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Development of A Data Base for Assessing Plastics Fire Hazards

James A. Slater

Center for Fire Research
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

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Sponsored in part by:
Consumer Product Safety Commission
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DEVELOPMENT OF A DATA BASE FOR ASSESSING PLASTICS FIRE HAZARDS[1]

James A. Slater

Abstract

The growing use of plastics has, in recent years, produced an increased concern over the potential flammability of plastics materials and products. In order to assess some of the real-life hazards associated with fire incidents involving plastics, a data base of residential fire accidents is being developed. The data consist of detailed case history reports based on a questionnaire form developed at the National Bureau of Standards and laboratory tests of samples retrieved at the fire scene. The major criteria for a fire incident to be included in the data base are that (1) an identifiable plastic product played a significant role in the fire and (2) the sequence of events can be partially reconstructed. Information is collected about the building environment in which the fire occurred, the products and the persons involved in the incident, the fire development and extinguishment. The field data are being coded and computerized. Sample tabulations of field and laboratory data from the first 25 accident cases are shown.

Key words: Accident analyses; fire hazards assessment; flammability tests; hazard analysis; human behavior; plastic fires; plastics; product safety; residential fires.

1. INTRODUCTION - THE PLASTICS FLAMMABILITY "PROBLEM"

During the last few years, an increasing amount of attention has been focused on the flammability hazards of plastics materials and products. This increased concern can be attributed to several factors perhaps the most significant of which is the enormous versatility of plastics which has allowed them to enter every conceivable area of the marketplace.

Plastics have become ubiquitous in our everyday experience. In housing, transportation, medicine, interior furnishings, communications and most other fields one can think of, synthetic polymeric materials

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[1] Based in part on a paper presented at the International Conference on Fire Safety, University of San Francisco, San Francisco, California, January 16, 1976.

have become a mainstay of current technology. Molded polystyrene furniture, foamed acrylic doors, polycarbonate windows and polyvinyl chloride DWV (drain-waste-vent) pipe are just a few specific examples [1,2][2].

As plastics applications become more diversified and "natural" materials become more difficult or costly to procure and process, markets that once belonged exclusively to wood, metal, glass and other "natural" materials are being penetrated by synthetics [3,4]. As a result, plastics consumption increased from 2.4 million metric tons in 1960 to over 12.5 million metric tons in 1974, while market projections for the next 25 years predict an average annual growth rate of six to eight percent. If this forecast proves true, it will mean a 450 percent increase in plastics consumption by the year 2000 [5,6].

Given this pattern of growth, it could be surmised that the incidence of fires involving plastics materials and products might be increasing as well. And indeed, firemen are reporting fire incidents involving plastics products more frequently than ever before. They along with consumers are voicing a growing concern about the flammability hazards of plastics [7,8].

Coincident with the rise of plastics in the marketplace, there has been a dramatic increase in concern for health and safety on the part of the consumer and the government. Consumer awareness of potential plastics flammability hazards has been especially stimulated by news stories on the toxicity of plastics fumes and the flammability of foamed plastics [9,10]. Reports on the carcinogenic effects of vinyl chloride, waste disposal problems and others may have also added to the climate of concern over the safety of plastics products.

In recent years, the Federal Government has taken a more active role in regulating consumer products from the standpoint of safety and health. The Consumer Product Safety Commission and the Occupational Health and Safety Administration have joined other agencies such as the Federal Trade Commission (FTC) and the Food and Drug Administration in examining the adequacy and scope of current health and safety standards for consumer products. In the flammability area, this has led to mandatory national standards for children's sleepwear, carpets, rugs, mattresses and more recently bookmatches.

The plastics flammability problem has been addressed in a 1974 ruling by the FTC which declared that manufacturers' characterizations of cellular or foamed plastics were misleading and did not accurately represent the burning characteristics of these materials [11]. As a result, 25 companies agreed not to use terminology such as "self-extinguishing" and "slow burning" in their marketing of cellular plastics unless these terms reflect the performance of the products under actual fire conditions.

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[2] Numbers in brackets refer to the literature references listed at the end of this paper.

The FTC action illustrates some of the problems associated with assessing the real-life fire hazards of plastics materials - the main one being the failure of fire research and technology to keep pace with advances in materials technology. Many of the current flammability test methods were developed for materials that behave quite differently than plastics upon exposure to heat. These tests are thus either not applicable at all or are of very limited value. Many plastics which pass certain existing flammability tests have been found to be considerably flammable under actual end-use conditions. In addition, different tests run on the same material can produce conflicting results with regard to the material's flammability depending upon how one defines or measures flammability.

In order to develop meaningful test methods and standards for the flammability of plastics products, it is essential to examine the fire behavior of these materials in the actual configurations, environments and uses in which they are found. However, at present there is no information base which one can draw upon to obtain answers to many questions regarding the specific roles of plastics materials and products in real fires. This includes such basic information as which products and which materials are involved in fire incidents. Much laboratory data has been accumulated from small and large scale flammability testing of plastics materials, but very little documentation exists on the true fire experience of these materials.

What, for example, are the important variables in plastics fires - flame spread, heat released, smoke obscuration, ease of ignition, toxic gases? Perhaps they are all important in some types of fires or for certain types of plastics while in other situations only one or two variables may be significant. How do these variables interrelate? Are there certain configurations, constructions, designs or applications that make a plastics product more of a fire hazard than it would be otherwise? How is the role played by the plastics products affected by the environment, i.e., by the size of the compartment, the composition and construction of the walls, floors and ceilings, the airflow and the design and placement of interior furnishings? Is the extent of involvement of the plastics products greatened or lessened by people's actions during the incident? How are people's reactions to the burning plastics related to the injuries they incur? What are the similarities and the differences between the burning behavior of plastics and that of traditional materials? Answers to questions such as these are needed to bridge the gap between laboratory testing and actual fire experience.

This paper presents a description of a data base designed to begin to fill the void in information regarding the real-life experience and potential flammability hazards of plastics products. The paper will describe in some detail the nature and scope of the information being developed and show some general directions that analysis of the data may take. The field and laboratory data which follow are provided primarily to illustrate the approach taken. They do not represent specific conclusions regarding hazards of the plastics; such conclusions may be possible as more information is obtained and analyzed.

2. DATA BASE DEVELOPMENT

Due to the lack of fire incident data detailed enough to evaluate the flammability hazards of plastics, the proliferation of plastics in the marketplace and the inadequacy of existing test methods, the National Bureau of Standards' Center for Fire Research has begun to create a data base of actual fire incidents involving plastics products. This data base will be used to identify and characterize the specific roles played by plastics in real fire situations and will provide a framework for hazard analysis, the setting of priorities for test method and standards development, and laboratory modeling.

