled the temperature, found that the extension-cord section close to the air-conditioner was too hot to hold in her hand. She threw the cord on the carpet, on top of some magazines in the same location. About two hours later, an active fire was discovered in the bedroom. This fire had started with ignition of the magazines and carpet and had spread to ignite a bed and other furniture.

A single-family home believed to have been built in 1930 experienced a fire at the location of a ceiling-light fixture. This light had been installed by one of the occupants shortly before the fire. It was being operated with 100-watt bulbs, instead of the 60-watt bulbs for which the ceiling fixture was rated. This recessed fixture was also being used without the insulating shield intended to protect the lamp connections and the structural wood from the heat of the light bulbs. The resultant overheating of the fixture ignited the wood ceiling strips that supported the fixture.

A single-story home, approximately forty years old, suffered a bedroom fire in April of 1980. In the area where ignition appeared to have started, <u>an extension cord and a radio power cord were fastened to the wall with nails above a bed headboard</u>. A lamp and a 1320-watt portable heater were plugged into the extension cord, but it was reported that only the radio was turned on at the time of the fire. <u>The fire investigators concluded that the nails had contacted both conductors of the cords so as to form conductive paths that caused overheating at the contact points between the nails and the wire conductors of the cords</u>. The first ignition occurred in a shirt that had been hung on the two nails. The burning shirt had dropped from the two nails onto the radio and onto the floor next to the bed, where its flames ignited the mattress and bedding.

c. Common Characteristics

<u>Extension Cords</u> -- Within this group of fire incidents. the great majority involved improper use of extension cords. They probably were overloaded, because the most common #18 AWG cords are rated only for 10 amperes, whereas most household branch circuits should be protected at the 15-ampere level. Many of the homes in these incidents had fuses in the branch-circuit sockets rated from 20 to 30 amperes. These levels of protection cannot protect light extension cords from overloading and overheating. In addition, some excessively long cords were used; others were fastened "permanently" with nails or staples that damaged the insulation; some were installed through doorways or under carpets where human traffic eventually damaged the insulation to the point where overheating of the cord occurred and in other cases damaged or spliced cords were used that should have been discarded.

<u>Incandescent Lights</u> -- Two general varieties of lamp were usually involved in different modes of improper use. In each case that involved permanently installed light fixtures overlamping was present to make overheating almost a certainty. In the two incidents involving portable lamps, presumably table lamps, they had been left on where bedclothes or a towel came in contact with the lamp bulb.

d. Reasons and Remedies

The behavior that led to many of these fires indicates lack of knowledge of how electricity can be involved in starting residential fires. For instance, visible warnings against overlamping the ceiling fixtures were ignored. More widespread and better education of consumers appears to be the most obvious method to try to reduce the incidence of fire from this source.

Increasing the ampacity and durability of extension cords may, in time, help to reduce fires caused by their improper use. Eliminating the #18 AWG cords at least makes the current rating (13 amperes) of the cords more consistent with the most prevalent 15-ampere branch-circuit ratings. In households where 20- to 30-ampere fuses are installed in Edison-base sockets, however, even the newer #16-AWG SPT-2 extension cords still are not protected from severe overloading by the overcurrent limiting. The improved UL standard for extension cords and appliance cords should help to reduce electrical fires, but its effectiveness will be reduced by continued sales of lower-quality non-UL cords and will depend upon the rate at which new UL-listed cords replace worn, damaged cords from service. Again, we need to continue informational efforts on the need to use high-quality cords listed by electrical testing laboratories and to discard worn, older cords that lack safety features available in new cords.

4. Inadequate Electrical Capacity

a. Definition

Included in this category are a variety of problems and defects that were associated with or were caused by inadequate capacity of a residential electrical system, either too little available amperage, or inadequate distribution of accessible power through the living spaces. Efforts to overcome these inadequacies without providing the necessary upgrading of the household electrical system have resulted in overloading and overheating of conductors and components. This overheating, in turn caused fires.

b. Characteristic Examples

A two-story row-house built during 1928/9 experienced a fire in the "cockloft" (attic space) over a second-floor bedroom. A ceiling stud exhibited fire patterns that indicated that a fabric-jacketed rubber branch-circuit cable had broken down internally, between its conductors, so as to overheat and ignite the ceiling stud. At minimum, the following appliances were known to have been supplied from this branch:

100-watt ceiling light
clock-radio
portable television
portable electric heater (oil-filled radiator)

As found after the fire, the fuse panel of this home had four 30-ampere fuses installed, and a copper penny was found under one of these. The service panel of this home provided four branch circuits, which should have been fuse-protected at 15 amperes.

A second-floor one-bedroom apartment suffered a fire in the concealed space underneath the bathtub. Two flexible metal conduit (BX) cables located in this area exhibited electric-arc damage (holes in the metal armor) and evidence of severe overheating damage (black tarry deposits from melting of the electrical insulation). The #14 AWG copper branch-circuit cables were connected to a service sub-panel fitted with 20-ampere fuses. (The branch-circuit rating was 15 amperes.) A penny, which negates any protection offered by the fuse, was found under one fuse.

A single-family home, dating from about 1916, suffered a fire that ignited the dining-room carpet while the owners were absent on vacation. A lightweight #18 AWG extension cord was used to supply power to a refrigerator. The fire investigators concluded that overheating of the cord ignited the carpet. The ignition-source cord was plugged into another extension cord which, in turn, was run through a wall and plugged into an "octopus plug" (cube-tap) in a kitchen outlet. All branch circuits of this home were connected through fuses rated at least 25 amperes, although all but one branch was #14 AWG fabric-jacketed rubber cable, rated 15 amperes. Throughout the rest of the house there was extensive use of cube taps and extension cords to extend the permanent wiring system. The #18 AWG cord, rated to carry 10 amperes, that supplied power to the refrigerator, is believed to be typical of the extension cords used in this home. This incident involved both an inadequate system and improper use of extension cords.