The approach being taken is a synthesis of case history reports based on a standard questionnaire form and laboratory experimentation involving samples retrieved at the fire scene. The current study has been restricted to accidental fires in residential occupancies in which an identifiable, non-fibrous[3] plastic material was involved. Fire incidents involving arson, motor vehicles, commercial or industrial properties have thus been excluded from the data base in order to restrict the scope of the project to a more manageable level. Also, fires in residential occupancies account for 72 percent of the annual U.S. fire deaths in buildings, and 40 percent of the total U.S. property loss and thus represent a major segment of the U.S. fire experience [12].

One additional requirement has been placed on the data collected. Only those incidents in which plastics products played a "significant" role are considered. In order to have been significant in a fire, a plastics product must have been one or more of the following:

- the first item to ignite,
- responsible for spreading the fire to another item,
- responsible for excessive smoke production,
- primarily responsible for property damage or injury.

This purposely limits the data base to those incidents in which plastics appear to have been a flammability problem.

It is important to note at this point that the fire incidents being investigated do not represent a statistically designed survey of plastics fires in the United States. However, it has been found from previous experience [13,14] in analyzing case history data of this type that discernible patterns appear in the data and that many facets of fire situations can be better understood using such a data base. The information being collected is designed to begin to fill the gaps in our detailed knowledge of real-life fires.

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[3] A non-fibrous material is defined as a substance which cannot be separated into threadlike structures. Its physical form may be solid (molded, formed), film, foam (flexible, rigid) or reinforced (laminated, filled).

3. FIELD DATA COLLECTION AND PROCESSING

One of the most important aspects of a project of this type is the need for quality control of the data from the initial investigation phase through the coding and computerization phases. To do the field investigations at the level of detail desired and to try to assure a reasonable level of consistency and comparability for different investigators and different fires, an extensive questionnaire form was developed. The form was designed to be used by the investigator in reconstructing the chain of events surrounding the ignition and subsequent fire development, detection and suppression with special emphasis on the products and people involved in the incident. Where possible, the National Fire Protection Association's Uniform Coding System [15] was used in formulating questions and response categories, although much additional information is sought that is not covered by that coding system. Figures A-1, A-2 and A-3 in the appendix show samples of the general information, product involvement, and personal involvement sections of the questionnaire form.

A complete case history consists of responses to multiple-choice questions as well as diagrams, photographs, a detailed narrative account of the incident, samples of products involved in the fire, fire department reports, medical data and detailed information pertaining to the products and persons involved. Over 135 data elements are coded and computerized for each plastics fire incident included in the data base. The major elements are listed in table 1 where they have been arranged arbitrarily into five categories - building environment, contents (products), people, detection/suppression and fire development/impact. Data elements listed under the Contents and People categories are obtained for each product and each person involved, respectively. The investigator attempts to obtain as much of this information as possible through interviews and observations at the fire scene. Rarely, however, is all this information available for a given fire incident due to the destruction of property, displacement of people and uncontrollable nature of the situation.

As of May 1977, 175 plastics fire incidents have been successfully investigated by both private contractors and fire departments in several locations in the United States. A sampling of the first 25 of these accident cases will be used to illustrate the types of data being collected.

4. FIELD DATA

4.1. Building Environment Information

In the building environment category (see table 1), the type of occupancy, construction and dimensions of the area of origin, ventilation factors and location of detection and control systems help describe the physical setting in which the fire occurred. For most fires which do not reach the flashover stage, the physical environment does not

Table 1. Major Data Elements

Building Environment	Contents	People	Detection/Suppression	Fire Development/Impact
Type of occupancy	Product name	Age	Method of discovery	Originating heat source
Occupancy age	Location	Sex	Detection system activation	Originating heat source age
No. of floors	Pre-fire condition	Education	Detection system effectiveness	Heat transfer method
Room (area) of origin	Age	Previous fire training/ experience	Control system activation	Cause of fire
Dimensions (room of origin)	Model characteristics	Health condition	Control system effectiveness	Time of fire
Wall composition (room of origin)	Product components	Location at ignition	Fire department presence	Extent of fire at discovery
Floor composition (room of origin)	Component composition	Activity at ignition	Extinguishment method	Fire department arrival time
Ceiling composition (room of origin)	Component construction	Initial awareness of fire		Extent of fire at fire department arrival
Interior finish	Order of involvement	Reactions to fire		Horizontal fire spread
Ventilation	Burning characteristics	Extinguishment attempt		Vertical fire spread
Detection equipment	Post-fire condition	Problems in escaping		Smoke spread
Detection equipment location		Method of escape		Plastics significance
Control systems		Injury disposition		Extent of damage
Control systems location		Location when injured		Property loss ($)

itself become a major factor in the fire development except in the sense that certain types of products and persons are more likely to be found in one setting than another. Obviously the presence of detection and suppression systems will affect the discovery and growth of a fire, so for analysis purposes information regarding their actual activation and effectiveness has been placed in a separate category (in table 1).

Some of the specific data elements which describe the physical environment in which the 25 fires occurred are shown in table 2. The list includes apartments, townhouses, detached single-family houses and a hospital, with buildings ranging in age from under five to over 25 years old at the time of the fire. Ten of the incidents began in kitchens while an equal number began in living rooms. Bedrooms, an exterior balcony and a storage room accounted for the remaining five. In order to assess the role played by walls, floors and ceilings in the fire development, information is obtained regarding the predominant (usually visible) wall, floor and ceiling materials in the area of origin. A look at the kitchen incidents in table 2, for example, shows two cases in which the floor was carpeted and another case which involved a ceiling of completely exposed, fiberglass insulation.

Very little information is available in these first 25 fire accidents regarding the effects of fire detection and control systems. Only the hospital had a detection and alarm system in the room of origin while two of the apartments reportedly had manual alarm systems accessible to the occupants but which were not used. Sprinklers in the hospital were activated and effective in controlling the fire. None of the other occupancies was reported to have had sprinklers.

4.2. Product Information

One of the most formidable problems in a study of this type is finding a method for categorizing the myriad of consumer products, plastic and non-plastic, involved in residential fires. A wide range of products is already evident in the first 25 cases as can be seen in table 3. Here typical plastics products are classified into general product categories such as food-related appliances, bedding, chairs and floor coverings. Notice that a specific product does not have to be entirely plastic to be considered a plastic product; rather it need only have identifiable components that are plastic. These are indicated in table 3 as well as their generic composition and general structural form. (Associated with each specific product is a case number which can be used to differentiate one fire incident from another and to cross-reference with other tables.)

The composition and structural form of plastics products involved in fires are particularly important for the evaluation of the flammability of these products or materials in both the laboratory and the field. This is a major thrust of our case history investigations. Polymer composition is obtained from product manufacturers whenever possible; otherwise, chemical analysis is performed on samples retrieved from the scene.

Table 2. Sample Building Environment Data Elements for 25 Fire Incidents

Type of Occupancy	Room of Origin	Wall Composition[a]	Floor Composition[a]	Ceiling Composition[a]	Occupancy Age (Yrs.)[b]	No. of Floors
Private dwelling (detached)	Kitchen (1)[c]	Plasterboard	Linoleum	Plaster	E	1-4
	Kitchen (8)	Plaster	Plastic tile	Plaster	C	1-4
	Kitchen (9)	Plastic tile	Linoleum	Fiberboard	F	1-4
	Kitchen (14)	Plastic paneling	Carpet	Plaster	C	1-4
	Kitchen (17)	Plasterboard	Carpet	Plasterboard	A	1-4
	Kitchen (18)	Plasterboard	Linoleum	Plasterboard	C	1-4
	Living room (6)	Plasterboard	Carpet	Plasterboard	E	1-4
	Living room (10)	Wood paneling	Carpet	Plaster	F	1-4
	Living room (13)	Concrete	Carpet	Plaster	D	1-4
	Living room (25)	Wood paneling	Linoleum	Acoustic tile	E	1-4
	Bedroom (7)	Concrete	Terazzo	Wood	D	1-4
	Bedroom (20)	Plaster	Wood	Plaster	F	1-4
Townhouse	Kitchen (3)	Fiberboard	Linoleum	Fiberglass insulation	F	1-4
	Kitchen (4)	Plastic tile	Plastic tile	Plasterboard	D	1-4
	Kitchen (24)	Plasterboard	Linoleum	Plasterboard	A	1-4
Apartment	Kitchen (2)	Concrete	Linoleum	Plaster	B	1-4
	Living room (19)	Plasterboard	Linoleum	Plasterboard	F	1-4
	Living room (23)	Plasterboard	Wood	Plasterboard	B	1-4
	Living room (5)	Plasterboard	Wood	Plasterboard	B	1-4
	Living room (11)	Concrete	Carpet	Plaster	B	1-4
	Living room (21)	Plasterboard	Wood	Plasterboard	F	1-4
	Living room (22)	Wood paneling	Carpet	Plasterboard	D	1-4
	Balcony (exterior) (15)	N/A	Concrete	N/A	B	1-4
	Bedroom (12)	Plaster	Carpet	Plaster	A	1-4
Hospital	Storage room (16)	Concrete	Concrete	Concrete	C	>8

[a]The wall, floor or ceiling composition specified is the predominant, visible outer layer in the room of origin. Underlying layers such as a carpet pad or wood under a carpet are not shown in this table.

[b]Age at time of fire incident: A = 0-5, B = 6-10, C = 11-15, D = 16-20, E = 21-25, F = >25.

[c]Numbers in parentheses are the accident case numbers for cross reference with other tables.

Table 3. Typical Plastics Products Found in 25 Residential Fire Incidents

General Product	Specific Product	Location During Fire	Order of Involvement	Plastic Component Name	Specific Composition[a]	Structural Form	Product Characteristics
Appliance (food-related)	Coffee Pot-Elec (4)[b]	Kitchen	3	Handle Base Cord-Elec	Phenolic Phenolic ?	Rigid Rigid Flexible	660W; 8-10 cup; metal pot
	Range-Elec (2)	Kitchen	1	Switch Button Switch Plate Switch Body Switch Insulation	Urea Polypropylene Phenolic Phenolic	Rigid Rigid Rigid Rigid	Controls in rear
	Range Hood (2)	Kitchen	2	Switch Button	Phenolic	Rigid	
Appliance (non-food-related)	Air Conditioner (22)	Kitchen	?	Case	?	Rigid	
	Lamp (12)	Bedroom	1	Base Lampshade Collar Cord-Elec Plug-Elec	Polystyrene Polystyrene Nylon Polyvinyl Chloride Polyvinyl Chloride	Rigid Rigid Rigid Flexible Rigid	Portable
	Light Fixture (4)	Kitchen	?	Cover	PMMA	Rigid	Ceiling fixture
	Timer-Elec (4)	Kitchen	1	Case	ABS	Rigid	24-hr
Kitchen Equipment	Baby Bottle (24)	Kitchen	1	Cap Seal	Polypropylene Polypropylene	Rigid Rigid	
	Bowl (18)	Kitchen	?	N/A	?	Rigid	
	Dispenser-Paper Towel (3)	Kitchen	?	N/A	Styrene-Butadiene	Rigid	Price $8
	Mat (17)	Kitchen	1	Sublayer-A	Styrene-Butadiene Rubber	Rigid	Stove Mat
	Pot (1)	Kitchen	1	Handle	Phenolic	Rigid	8 in diam.; teflon coated
Bed	Mattress (7)	Bedroom	2	Sublayer-A Sublayer-B	*Polyurethane *Styrene-Butadiene Rubber	Rigid Foam Flexible Foam	King-size
Bedding	Pillow (25)	Living Room	1	Sublayer-A	Styrene-Butadiene Rubber	Flexible Foam	3.0-3.5 lb/ft^3

Table 3 (Cont.)

General Product	Specific Product	Location During Fire	Order of Involvement	Plastic Component Name	Specific Composition[a]	Structural Form	Product Characteristics
Chair	Chair-Bean Bag (22)	Living Room	1	Sublayer-A	Polyurethane	Flexible Foam	Shredded polyurethane interior
	Chair-High (8)	Kitchen	1	Seat	PVC/Polyurethane	Non-woven Fabric/ Flexible Foam	1.5 in thick seat and back cushions
				Back	PVC/Polyurethane	Non-woven Fabric/ Flexible Foam	
	Chair-Upholstered (21)	Living Room	?	Arm	?/?	Non-woven Fabric/ Flexible	Recliner
				Back	?/?	Non-woven Fabric/ Flexible	
				Seat Cushion	?/?	Non-woven Fabric/ Flexible Foam	
				Back Cushion	?/Polyurethane	Non-woven Fabric/ Flexible Foam	
	Sofa-Sleep (13)	Living Room	2	Unknown	*PVC/*Polyurethane	Non-woven Fabric/ Flexible Foam	3 seat cushions; arms price $199
Cabinetry	Counter (8)	Kitchen	2	Outer Layer	*Melamine-Formaldehyde	Rigid	
	Table (TV) (23)	Living Room	2	N/A	Polyvinyl Chloride	Rigid	Mediterranean style; swivel top
Floor Covering	Carpet (4)	Kitchen	7	Backing	*Styrene-Butadiene Rubber	Flexible	Small throw rug
	Carpet Pad (12)	Bedroom	2	Outer Layer	*Styrene-Butadiene Rubber	Flexible Foam	Waffled construction
	Tile-Floor (4)	Kitchen	8	Outer Layer	*Polyvinyl Chloride	Flexible	Peel and stick type
Wall Covering	Tile-Wall (9)	Kitchen	2	N/A	Polystyrene	Rigid	
	Wallpaper (18)	Kitchen	?	Outer Layer	Polyvinyl Chloride	Coating	
Recreational (electronic)	Television (11)	Living Room	1	Case	Styrene-Butadiene	Rigid	Color; 19 in; portable
Recreational (non-electronic)	Toy (21)	Bedroom	?	N/A	?	Rigid	Airplane model

Table 3 (Cont.)