A single family home, reported to have been built in 1950, experienced a fire in the living room. A dual outlet appeared to have suffered an insulation breakdown, arced over, melted, and ignited an overstuffed chair placed in front of the outlet. The outlet appeared to have failed because of a severe overload. The investigator reported that several "zip type extension cords" connected to other appliances were connected to the outlet, in addition to a portable electric heater, at the time of the fire. The branch circuit connected to the failed outlet had a 30-ampere fuse installed in series with #14 AWG copper (15-ampere rated) cable. (This dwelling was being heated by portable electric heaters in every room because the gas service had been shut off for several months).

A single-family home built in 1953 experienced a fire that started in the plug of a ten-year-old refrigerator. The fire destroyed combustible material on top of the refrigerator as well as a socket adapter, porcelain light fixture, and splices and compression fittings in a metal junction box. Because there were too few outlets available in the area where two refrigerators were located, a light socket adapter was placed in an overhead light socket, two refrigerator cords were plugged into the adapter, and a 100-watt bulb was installed in the adapter socket. (The power rating of this type of adapter is typically 660 watts, which in most cases may be adequate for one refrigerator, but not two.) At the time of the fire both refrigerators were operating and were reported to have been operating with this same a-c line supply arrangement for about ten years. The branch circuit cable, #12 AWG copper rated at 20 amperes, was connected through a 20-ampere circuit-breaker. To protect the 660-watt adapter (approx. 5.5 amperes), a circuit-breaker rated at 5.5 amperes or less would have been required.

c. Common Characteristics

Practically all of these fire incidents involve either ignorance of ampacity ratings of branch circuits and household electric cords or, probably, ignoring these ratings because the dangers of failing to observe these limitations were underestimated, or discounted in comparison with economic considerations. Common examples are:

Overfusing -- Many of the fuse panels installed in these homes accepted the older Edison-base plug fuses which have the same threaded base size for all fuse ampacities. Often these were found with 25- and 30-ampere fuses serving branch-circuit wiring rated at 15 amperes. There were some instances of the ultimate in overfusing -- a copper penny under the fuse.

Misusing Extension Cords -- The extension cord is a readily available, inexpensive device that is commonly used to provide electricity in residential areas where the there are either no outlets or an insufficient number for the electrical appliances in use. Extension cords were very extensively distributed in many of the homes where "Inadequate Capacity" fires occurred and were directly or indirectly involved in many of the fires in this category. Until 1986, the most popular indoor cords were made up with #18 AWG copper conductors, rated at 10 amperes. In many of the homes involved in these fires, these cords were connected to 15-ampere branch circuits fused at 20 amperes or more. As a result, the household overcurrent protection did not prevent overheating and ignition of these extension cords.

Electric Heating: In several of these homes, the lack of electrical capacity was exacerbated by extensive use of portable electric heaters. This was a result of fuel gas service having been cut off because of nonpayment of bills. Often loss of gas service resulted in substituting electric power for gas in cooking as well as heating so as to increase the electric demand upon an already overloaded system.

d. Reasons and Remedies

The apparent reason for most of these fires was that the original electrical system installed when the house was built was never updated to meet the household's increased demand for electric service and power. The presence of the Edison-base fuse boxes, which allow interchanging of fuses of different ampere ratings, facilitated overfusing the existing branch circuits. This problem could have been eliminated by installing appropriate adapters in the Edison-base sockets so that only Type S fuses, which are not interchangeable among the current ratings, can be used.

In a few more recently built homes, the total capacity of the system probably was adequate, but the lack of an outlet in some location was the cause of an unsafe extension of the system. Apparently the persons responsible for these homes and their electrical systems were not aware of the limiting ratings of light gauge extension cords and light-socket adapters.

The only practicable method, at the moment, to reduce the incidence of this kind of hazard appears to be education and publicity to motivate homeowners to update home electrical systems to meet current NEC requirements, as a minimum. An obvious problem is meeting the costs of making these improvements; this is particularly true for households that already have economic problems such as inability to pay gas-heating bills. The National Electrical Code (NEC) and other applicable voluntary standards, if observed, would eliminate almost all of these fires. If well-trained electrical inspectors were available in greater numbers, more active enforcement of the NEC could help to reduce fires.

5. Improper Initial Installations

a. Definition

This category, the second most-frequently identified in these fire investigations, refers most often to defects associated with the installation of the first electrical system in the residence. In a few instances, this classification was used to designate defects associated with major rehabilitations of the electrical system, or other additions too comprehensive to be designated as "changes".

b. Characteristic Examples

A two-and-one-half story frame dwelling constructed in 1930 sustained a basement ceiling fire May 19, 1980. This fire spread to two floor joists and to the kitchen subfloor and floor. Investigation of this fire disclosed that overheating had occurred in a junction box that also supported a light fixture. Four two-conductor #14 AWG cables were spliced together in this box. It appeared, after the fire, that the wire splices had not been fabricated properly initially. Rather than being securely twisted together, it appeared that the wires had been loosely wrapped together and taped. They had not been soldered, and the installation probably was made before twist-on pressure connectors were available. In time the contact between the spliced wires loosened so that resistance heating and/or arcing caused overheating. After ignition had occurred, shorting between the wires caused a 30-ampere fuse to open (fuse should have been 15-ampere), but this happened too late to prevent the fire.