General Product	Specific Product	Location During Fire	Order of Involvement	Plastic Component Name	Specific Composition[a]	Structural Form	Product Characteristics
Hardware	Washer-Faucet (18)	Kitchen	?	N/A	*Neoprene	Rigid	.5 in diameter
Electrical Distribution Equipment	Electric Outlet (4)	Kitchen	3	N/A	?	Rigid	
	Extension Cord (7)	Bedroom	1	Plug-Elec	Polyvinyl Chloride	Rigid	Heavy duty; 110V; 2 ft long
				Wire Insulation	Polyvinyl Chloride	Flexible	
Structural	Cove Base (16)	Storage Room	?	N/A	Styrene-Butadiene Rubber	Rigid	Tan; 6 in x .125 in
Other Non-Furnishings	Trash (13)	Living Room	1	N/A	?	Film	Plastic and paper

[a]Composition is determined from manufacturers' information or chemical analysis in the laboratory. When composition has not been confirmed, the reported information is given in the table and marked with an asterisk (*). PMMA = polymethyl methacrylate; ABS = acrylonitrile-butadiene-styrene; PVC = polyvinyl chloride.

[b]Numbers in parentheses are the accident case numbers for cross reference with other tables.

Structural form of materials has been defined for coding purposes according to a set of four general classifications - fabric or fibrous, film, rigid and flexible. Fabric is divided into woven and non-woven fabrics, the latter including vinyl upholstery, for example. Films include very thin sheeting, coatings or laminates under 30 mil (0.8 mm) thick such that the thickness is very small relative to the length and width. Sheeting greater than 30 mil (0.8 mm) thick, as well as rods, blocks, and molded, casted and extruded materials are categorized as rigid forms. Rigid foams are specifically identified also. The flexible category is used for stuffing and batting (e.g., in upholstered furniture), semi-rigid and other non-rigid materials exclusive of fabrics, and flexible foams which are classified separately. Although these categories were created with synthetic polymeric materials in mind, they are used for convenience to classify all types of materials.

In all, 88 products (plastic and non-plastic) with a total of 155 identifiable components are represented in the first 25 accident cases. Tables 4 and 5 have been organized by room of origin to show the kitchen fires and living room fires, respectively. Within each table, fire incidents have been grouped by originating heat source. Products involved in each fire are shown starting with the heat source, the mode of heat transfer to the first product ignited and then to other products involved. The order of involvement of each product is given when known. Also shown is the reported significance of the plastics products in the fire.

The second incident in table 4 (Case No. 9) is representative of many kitchen fires. In this case heat from an electric range burner ignited grease in a pan. The resulting flames then ignited the polystyrene wall tile behind the range. Smoke production and the resulting injury were the significant contributions made by the plastic wall tile.

A typical living room fire involved a television (Case No. 6, table 5) which short-circuited and subsequently involved the wall, carpet and TV table in the fire. In this case, a plastic product was the first item ignited. In addition, plastics contributed significantly to smoke production, fire spread and melted in such a way as to be a further hazard.

4.3. Human Behavior Information

While the product involvement in a fire incident is a primary interest in this study, the human involvement is frequently a significant factor in the initiation, growth, and control of the fire as well as the property damage and personal injury incurred. Consequently, certain human behavioral aspects have been included in the field investigations. Besides age, sex, education and state of health prior to the fire, attempts are made to trace people's actions from their original location at the time of ignition through subsequent interactions with the developing fire and with other people at the scene.

Table 4. Products Involved in Fire Incidents Originating in the Kitchen

Originating Heat Source	Heat Transfer Method	Reported Plastics Significance[a]	Product Name	Location During Fire	Order of Involvement[b]
Range-Elec (2)[c]	Short circuit	1st	Range-Elec	Kitchen	1
			Range Hood	Kitchen	2
Range-Elec (9)	Heat from proper operation	Smoke/Injury	Grease-Food	Kitchen	1
			Tile-Wall	Kitchen	2
Range-Elec (17)	Heat from proper operation	1st/Smoke	Mat	Kitchen	1
Range-Elec (18)	Heat from proper operation	Spread	Grease-Food	Kitchen	1
			Bowl	Kitchen	?
			Washer (faucet)	Kitchen	?
			Wallpaper	Kitchen	?
			Cabinet	Kitchen	?
Range-Elec (24)	Heat from proper operation	1st/Smoke/Spread	Baby Bottle	Kitchen	1
			Range Hood	Kitchen	2
Range-Gas (1)	Flame	1st	Pot	Kitchen	1
Range-Gas (3)	Unknown	Melt/Spread	Dispenser-Paper	Kitchen	?
			Insulation	Ceil./Flr. Inter.	?
			Insulation	Wall Interior	?
			Pot	Kitchen	?
Timer-Elec (4)	Short circuit	1st/Smoke/Spread	Timer-Elec	Kitchen	1
			Extension Cord	Kitchen	2
			Electric Outlet	Kitchen	3
			Coffee Pot-Elec	Kitchen	3
			Tile-Wall	Kitchen	5
			Curtain	Kitchen	6
			Carpet	Kitchen	7
			Tile-Floor	Kitchen	8
			Spice Rack	Kitchen	?
			Dispenser-Paper	Kitchen	?
			Light Fixture	Kitchen	?
			Mat	Kitchen	?
Toaster (14)	Heat from proper operation	Melt/Spread	Towel	Kitchen	1
			Dispenser-Paper	Kitchen	2
			Cabinet	Kitchen	3
			Counter	Kitchen	3
Candle (8)	Flame	1st/Smoke/Spread	High Chair	Kitchen	1
			Tile-Floor	Kitchen	2
			Cabinet	Kitchen	2
			Counter	Kitchen	2
			Reading Material	Kitchen	?

[a] 1st = 1st item to ignite was plastic; Smoke = excessive smoke production; Heat = excessive heat production; Melt = melted or dripped creating a hazard; Spread = propagated fire to another item; Injury = contributed to injury or death.

[b] If 2 or more items became involved simultaneously or the relative order of the 2 items could not be determined but the sequence before and after these 2 items was known, then the 2 items were given the same order number.

[c] Numbers in parentheses are the accident case numbers for cross reference with other tables.

Table 5. Products Involved in Fire Incidents Originating in the Living Room[a]

Originating Heat Source	Heat Transfer Method	Reported Plastics Significance[b]	Product Name	Location During Fire	Order of Involvement[c]
Floor Furnace (22)[d]	Heat from proper operation	1st/Spread/Injury	Bean Bag Chair	Living Room	1
			Sofa	Living Room	?
			Upholstered Chair	Living Room	?
			Paneling-Wall	Living Room	?
			Television	Living Room	?
			Air Conditioner	Kitchen	?
			Lamp	Bedroom	?
Furnace-Oil (25)	Heat from proper operation	1st	Pillow	Living Room	1
Television (6)	Short circuit	1st/Smoke/Melt/ Spread	Television	Living Room	1
			Wall	Living Room	2
			Carpet	Living Room	3
			Table (TV)	Living Room	?
Television (11)	Short circuit	1st/Smoke/Melt/ Spread/Injury	Television	Living Room	1
			Table	Living Room	2
Television (23)	Short circuit	1st/Smoke/Spread/ Injury	Television	Living Room	1
			Table (TV)	Living Room	2
			Upholstered Chair	Balcony (exter.)	3
Cigarette (5)	Hot ember or ash	Injury	Upholstered Chair	Living Room	?
			Shirt	Living Room	?
			Undershorts	Living Room	?
			Pants	Living Room	?
			Blanket	Living Room	?
Smoking Material[e] (10)	Hot ember or ash	1st/Smoke/Heat/ Spread/Injury	Sofa	Living Room	1
			Upholstered Chair	Living Room	2
			Paneling-Wall	Living Room	2
Smoking Material[e] (19)	Unknown	1st/Spread	Upholstered Chair	Living Room	1
			Tile-Floor	Living Room	2
Match (13)	Spark, ember or flame	Smoke/Heat/Melt/ Spread	Trash	Living Room	1
			Sleep Sofa	Living Room	2
			Upholstered Chair	Living Room	3
Unknown (21)	Unknown	Heat/Spread	Sofa	Living Room	1
			Upholstered Chair	Living Room	?
			Upholstered Chair	Living Room	?
			Table	Living Room	?
			Table	Living Room	?
			Television	Living Room	?
			Door	Living Room	?
			Curtain	Living Room	?
			Toy	Bedroom	?

[a]Living room includes family room, den and recreation room.

[b]See note a to Table 4.

[c]See note b to Table 4.

[d]See note c to Table 4.

[e]Specific smoking material (e.g., cigarette, cigar or pipe) unknown.

Some of the human elements related to the kitchen and living room fire incidents are shown in tables 6 and 7. Incidents are grouped by originating heat source. The persons directly involved in each incident are listed and, for each, their location and activity at the time of ignition, the means by which they initially became aware of a fire and their first three reactions to the situation. Extinguishment attempts and injury disposition are also shown.

Consider, for example, the first case shown in table 6 (Case No. 2). Here three people were sleeping in different bedrooms when a fire began due to a short-circuit (see table 4) in the electric range in the kitchen. A 26 year old male was awakened by the smell of smoke. He investigated the source, helped the other people in the dwelling escape and escaped himself. The two people warned by the 26 year old left the dwelling and did nothing further regarding the fire ("N/A" in table). None of the three attempted extinguishment nor was injured. A fourth person (35 year old male) was awake outside the building when he smelled smoke and investigated the source. He notified other people, entered the dwelling and attempted extinguishment with a chemical extinguisher.

The reactions coded in these incidents are based on the reason or motivation behind the action rather than the specific action that took place. Case No. 21 in table 7 illustrates this point. A 28 year old male was awakened by the smell of smoke in his bedroom. He left the bedroom and tried to open the front door to the apartment in order to obtain a fire extinguisher in the building hallway. The intense heat in the living room drove him back to the bedroom where he helped another occupant escape. The man's reason for going into the living room (to obtain an extinguisher) has been coded as his first reaction rather than the specific act of going from bedroom to living room.

4.4. Fire Development and Losses

Finally, in order to put all the product and human behavior information in perspective, tables 8 and 9 present some data on the overall fire development and resulting losses, again using the kitchen and living room incidents as examples. The fire is traced from its cause and originating heat source to the extent of burning at the time of discovery and to its extent when the fire department arrived on the scene. The final outcome of each fire is expressed in terms of the total extent of damage (including smoke), property loss in dollars and the number of injured persons (including deaths). Most of the kitchen incidents in table 8 were contained within the room of origin, extinguished prior to arrival of the fire department and resulted in no injuries. Living room fires in table 9 have a greater extent of damage in general than the kitchen fires, and seven of the ten living room incidents involved an injury.

Table 6. Activities and Reactions of Persons Involved in Fires Originating in the Kitchen

Originating Heat Source	Age/ Sex	Location at Ignition	Activity at Ignition	Initial Awareness of Fire	Reaction # 1	Reaction # 2	Reaction # 3	Extinguishment Attempt	Injury Disposition
Range-Elec (2)[a]	24/M	Bedroom # 1	Sleeping	Heard other person call	Escaped from dwelling	N/A	N/A	None	Not injured
	24/F	Bedroom # 2	Sleeping	Heard other person call	Escaped from dwelling	N/A	N/A	None	Not injured
	26/M	Bedroom # 3	Sleeping	Smelled smoke	Investigated source	Helped someone escape	Escaped from dwelling	None	Not injured
	35/M	Outside bldg.	Awake/ uninvolved	Smelled smoke	Investigated source	Warned other persons	Entered dwelling	Chemical extinguisher	Not injured
Range-Elec (9)	70/M	Living room	Awake/ uninvolved	Heard other person call	Tried to extinguish	N/A	N/A	Smothering	First aid
	70/F	Living room	Awake/ uninvolved	Saw smoke	Warned other person	N/A	N/A	None	First aid
Range-Elec (17)	48/F	Bedroom	Awake/ uninvolved	Saw flames and smoke	Warned other person	Tried to move burning object	Tried to extinguish	Removed burning object from heat; Water	Not injured
	48/M	Bathroom	Awake/ uninvolved	Heard other person call	Investigated source	Tried to extinguish	N/A	Smothering	Not injured
Range-Elec (18)	40/F	Living room	Awake/ uninvolved	Heard fire or its effects	Investigated noise	Called FD	Escaped from dwelling	None	Not injured
	?/F	Living room	Awake/ uninvolved	Heard other person call	Escaped from dwelling	N/A	N/A	None	Not injured
Range-Elec (24)	32/F	Outside bldg.	Awake/ uninvolved	Saw smoke	Helped someone escape	Turned off equipment	Tried to extinguish	Turned off equipment; Removed burning object from heat; Water	Not injured
Range-Gas (1)	64/M	Living room	Awake/ uninvolved	Smelled smoke	Investigated source	Called FD	Escaped to other area in dwelling	None	Not injured
	64/F	Kitchen	Using orig. heat source to prepare food	Heard other person call	Turned off equipment	Escaped to other area in dwelling	N/A	None	Not injured

Table 6 (Cont.)