In 1979, a bedroom addition was made to a 1956 single family home. The homeowner permit for this addition called for the installation of a distribution sub-panel in a bedroom closet. An NM cable was installed so as to run between a heating duct and its supporting metal strap. Subsequent vibration of the duct wore through the cable insulation and established a resistive circuit between the "hot" conductor and the grounded heating duct. In 1980 this circuit caused overheating that ignited the wooden structure. The cable and duct had been buried in fiberglass insulation.

A 1963-built single family home was equipped with a circuit-breaker panel and box that was mounted on an exterior wall. In 1985, a fire occurred in this service box. Ignition was initiated by one ungrounded aluminum conductor of the service entrance cable. This conductor broke loose from the hex-head screw type terminal that connected it to the distribution bus of the circuit-breaker panel. The ignition occurred when the bare end of the service- entrance conductor contacted the back panel of the service box. The connector for that conductor was completely destroyed and the connector for the other ungrounded conductor was partially destroyed, both by electrical heating or arcing. It appeared that the cable conductors had not been properly secured mechanically and electrically when the service panel was assembled. The neutral terminal was marked "CU-AL".

A single-family home, built in 1956, sustained a fire in the attic crawl space in 1981. It originated where two fabric-jacketed rubber #14 AWG copper cables were bent over a ceiling joist. Injury to the conductor insulation at the time of the installation, either from a hammer blow or an overdriven staple, initiated breakdown of the cable insulation that caused overheating and the fire.

c. Common Characteristics

The predominant underlying cause of the fires that were judged to belong in this category was poor workmanship. The ignition sources, while being distributed in a number of areas of the electrical system, tended to belong to one or two types of failure.

Electrical connections -- loose binding screws, multiple wires under binding screws, copper and aluminum wires under the same binding screw, branch-circuit splices twisted together with neither solder nor twist-on connectors, failure of service-entrance cable connections at the service-panel -- all were found to be responsible for residential fires.

One type of connection problem seems to be accentuated by careless initial installation. Connections between dissimilar metals, e. g., aluminum wire and steel screws, have questionable reliability at best, even with screws and clamps tightened down thoroughly. Less tight connections that probably would serve adequately with copper conductors, can exhibit corrosion, high resistance contacts, and overheating when applied to aluminum conductors.

Damaged electrical insulation resulted from initial errors in several ways. Mechanical damage to service entrance cable allowed rain and other moisture to enter the inner cable where it caused gradual deterioration of the insulation between the conductors and resultant overheating. Installation of branch-circuit cables in contact with grounded metal surfaces such as heating ducts or aluminum siding caused vibration or other relative movement, over the course of time,to wear through the insulation.

One particularly threatening characteristic of many of the fire hazards in this category is that they give little, if any warning in a situation where the problem gradually becomes critical over a period of more than 20 years. Most of the affected areas are hidden in junction boxes, conduits, cables, service panel boxes, etc., where damage is not likely to be observed until a hazardous failure occurs.

d. Reasons and Remedies

We do not have any data that establishes reasons why hazardous defects are generated in the processes of constructing new residences and making substantial additions or modifications to existing homes. It is possible that the people doing this work either do not know how to perform it correctly and safely or, if they do know how, are not motivated sufficiently to avoid occasional serious lapses. Possibly they do not realize the seriousness of the hazards presented by the household electrical system when appropriate attention is not paid to correct installation.

There is no obvious single answer to provide reduction of the hazards created by poor electrical workmanship. Licensing and training of electricians is very important, and ideally, only qualified electrical workers should work on home electrical systems. In many jurisdictions there is no regulation or enforcement of the required training or qualifications of electrical workers, so that whatever pro tection there is must be provided by inspection during and after the performance of the work.

If strict electrical inspection is performed, some errors will be discovered and corrected. To receive inspection, a permit must have been obtained from the local authority, inspection service must be available in the area, and there must be enough inspectors so that they can do a thorough job. Many districts in the United States fail to provide this protection for various reasons. Once outside major metropolitan areas, there are many districts that have no electrical inspection at all.

Helpful changes would be greater care on the part of people who install residential electrical systems, coupled with improved understanding of safe wiring practices. With regard to existing systems, more and better inspections are obvious methods to finding incipient defects. At the present time, it is unusual for homeowners to have their electrical system inspected, unless some problem has become apparent. The cost of having the inspection conducted and of making the repairs indicated by the results seem to be difficult obstacles to improving the safety of electrical systems. Perhaps this cost would seem less formidable, if accurate estimates of the distributed costs (e.g., fire insurance) and potential individual costs of electrical fires were available.

6. Faulty Products

a. Definition

This category consists of fire incidents which were determined to have been caused by some device or component that was defective, either because of some inherent characteristic, or because of some unique defect of the products involved in the fire incident.

b. Characteristic Examples

A two-story frame house, believed to have been first occupied in 1962 or 1963, suffered a fire in the basement in July, 1985. Investigation by the fire authorities and an electrical investigator revealed that the fire originated in a faulty electrical service panel. The cartridge-fuse holder that transferred current to the electrical clothes dryer appeared to have suffered overheating damage, caused by defective connections to the service panel bus bars. This overheating damaged the service panel insulation and this damage, in time, resulted in electrical arcing between the bus bars, and the fire in the service cabinet.

A two-story brick home, estimated to be approximately fifty years old, experienced a living-room fire in February of 1985. The fire and electrical investigation narrowed the ignition source to a floor receptacle behind a sofa and set in a carpeted floor. The specific mechanism of failure was electrical arcing between the "hot-side" binding screw and the yoke (ground). It was reported that the only electrical device plugged into the outlet at the time of the fire, a lamp, was switched off. The connections to the outlet were back-wired (push-in) type. The outlet ignited the carpet and the sofa.