Originating Heat Source	Age/ Sex	Location at Ignition	Activity at Ignition	Initial Awareness of Fire	Reaction # 1	Reaction # 2	Reaction # 3	Extinguishment Attempt	Injury Disposition
Range-Gas (3)	57/F	Outside bldg.	Awake/ uninvolved	Saw flames and smoke	Called other person for help	Called FD	Entered dwelling	Water	Not injured
Timer-Elec (4)	13/F	Bedroom # 1	Sleeping	Heard other person call	Escaped from dwelling	N/A	N/A	None	Not injured
	40/F	Bedroom # 2	Sleeping	Smelled smoke	Other	Warned other person	Escaped from dwelling	None	Not injured
Toaster (14)	57/F	Bathroom	Awake/ uninvolved	Smelled smoke	Tried to obtain extinguishing agent	Tried to move burning object	Turned off equipment	Removed burning object from heat; Turned off equipment; Smothering	Not injured
Candle (8)	21/F	Outside bldg.	N/A	Saw/smelled smoke	N/A	N/A	N/A	None	Not injured
	50/F	Outside bldg.	N/A	Saw/smelled smoke	Other	Called FD	N/A	None	Not injured
	52/M	Outside bldg.	N/A	Saw/smelled smoke	Investigated source	Tried to move burning object	Tried to extinguish	Removed burning object from heat; Water	Not injured

[a]Numbers in parentheses are the accident case numbers for cross reference with other tables.

Table 7. Activities and Reactions of Persons Involved in Fires Originating in the Living Room

Originating Heat Source	Age/ Sex	Location at Ignition	Activity at Ignition	Initial Awareness of Fire	Reaction # 1	Reaction # 2	Reaction # 3	Extinguishment Attempt	Injury Disposition
Floor Furnace (22)[a]	21/F	Bedroom	Sleeping	Alerted by other person	Unknown	Escaped from dwelling	Unknown	None	Not injured
	25/M	Bedroom	Sleeping	Alerted by other person	Tried to move burning object	Helped someone escape	Helped someone escape	Removed burning object	Hospitalized
Furnace-Oil (25)	2/F	Bedroom # 1	Sleeping	Alerted by other person	Dressed	Escaped from dwelling	N/A	None	Not injured
	5/M	Bedroom # 1	Sleeping	Alerted by other person	Dressed	Escaped from dwelling	N/A	None	Not injured
	29/F	Bedroom # 2	Sleeping	Smelled smoke	Investigated source	Called FD	Warned other person	None	Not injured
	31/M	Bedroom # 2	Sleeping	Alerted by other person	Investigated source	Dressed	Helped someone escape	None	Not injured
Television (6)	1/M	Bedroom	Sleeping	Unknown	Unknown	Unknown	Unknown	None	Not injured
	2/F	Living room	Using orig. heat source	Alerted by other person	None	Escaped from dwelling	N/A	None	Not injured
	6/F	Living room	Using orig. heat source	Smelled smoke	None	Escaped from dwelling	N/A	None	Not injured
	8/F	Living room	Using orig. heat source	Smelled smoke	None	Escaped from dwelling	N/A	None	Not injured
	28/F	Living room	Using orig. heat source	Smelled smoke	Turned off equipment	Called FD	Helped someone escape	None	Not injured
Television (11)	41/M	Bathroom	Awake/ uninvolved	Alerted by other person	Dressed	Investigated source	Escaped to other area in dwelling	Chemical extinguisher	Not injured
	44/F	Bedroom	Sleeping	Smelled smoke	Called for help	Turned off equipment	Tried to extinguish	Turned off equipment; Chemical extinguisher	First aid
	?/F	Other apt. in building	Uninvolved	Saw/smelled smoke	Tried to obtain extinguishing agent	Investigated source	Called FD	None	Not injured
Television (23)	28/M	Kitchen	Awake/ uninvolved	Smelled smoke	Investigated source	Turned off equipment	Tried to obtain extinguishing	Turned off equipment; Smothering	First aid

Table 7 (Cont.)

Originating Heat Source	Age/ Sex	Location at Ignition	Activity at Ignition	Initial Awareness of Fire	Reaction # 1	Reaction # 2	Reaction # 3	Extinguishment Attempt	Injury Disposition
Cigarette (5)	62/F	Kitchen	Preparing food	Alerted by other person	Investigated source	Tried to extinguish	Tried to obtain extinguishing agent	Smothering; Water	Not injured
	64/M	Living room	Smoking and sleeping	Unknown	Unknown	Called for help	Unknown	Unknown	Died
	?[b]/F	Kitchen	Preparing food	Alerted by other person	Investigated source	Tried to extinguish	Unknown	Smothering	Not injured
	?/M	Other apt. in building	Awake/ uninvolved	Alerted by other person	Investigated source	Tried to obtain extinguishing agent	Tried to extinguish	Chemical extinguisher	Not injured
Smoking Material[c] (10)	5/?	Bedroom # 1	Sleeping	Alerted by other person	Escaped from dwelling	N/A	N/A	None	Not injured
	7/?	Bedroom # 1	Sleeping	Alerted by other person	Escaped from dwelling	N/A	N/A	None	Not injured
	10/M	Bedroom # 1	Sleeping	Smelled smoke	Warned other person	Escaped from dwelling	N/A	None	Not injured
	25/F	Bedroom # 2	Sleeping	Alerted by other person	Helped someone escape	Escaped from dwelling	Called FD	None	Not injured
	30/M	Living room	Smoking and sleeping	Unknown	Tried to extinguish	Called FD	Escaped to other area in dwelling	Water extinguisher	Died
Smoking Material[c] (19)	57/M	Living room	Smoking and sleeping	Unknown	Unknown	Unknown	Unknown	Unknown	Died
Match (13)	56/M	Yard	Awake/ uninvolved	Alerted by other person	Tried to obtain extinguishing agent	Tried to extinguish	Entered dwelling	Water	Not injured
	65/F	Utility room	Awake/ uninvolved	Saw/smelled smoke	Called for help	Irrational behavior	Escaped from dwelling	None	Not injured
	68/M	Living room	Smoking	Saw flames and smoke	Tried to move burning object	Tried to extinguish	Investigated source	Removed burning object from heat; Water	Not injured
Unknown (21)	28/M	Bedroom	Sleeping	Smelled smoke	Tried to obtain extinguishing agent	Escaped to other area in dwelling	Helped someone escape	None	Hospitalized

[a]Numbers in parentheses are the accident case number for cross reference with other tables.

[b]21-65 yrs. old.

[c]Specific smoking material (e.g., cigarette, cigar or pipe) unknown.