A two-story frame dwelling, believed to have been built in 1910, experienced a bedroom fire in January of 1981. The source of ignition was found to be the plug and appliance cord of a 12.5-ampere rated electric heater. The plug had been replaced twice because overheating had damaged the plug and wire insulation. The replacement plug was rated to carry 15 amperes. The plastic insulation of the plug and cord ignited and burned; arcing occurred across the male plug.

A single-story frame dwelling, built in 1967, suffered a kitchen fire in June, 1980. One of the occupants detected an increasingly strong "burnt" odor while she was working on laundry. After further increases in the odor and in a sizzling or frying sound, she walked into the kitchen and observed a red glow and a small flame in the space between the refrigerator and the kitchen wall. After the fire was extinguished it was found that the neutral blade of the refrigerator plug had melted its side of the plug cap and that the insulation of the plug and cord had ignited. The neutral contact of the outlet supplying the refrigerator had melted the surrounding insulation and was itself burned and partially melted. It appeared that the initial failure may have been in the wire connection to the plug blade.

c. Common Characteristics

A-C power connectors were the most common component that exhibited failure in these products that were judged to be faulty. Overheating of plugs was observed either if the plugs were inserted in outlet receptacles or in extension-cord receptacles. Outlet receptacles failed because of the properties of aluminum branch wires, because external pressures on the face of the outlet disturbed the wiring inside the junction box so that arcing and overheating took place inside the box or because a-c plugs inserted in the receptacle overheated when the wire connection to a blade developed electrical resistance in the current path. In a number of these fire incidents, it was not possible to determine conclusively that either the cord and plug or the receptacle outlet was the original source of the overheating. Specific connectors associated with particular appliances such as a nightstand lamp, a flat iron, and a waterbed heater also demonstrated overheating failures that caused fire incidents.

Other types of failures that were present in this category occurred in contacting devices such as switches and control thermostats, and electrical cables. Two incidents involved flexible armored cable (BX); cable that had been in use for many years and was not known to be overloaded seemed to suddenly develop resistance paths between the "hot" side of the line and the flexible armor sheath. Either because the resistance of the current path was sufficient, or because the armor sheath was not effectively grounded so that the leakage current from the line conductor could increase to actuate the fuse or circuit breaker, the BX cables overheated and ignited structural wood and other materials in contact with the cables.

d. Reasons and Remedies

The information in these fire reports is not sufficiently detailed to pinpoint specific reasons for the product failures in very many cases. For instance, we do not know how many of the appliances and extension cords involved were listed by Underwriters Laboratories , or, if they were, which issue of the appropriate voluntary standard they were supposed to meet.

The record of specific devices and components involved in fire ignitions indicates that a-c line plugs and receptacles seem to break down in service in such a way as to cause ignition more frequently than other devices. Often, it is not clear that one or the other was primarily responsible for the failure; possibly neither one was adequate for the application.

To our knowledge, the specific weaknesses of a-c plugs and receptacles have not been well defined. Manufacturers of portable electric space heaters ,in conjunction with Underwriters Laboratories, are now conducting a study of wire-blade connecting means with the objective of overcoming problems that have been observed with high-current applications. ESES is conducting a study of receptacle technology with the aim of recommending improvements to the voluntary standard for these devices. Potentially these studies could lead to greatly improved performance of both components, but any substantial reduction in fire incidence as a result would probably not become apparent for several years.

CONCLUSION

Available data indicate that fires in electrical distribution systems contribute significantly to the U.S. fire problem, accounting for a consistent portion of that problem, year after year. These fires are notoriously difficult to evaluate accurately because of the complexity of the electrical system and the difficulty of identifying details once a destructive fire has occurred. As discussed earlier, the investigations included in this this effort were not a controlled sample. Therefore, the possibility for bias in selection must be considered. For example, it is possible that the fires not investigated had different causes. Even so, it seems reasonable to assume that the causes identified here depict some major part, even if not the whole, of the electrical distribution system fire problem.

Three major characteristics were identified by this effort-inadequate electrical system capacity, consumers' inappropriate actions to modify or accommodate that inadequacy, and construction of improper initial installations. It is not clear how these fires could be reduced most effectively. However, some of the possibilities include:

1) Development of an information campaign to inform consumers that repairs must be made properly and to recognize that electrical systems have a finite life, just as other products do. A number of possibilities for information distribution could be explored such as the active participation of fire departments during their fire safety campaigns.

2) Development of a rehabilitation guideline that would help consumers decide when they need work on the system and, perhaps, provide guidance for work to proceed in stages if economically necessary.

3) Develop a letter to states and localities that emphasizes this hazard and encourages them to become more active in this area, e.g., education or stricter inspections initially and at resale.

4) Encourage states and other jurisdictions to provide more resources for electrical inspection.

5) Encourage states to require more training for those installing electrical systems.

Accomplishing changes that address this hazard will be a lengthy and complex task. Consumers must be convinced of the dangers of "do-it-yourself" work on the electrical system--work done either by themselves or their "experienced" neighbors. However, the consumer concerns about repair cost demonstrated in these investigations indicate that achieving this change will be very difficult. The involvement of economic issues found here is consistent with the findings of others that "suggest that poverty is a major determinant of fire fatalities".[13] It is critical then that staff include efforts to address this aspect of the problem among any actions we may propose.

In sum, we found that most of these investigated fires were directly attributable to situations where the specifications of the National Electrical Code were not met for one reason or another. Therefore, we believe that efforts to address this fire problem should, for now, concentrate on more extensive adoption and enforcement rather than on further modifying the Code.

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[13] David Hemenway, "Fire Fatalities and Poverty," Atlantic Economic Journal, Vol. XV, No. 1, March 1987

Appendix A: Glossary

branch circuit: the circuit conductors between the final overcurrent device and the outlets for lights, appliances, etc. Depending upon the period when the electric system was installed, and the requirements imposed by local authorities, the following materials have been used for branch-circuit wiring:

> **armored cable:** commonly called "BX", a marking on the armor that now identifies cable manmufactured by the General Electric Co., consists of two or three insulated conductors and, sometimes, a bare bonding strip of copper or aluminum to provide, in conjunction with the armor, a grounding conductor, enclosed in a flexible metal enclosure (tube). This cable is provided as a complete assembly of two, three, or more conductors in the flexible metal tape armor.
>
> This type of cable was intended to complement a system of branch-circuit wiring that would fully enclose the conductors in a grounded metal envelope. Splices and connections to switches and receptacle outlets were to be enclosed in metal boxes (junction boxes or outlet boxes) and the flexible armor of the cable was to be fastened to each junction box by means of clamps gripping the cable and secured to the box. The cable was to be supported by passage through holes in solid materials, by the box fasteners, and by metal staples driven into wood structural members.
>
> The purpose of enclosing wiring systems in grounded-metal shields is to contain ground faults --failures of the insulation system that permit current flow from supply conductors to grounded structure -- within the shield and to provide a low-impedance path to ground so that the fault will activate the overcurrent protection device and thus disconnect the faulty circuit.
>
> Among the fire incidents discussed in this report are examples of faults in armored cable that caused overheating and ignition but did not actuate the overcurrent protection on the branch circuit. A high-resistance fault, or resistance in the armor and other circuit elements in the path back to the system ground can limit the fault current to a level that permits overheating and ignition without actuating the branch overcurrent protection.

electrical metallic tubing: "emt", or "thinwall", a commonly used variety of rigid electrical conduit that can be formed on the job site and can be connected to junction boxes and spliced together (the outer tubing, not the conductors) by means of screw-fastened ferrules or cylindrical pressure fittings. Generally, this material is expected to provide more reliable grounding of the shield than armored cable.

flexible metal conduit: a wiring system that is functionally very similar to armored cable, except that the flexible tubing and the insulated conductors are supplied separately and are assembled at the job site.

knob and tube: the earliest form of house wiring commonly found in service. It consists of single insulated wires with the grounded neutral and the "hot" conductors run independently. The name derives from the ceramic mountings (knobs) that insulate and support the wires from wood framing and other parts of the house structure, and from the insulating fabric tubes used to protect the conductors as they pass through walls and partitions. Splices were made by stripping the insulation from an inch or so of the conductor, wrapping one conductor around the other, or twisting them together, and then soldering the splice. Before self-adhesive rubber tape was available, splices were required to be double taped, first with rubber insulating tape, and then with self-adhesive "friction" tape ,to hold the rubber tape in place.

It was not usual to install thermal insulation in homes during the period when knob-and-tube wiring was generally in use. Ampere ratings for this wiring system were determined by tests conducted in "free air". Increased thermal insulation of older homes has resulted in burial of knob and-tube and other wiring systems in insulating materials that increase the operating temperature of the conductors and that may decrease the life of the wire.

nonmetallic-sheathed cable -- "NM" or "ROMEX" (formerly a tradename of the Rome Wire Co.), a manufactured assembly of two or more insulated conductors having an outer sheath of moisture-resistant, flame-retardant, nonmetallic material. At one time, this consisted of rubber-insulated conductors inside an impregnated woven cotton jacket. Currently manufactured NM cable employs polyvinyl chloride (PVC) for both the wire insulation and the jacket. This cable may also include an uninsulated conductor, for the grounding conductor.

circuit breaker: a protective device designed to open an electrical circuit automatically in response to a predetermined combination of overcurrent and time period (of the overcurrent). This device also incorporates means for opening and closing the circuit by nonautomatic means (i. e., a switch).

fuse: a protective device designed to open an electrical circuit when overcurrent flows through its fusible member for a predetermined time period. The fusible member is directly heated and destroyed by the passage of the overcurrent. Fuses employed in household branch circuits generally are discarded after the fusible element is destroyed. In different applications, other types of fuses contain replaceable fusible elements.

> **cartridge fuse:** a fuse constructed in the form of a long cylinder with a metal contact collar at each end of the cylinder. Usually these fuses are held in place by means of spring metal clips, one at each end, that grip the contact collars firmly. In household use, cartridge fuses often are used for high-amperage applications such as the "main" circuits fed by the service-entrance cable, water-heater circuits, dryer circuits, etc.
>
> **Edison-base fuses:** plug fuses that are mounted in a screw-base socket similar to the socket for a common incandescent bulb. They were commonly used for branch-circuit overcurrent protection in homes that now are more than forty years old, but were replaced by Type S fuses in new construction, for safety reasons. Many of the homes represented in these fire reports illustrate the basic problem with the Edison-base fuse -- the various current-ratings are interchangeable in the same socket so that a home occupant can replace a fuse of the correct rating for a branch circuit with a higher amperage unit, to remedy repeated "blowing", of the fuse, instead of correcting the problem that is causing the overload of the branch circuit.
>
> **type S fuse:** plug fuses that mount in screw-base sockets in a series of sizes that correspond to the current rating of the fuse. This device was designed to overcome the overfusing problems encountered with the earlier Edison-base fuse. The different sizes of base prevent substitution of higher-rated fuses in place of the correct fuse for the circuit.

junction box: (also, outlet box) a small box, usually metal, used to enclose splices between branch circuit cables, receptacle outlets, switches, connections to light fixtures, etc. If metal, they must be connected to ground. As supplied, these boxes are pierced with a variety of cutouts to accomodate cable connectors and to facilitate "ganging" the boxes together for multiple switches, outlets, dimmers, etc.