Table 8. Fire Development and Resultant Damage for Fires Originating in the Kitchen

Originating Heat Source	Cause of Fire	Extent at Discovery	Extent at FD Arrival	Extent of Damage	Property Loss[a]	No. of Injuries
Range-Elec (2)[b]	Elec failure/not in use	1st item	Extinguished	Part of room	C	0
Range-Elec (9)	Cooking/overheated grease	Part of room	N/A	Floor	C	2
Range-Elec (17)	Cooking/not grease	1st item	N/A	Room	?	0
Range-Elec (18)	Cooking/overheated grease	Part of room	Extinguished	Room	B	0
Range-Elec (24)	Cooking/not grease	1st item	Part of room	Part of room	B	0
Range-Gas (1)	Cooking/not grease	1st item	Extinguished	1st item	A	0
Range-Gas (3)	Combustibles too near heat source	Part of room	Extinguished	Part of room	B	0
Timer-Elec (4)	Elec failure/proper use	Part of room	Part of room	Floor	C	0
Toaster (14)	Cooking/not grease	Part of room	Extinguished	Room	B	0
Candle (8)	Heat source too near combustibles	1st item	Extinguished	Building	C	0

[a] A = $0-99; B = $100-999; C = $1,000-9,999.

[b] Numbers in parentheses are the accident case numbers for cross reference with other tables.

Table 9. Fire Development and Resultant Damage for Fires Originating in the Living Room

Originating Heat Source	Cause of Fire	Extent at Discovery	Extent at FD Arrival	Extent of Damage	Property Loss[a]	No. of Injuries
Floor Furnace (22)[b]	Combustibles near heat source	Floor	Floor	Floor	C	1
Furnace-Oil (25)	Combustibles near heat source	1st item	1st item	Part of room	B	0
Television (6)	Elec failure/proper use	1st item	Part of room	Floor	B	0
Television (11)	Elec failure/proper use	1st item	Extinguished	Floor	C	1
Television (23)	Elec failure/not in use	1st item	Floor	Floor	C	1
Cigarette (5)	Smoking and Sleeping	Part of room	Extinguished	Part of room	?	1
Smoking Material[c] (10)	Unknown use	1st item	Part of room	Building	?	1
Smoking Material[c] (19)	Smoking and sleeping	Self-extinguished	Extinguished	Part of room	B	1
Match (13)	Discarded smoking material	Part of room	Part of room	Building	C	0
Unknown (21)	Unknown	Room	Unknown	Floor	C	1

[a] B = $100-999; C = $1,000-9,999.

[b] Numbers in parentheses are the accident case numbers for cross reference with other tables.

[c] Specific smoking material (e.g., cigarette, cigar or pipe) unknown.

5. LABORATORY CHARACTERIZATION

Retrieval of samples at the scene of a fire is an integral part of the field investigations. One of the major objectives of this study is to develop laboratory procedures for characterizing or evaluating the flammability of plastic materials and products relative to the fire incident in which the materials were involved. This is particularly difficult due to the paucity of acceptable standard test methods for evaluating the products in a realistic manner. At the same time, the pieces of material retrieved at the scene are usually so small they preclude the use of many test methods due to an insufficient quantity of the material to be tested.

Within these constraints and without actually trying to develop new tests, existing testing procedures have been applied or adapted to the problem at hand. It is, first of all, useful to divide the laboratory tests into three types - basic property, fire performance and simulation. Each of these is enumerated in table 10. Basic properties define inherent characteristics of materials and may be associated with fundamental differences in structure and composition. They are not by themselves a measure of flammability behavior but are causally related to fire performance. On the other hand, fire performance properties are direct measures of a material's flammability behavior under closely controlled experimental conditions which may or may not reflect the actual exposure conditions to which the material would be subjected in a real fire. Performance properties, however, do permit a relative assessment of the fire response of different materials.

Table 10. Laboratory Characterizations of Accident Case Samples

Basic Properties	Fire Performance Properties	Simulations
Generic composition	Self-ignition temperature	Sunlight ignition of PVC upholstery
Fire retardants	Smoke density	Burning characteristics of polyethylene trash bags
Density	Burning characteristics	Response of plastic ceiling panels to kitchen grease fires
Non-combustible content		
Melting point		

The biggest problem with the basic and fire performance tests is that they do not, at present, have the capacity to predict the behavior of individual products, or systems of products, under actual end use conditions. For this reason, full and reduced scale simulations of accidents are essential to verify and interpret the actual fire behavior of products, especially as reported in the field investigations. In the present study, several reported accident patterns have been simulated in order to corroborate and more fully understand the potential hazards involved. These have included the effects of sunlight exposure on the auto-ignition of PVC upholstery fabrics, the burning characteristics of polyethylene trash bags, and the response of plastic suspended ceiling panels to simulated kitchen grease fires (see table 10).

Experimental work has concentrated on the development of a set of routine laboratory procedures for characterizing sample plastics materials retrieved during fire investigations. The inadequacy of many common testing procedures compounded by the insufficient quantities of sample, heat stressing and partial decomposition undergone by the products during the fire have to a large degree determined the nature of the current testing program.

Data are being collected for five basic properties and three fire performance properties. In the basic area, chemical composition is considered of primary interest since if there is too little sample to run other tests, knowledge of the type of product and generic composition can be used to relate one product to other similar products for which more data are available. Generic composition is obtained through infrared spectroscopy which identifies the basic polymer (e.g., polyethylene, polyurethane or styrene-butadiene). X-ray fluorescence spectroscopy is then employed to identify elements such as chlorine, antimony, bromine and phosphorus which are indicative of fire retardants in the material. An estimate of the inert, non-volatizable or non-combustible content of the material is also obtained by heating specimens of the material in crucibles suspended over an open flame. The weight loss of the sample is a measure of the decomposable and burnable content of the material.

Density measurements of non-foamed materials are made using a buoyancy in water technique which works extremely well with irregularly shaped samples such as are found at a fire scene. This method does not work for many foamed and fibrous materials which therefore require dimensional measurements and direct weighing to compute the density.

The melting or softening point is the last of the basic property tests being conducted. This is done by visually observing the behavior of small pieces of a material as they are gradually heated on a metal block of a Fisher-Johns Melting Point Apparatus. The temperatures or temperature ranges at which the material appears to soften and melt are noted.

Basic properties such as the ones discussed above and others such as thermal conductivity and specific heat are not by themselves sufficient for predicting the flammability characteristics of materials in general, although they obviously affect these characteristics. It is first necessary to define a meaningful set of fire performance properties which may then be linked to the underlying basic properties. Most of the commonly used test procedures fall in the domain of fire performance tests and include flame spread, heat release, ignition and smoke properties. Out of these, three tests were adapted for use in this study - self-ignition temperature, smoke density and a qualitative analysis of burning characteristics.