outlet: a point on the electrical wiring system where current is taken from the supply to energize lights, appliances, and other utilization equipment.

outlet box: see junction box.

overcurrent: any current that exceeds the rated current of equipment or the rated ampacity of an electrical conductor. Overcurrents can be caused by excessive demand connected to a branch circuit, by a short circuit (the two conductors of the branch circuit connected together or connected by means of an external low impedance), or by a ground fault (ungrounded conductor of the branch circuit connected to the grounding circuit).

overcurrent protection: a device or system designed to open an electrical circuit if a predetermined excess amperage flows for a predetermined period of time.

receptacle: a contact device installed at the outlet for the connection of a single attachment plug. In the homes described in these fire reports, there are several varieties of receptacles installed and in use with corresponding plugs:

> **three-pole:** a receptacle that accepts two parallel blades and a round pin. The parallel-blade slots fulfill the same function as in a two-pole polarized receptacle; the round socket is connected to system ground, and also establishes the orientation and therefore the polarity of the parallel slots. Currently this is the configuration required in new construction by the National Electrical Code. One purpose is to reduce shock hazards, but the availability of the ground circuit throughout the system improves fire safety also.
>
> **two-pole, polarized:** a receptacle that accepts two parallel blades of different widths. Corresponding plugs can only be inserted in the receptacle in one orientation, so that the wider socket (neutral or ground side) will accept the wider blade that is connected to the point of the appliance circuit which is intended to be at neutral potential. Correspondingly, the ungrounded, "hot" side of the supply will be connected to the switch of the appliance, or other point in its circuit intended to be at the ungrounded potential.
>
> **two-pole, unpolarized:** a receptacle that accepts two parallel blades of the same width. A mating plug can be oriented in either relative rotation so that the connection of the light or appliance circuit is not controlled with respect to the polarity of the electrical supply. This is the earlier version of the two-pole system and was gradually replaced by the polarized receptacle, to reduce shock hazards.

receptacle outlet: an outlet where one or more receptacles is installed (usually two in the form of a duplex receptacle).

service box: the box that encloses the interconnections between the service-entrance cable and the individual branch circuits that distribute electric power to the various outlets in the residence. This includes the circuitbreaker or switch and fuse that serves as the main control and cutoff of the supply. This box should completely enclose this equipment with metal and should be grounded. (see service panelboard)

service drop: the outdoor conductors that extend from the electric utility pole or other support to the residence, where the conductors are connected to the service entrance conductors. This term is peculiar to overhead distribution systems, as opposed to underground distribution systems installed in some newer subdivisions. Almost all of this group of fire reports relate to overhead distribution installations. Older service drops consist of three individual conductors supported from ceramic insulators. These wires are covered with a material that is described as weather protection. More recently, a single cable ("Triplex") is used, made up of two insulated conductors and a bare conductor, two supply conductors and a grounding conductor.

service entrance conductors: the electrical wires that connect the service drop to the distribution system of an individual residential occupancy. These conductors must be sized to carry the total load of the residence. Some older homes still have individual service entrance wires mounted on insulators. Depending upon exposure of these conductors to weathering and mechanical damage, some jurisdictions may require that these conductors be enclosed in rigid or flexible conduit. Most commonly, the service entrance function is fulfilled by a multiconductor cable covered by a flame-retardant moisture-resistant covering. Depending upon the configuration of the particular installation, portions of the service-entrance cable may be run on either side of the utility meter, to the service box, and to the service drop.

service equipment: electric conductors and other apparatus that convey and distribute power from the electric utility local distribution to the individual branch circuits of the residence. Like the system components in the residence, this equipment operates at 120/240 volt levels.

This definition of **service equipment** is specific to this report and was selected as a convenience in classifying fire locations in the residential wiring system. The National Electric Code employs a narrower definition -- "necessary equipment, usually consisting of a circuit breaker or switch and fuses, and their accessories, located near the point of entrance of supply conductors to a building or other structure, or an otherwise defined area, and intended to constitute the main control and means of cutoff of the supply". This equipment is included in the broader definition used in this report.

service panel/panelboard: the equipment that interconnects the electric utility system to the residential branch circuits. It should provide reliable means for securing the connections between the bus system of the panel and the SEC conductors, between the bus system and overcurrent protection devices (fuses or circuitbreakers) and between the overcurrent protection devices and the individual branch circuits. Also, in addition to overcurrent protection, the service panel should provide means for nonautomatic disconnection of each branch circuit from the system and for disconnecting the utility supply from the residential system. (see **service box**).

twist-on pressure connectors: "WIRE NUTS" (a tradename), a wire-splicing device that is intended to protect the exposed metal of the wire at the splice by means of electrical insulation. Initially, the wires to be spliced may, or may not, be twisted together (The instructions provided with the connectors may not require twisting first, but some electricians prefer to do so.) A common form consists of a tapered insulating cap over a tapered steel spring. The bare wires to be spliced are inserted into the threaded cone and, as the connector is turned by hand, the thread formed by the tapered spring cuts a partial thread in the wires and compresses them by means of the taper in the cap. In a properly finished splice, the insulation of the cap completely covers the exposed metal of the wire and overlaps the wire insulation. These twist-on connectors are supplied in a series of sizes to accommodate a variety of sizes and numbers of wires in a splice.

Appendix B

Fire Estimation Procedures

CPSC projections were made by applying proportions observed in fire incident data (NFIRS) collected through the U.S. Fire Administration to aggregate national estimates developed annually by the National Fire Protection Association (NFPA).

The aggregate estimates made annually by the National Fire Protection Association were from a statistically-drawn national survey of fire officials. Extrapolations from the sample provide an estimate of the total number of structural fires attended annually by fire services, along with the resulting deaths, injuries and property loss, by type of occupancy (residential, commercial, motor vehicle, etc.). These estimates are published annually in the Fire Journal. The survey does not include information about the origin of the fire, for example, the number of fires started by fixed wiring.

The fire incident data (NFIRS) collected by the U.S. Fire Administration originate with a one-page standardized reporting form that local fire departments within cooperating states agree to complete for every fire that they attend. These fire reports are sent to a central state authority, usually the state fire marshall, where they are coded, computerized and transmitted to the U.S. Fire Administration. They include information about the equipment involved in ignition, the form of heat that caused ignition, the material that was first ignited, the extent of damage, the number of injuries and other variables.

The NFIRS data are not a randomly-drawn probability sample of all fire incidents. Although 39 states currently participate, not every fire jurisdiction within a participating state submits data. Nevertheless, the data base is very large, including in 1985 more than 235,000 residential, structural fires out of a total of 622,000 such fires estimated by the National Fire Protection Association. It is by far the most valuable source of data about the broad range of product-specific fires.

Each NFIRS fire was assigned a weight which was developed by dividing the NFPA estimate of residential fires in the U.S. by the number of NFIRS fires citing known equipment. For 1985, that weight was 3.01183 based on the following:

$$\frac{\text{1985 NFPA estimate of residential structural fires (622,000)}}{\text{NFIRS fires citing known equipment (206,519)}} = 3.01183$$

Each fire was weighted by this factor and summed to produce the appropriate estimate. Estimates for deaths, injuries, and property loss were developed using the same procedure applied to the appropriate NFPA estimates and NFIRS frequency counts.

To develop product-specific estimates that could not be obtained using NFIRS codes alone, for 1985, CPSC collected 11,333 incident reports of residential structural electrical fires from 19 states and the District of Columbia. With the cooperation of the National Fire Information Council and the U.S. Fire Administration, participating jurisdictions sent copies of their incident reports for all residential fires involving electrical forms of heat. These incident reports were reviewed and coded for consumer product involvement in addition to retaining the usual NFIRS equipment codes. The following areas participated:

Alaska
District of Columbia
Delaware
Florida
Hawaii
Iowa
Idaho
Kansas
Massachusetts
Maine
Minnesota
New York
Ohio
Oregon
South Carolina
South Dakota
Texas
Utah
Wisconsin
Wyoming

Using the CPSC electrical fire data base which included specific product coding, we identified a primary NFIRS reporting code for a product. We then applied the proportion of the NFIRS code that involved that product to the estimate for the primary NFIRS code and adjusted that figure to include additional product fires which were reported in other NFIRS codes. The estimates for deaths, injuries, and property loss used the same proportional distributions as fires.

*or lack of equipment involvement

This data base is not a randomly selected sample of jurisdictions. However, no identifiable bias was found that affected the distribution (and estimates) of products reported within specific NFIRS equipment codes.

This procedure was used to obtain separate estimates for extension cords, appliance cords, receptacle outlets, switches, fuses and circuit breakers for 1985. It is not appropriate to apply these distributions to estimates for earlier years.

Table B-1

Estimated Residential Structural Fires Involving Electrical Distribution Systems, by Year 1980-1985

	Total	1980	1981	1982	1983	1984	1985
		No.	No.	No.	No.	No.	No.
Total Residential	4,053,500	757,500	733,000	676,500	641,500	623,000	622,000
All Electrical Distribution System	337,600*	64,600	59,200	57,300	53,300	51,000	52,200
Fixed Wiring	123,100	22,300	20,900	21,400	19,700	19,100	19,700
Cord, Plug	63,400	12,200	11,200	10,700	10,200	9,200	9,900
Switch, Outlet	39,600	7,400	7,100	6,500	6,200	6,200	6,200
Light Fixtures	39,100	7,700	7,200	6,600	5,900	5,800	5,900
Lamp,Light Bulb	23,100	4,300	4,300	3,900	3,600	3,700	3,300
Overcurrent Protection	20,000	3,700	3,300	3,300	3,200	3,200	3,300
Meter Box	5,000	800	800	800	900	900	800
Transformer	3,500	600	700	600	600	500	500
Other	10,600	2,100	2,000	1,800	1,700	1,500	1,500
Unknown	10,200	3,500	1,700	1,700	1,300	900	1,100

*Electrical distribution system fires accounted for an estimated 9% of all residential structural fires in 1980 and 8% each year in 1981-1985.

Estimates were derived by applying proportions observed in National Fire Incident Reporting System data (NFIRS) from the U.S. Fire Administration to aggregate national estimates from an annual survey conducted by the National Fire Protection Association (NFPA).

Source: Consumer Product Safety Commission/EPHA

Table B-2

Estimated Civilian Deaths Resulting from Residential Structural Fires Involving Electrical Distribution Systems, by Component and Year, 1980-1985

		Year					
	TOTAL	1980	1981	1982	1983	1984	1985
All Residential	30,010	5,445	5,540	4,940	4,820	4,240	5,025
All Electrical Distribution System	2,490	470	470	360	410	380	400
Percent of All Residential	8%	9%	8%	7%	9%	9%	8%
Fixed Wiring	930	180	200	130	140	110	170
Cord, Plug	800	150	130	140	110	140	130
Switch, Outlet	170	20	20	20	50	10	50
Light Fixture	190	20	40	40	30	40	20
Lamp,Light Bulb	120	10	20	10	20	40	20
Overcurrent Protection	100	30	20	--	20	10	20
Meter Box	10	--	10	--	--	--	--
Transformer	10	10	--	--	--	--	--
Other	20	--	--	*	20	*	--
Unknown	130	50	20	10	20	20	10

Note: Estimates rounded to nearest 10. Estimates may not add to total due to rounding.
* Estimate rounds to less than 10 deaths.

Estimates were derived by applying proportions observed in National Fire Incident Reporting System data (NFIRS) from the U.S. Fire Administration to aggregate national estimates from an annual survey conducted by the National Fire Protection Association (NFPA).

Source: Consumer Product Safety Commission/EPHA

Table B-3

Estimated Civilian Injuries Resulting from Residential Structural Fires Involving Electrical Distribution Systems, by Component and Year, 1980-1985

		Year					
	TOTAL	1980	1981	1982	1983	1984	1985
All Residential	123,125	21,100	20,375	21,100	21,450	19,275	19,825
All Electrical Distribution System	8,980	1,600	1,450	1,710	1,450	1,460	1,310
Percent of All Residential	7%	8%	7%	8%	7%	8%	7%
Fixed Wiring	2,440	380	410	500	410	400	340
Cord, Plug	2,820	450	400	610	430	510	420
Switch, Outlet	800	110	170	120	140	130	130
Light Fixture	940	250	180	140	140	110	120
Lamp, Light Bulb	840	140	120	180	150	120	130
Overcurrent Protection	370	50	50	30	60	110	70
Meter Box	40	10	20	*	*	*	10
Transformer	90	50	--	10	20	*	1
Other	200	10	30	40	70	20	30
Unknown	430	150	70	80	30	60	40

Notes: Estimates rounded to nearest 10. Estimates may not add to total due to rounding.

*Estimate rounds to less than 10 injuries.

Estimates were derived by applying proportions observed in National Fire Incident Reporting System data (NFIRS), U.S. Fire Administration to aggregate national estimates from an annual survey conducted by the National Fire Protection Association (NFPA).

Source: Consumer Product Safety Commission/EPHA

Appendix C

Data Collection Methodology

Investigated Fires

The 149 fires included in this report were collected in a two-phase effort. For both phases, CPSC sponsored a 3 day training course in the operation of the residential electrical distribution system which was presented to personnel of fire departments that had agreed to participate. Fire departments were selected on the basis of 1) their estimated capacity to attend a sufficient number of fires of this nature, and 2) their willingness to devote a substantial number of extra hours to such investigations. The departments were reimbursed for their time on each investigation that met the scope of the project--a residential fire found to originate in a component of the residential electrical distribution system.

The U.S. Fire Administration and its consultant John Ricketts implemented the first phase--developing the data collection questionnaire, providing the training, and monitoring data collection for CPSC. This effort resulted in 105 completed investigations. The results of that effort were analyzed in a 1983 report completed for CPSC by the Center for Fire Research, National Bureau of Standards.1/

In order to enlarge the size of this data base, we initiated a second phase of data collection in 1984. This effort retained the same data collection criteria and questionnaire, but used a different contractor, Corporate Consultants, to deliver the training. This phase added an additional 44 investigations. Table C-1 presents the cities participating in each phase with the number of in-scope investigations they completed.

1/ Alan Gomberg, John R. Hall, Jr., and Richard Bukowski, "Analysis of Electrical Fire Investigations in Ten Cities," NBSIR 83-2803, U.S. Department of Commerce, National Bureau of Standards, December, 1983.

Fire departments were instructed to investigate every fire believed to originate in a component of the residential electrical distribution system. However, an investigation was accepted as in-scope for the project only if there was sufficient physical evidence to substantiate a determination of electrical distribution system involvement. This had the effect of excluding many larger loss fires.

It is important to recognize that individual case selection was made by the local fire departments. This selection involved a number of factors, including whether fire investigators were available when needed, a matter of timing within the department. The effect of these factors on the study results is unclear

Table C-1

Investigated Electrical Distribution System Fires by City and Time Period

		Years	
	TOTAL	1980-1981	1984-1985
CITIES			
	149	105	44
AKRON, OH	22	22	--
AUSTIN, TX	6	--	6
BALTIMORE,MD	10	--	10
GRAND RAPIDS,MI	4	4	--
FAIRFAX, VA	1	--	1
LONG BEACH, CA	9	8	1
NEW ORLEANS,LA	3	--	3
OAKLAND, CA	1	1	--
ONONDAGA CO.,NY (SYRACUSE)	6	--	6
PHILADELPHIA, PA	6	--	6
PORTLAND, OR	10	10	--
SACRAMENTO,CA	13	13	--
SAN DIEGO, CA	9	7	2
SAN FRANCISCO, CA	16	16	--
SAN JOSE, CA	15	11	4
TOLEDO, OH	18	13	5

Source: Consumer Product Safety Commission/EPHA

	PRODUCT/HAZARD	COMPARABLE PRODUCTS		
PROJECT NAME	Res. Electrical Dist. System	Other Elec. Resid.	All Residential	
ESTIMATED FREQUENCY OR COUNT OF CASES	52,200 Fires	121,800 Fires	622,000 Fires	
SOURCE OF FREQUENCY	NFIRS/NFPA	NFIRS/NFPA	NFIRS/NFPA	
SAMPLE SIZE	17,338	40,469	235,333	
RATE PER 100,000 households (State Denominator)	60.7	141.6	723.2	
NUMBER OF Fire DEATHS-CY 1985 (State Time Period)	420	530	5,025	
NUMBER OF PRODUCTS IN USE	Not Available	Not Available	Not Available	
Most Frequent Patterns	o o o o	o o o o	o o o o	o o o o

COMMENTS			
No. of Fire Injuries	1,300	4,200	19,825
Deaths/1000 fires	8	4	8
Injuries/1000 fires	25	34	32
Est. $ Loss	$623.6 million	$576.4 million	3,774 million
Est. $ Loss/Fire	$11,900	$4,700	$6,100

*Estimates were based on 1985 data