The self-ignition temperature of samples is being determined basically in accordance with the ASTM test method for ignition properties of plastics [16]. In this procedure, a specimen is suspended in a heated air stream in a furnace. For our purposes, the minimum air temperature at which flaming combustion occurs is denoted as the self-ignition temperature. An abbreviated version of this procedure is employed when the amount of available sample is too limited to run the normal procedure. Using the abbreviated method, materials are classified into one of four self-ignition temperature categories: (a) below 350°C, (b) 350°-450°C, (c) 450°-550°C and (d) above 550°C.

Smoke production is being measured using the standard NBS Smoke Chamber [17,18]. Unfortunately, this procedure requires a 3 inch (7.6 cm) square specimen of the material to be tested which is rarely available in a fire situation. As a result, experiments are being carried out with 2 inch (5.1 cm) square specimens which, if successful, would increase the potential use of the Smoke Chamber.

A frequent problem encountered in trying to evaluate samples from the field is the need to decide which of several tests to run if the amount of retrieved sample is limited. For this reason, a qualitative screening procedure was developed for assessing the response of a horizontally supported sample to an open flame heat source. The chart shown in figure 1 is used to record the observed behavior including smoke, flame height, melting, dripping, and ability to self-extinguish after the flame source is removed. This permits a rough determination of the type of plastic and its relative flammability behavior.

Table 11 summarizes the laboratory data that have been compiled to date for selected products in the first 25 accident cases. Self-ignition temperature data are the least complete because the test requires more sample than is frequently available. Similarly, smoke density measurements are not shown at all in the table because of the general lack of appropriate specimens 3 inch (7.6 cm) square to test in the NBS Smoke Chamber. However, a qualitative appraisal of smoke production is shown in the Burning Characteristics smoke data which is somewhat analogous to the observations one might make at the scene of a fire (see fig. 1).

BURNING CHARACTERISTICS CHECKLIST

CASE NO. _____ ITEM _____

A) EASE OF IGNITION:

_____ DID NOT IGNITE
_____ IGNITED ON 1ST EXPOSURE (< 15 SEC)
_____ IGNITED ON 2ND EXPOSURE (< 30 SEC)
APPROXIMATE IGNITION TIME _____ SEC

B) TYPE OF COMBUSTION:

_____ SMOLDERING ONLY _____ FLAMING ONLY
_____ SMOLDERING ——————> FLAMING
_____ FLAMING ——————> SMOLDERING
_____ SELF-EXTINGUISHING

C) FLAME COLOR

_____ BLUE _____ YELLOW _____ ORANGE
_____ OTHER _____

D) VISIBLE FLAME HEIGHT:

_____ LOW (< 3 CM)
_____ MEDIUM (3-6 CM)
_____ HIGH (> 6 CM)

E) SMOKE:

_____ NONE _____ BLACK _____ GRAY _____ WHITE
_____ DENSE (HIGH OPACITY) _____ NOT DENSE (LOW OPACITY)
_____ SOOTY (VISIBLE PARTICULATES) _____ STRINGY

F) ODOR:

_____ PUNGENT _____ PLEASANT _____ ACID
_____ FISHY _____ ANTISEPTIC

_____ VINEGARY _____ CAMPHOR _____ RUBBERY
_____ PARAFFIN (WAX) _____ BURNT HAIR

_____ PHENOLIC _____ FORMALDEHYDE _____ STYRENE

_____ STRONG _____ WEAK

G) MATERIAL RESPONSE:

_____ DISCOLORS _____ BROWNS _____ BLACKENS
_____ SOFTENS _____ BUBBLES _____ MELTS
_____ DRIPS (NON-FLAMING) _____ DRIPS (FLAMING)

_____ CHARS _____ INTUMESCES _____ CRACKS
_____ WHITE ASH _____ DISINTEGRATES

H) REMARKS:

Figure 1. Burning characteristics checklist.

Table 11. Selected Laboratory Data from Accident Cases 1-25

Item Type	Component Name	Generic Composition[a]	Specific Gravity	Melting Point (°C)	Weight Loss (%)	Self-Ignition Temperature (°C)	Burning Characteristics: Combustion[b]	Burning Characteristics: Smoke[c]	Case No.
Coffee Pot-Elec	Base	PH	1.35	N/A	58	---[d]	---	---	4
Range-Elec	Switch plate	PP	0.92	166	100	375	F,M,D	B,L,sooty	2
Lamp	Base	PS	1.04	178-187	99	---	F,M,D	B,H,sooty,stringy	12
Lamp	Collar	NY	1.00	210	95	---	F→S,M,D/S.E.	N	12
Lamp	Cord-Elec	PVC	1.14	160-165	63	---	F→S/S.E.	B,L,sooty,stringy	12
Light Fixture	Cover	PMMA	0.98	210	100	---	F,M,D	G,L	4
Baby Bottle	Cap	PP	0.91	170-175	100	---	F,M,D	W	24
Baby Bottle	Seal	PP	0.92	170-175	100	---	---	---	24
Dispenser-Paper Towel		SB	0.99	140-147	97	450-550[e]	F,D	B,sooty	3
Dispenser-Paper Towel		PS	1.07	160-175	98	---	F,M,D	B,H,sooty,stringy	4
Mat-Stove		SBR	1.72	>300	37	435	F→S/S.E.	B,H,sooty	17
Pot	Handle	PH	1.35	N/A	57	558	S.E.	B	1
Chair-Bean Bag	Stuffing(foam)	PU	----	210	99	---	F,M,D	G,L	22
Chair-Upholstered	Outer upholstery	PVC	0.79	---	83	350-450[e]	---	---	5
Chair-Upholstered	Sublayer A(foam)	SBR	----	210-215	68	---	---	---	5
Sofa	Seat Cush/ Sublayer A(foam)	PU	.063	---	58	325-360	F,M,D	N	10
Sofa	Sublayer A(foam)	PU	.046	---	55	---	F,M,D	G,L,sooty	22
Sofa	Sublayer B(foam)	PU	.020	---	98	---	F	G	22
Floor Tile		?	1.35	150-160	54	485	---	---	4
Floor Tile	Top layer	PVC/limestone	1.42	191-197	37	---	S	B	8
Wall Tile		PS	1.05	147-153	100	---	F,M,D	B,H,sooty,stringy	4
Wall Tile		PS	1.07	180-185	90	450-550[e]	F,M,D	B,H,stringy	9
TV	Case	SB	0.97	170-175	100	---	F→S,M,D/S.E.	B,H,sooty,stringy	11
Elec Extension Cord	Plug	PVC	1.32	150-160	71	---	F→S,M/S.E.	N	7
Cove Base		SBR	1.80	>300	32	420	F→S/S.E.	B→W,H,sooty,stringy	16

[a] NY = nylon; PH = phenolic; PMMA = polymethyl methacrylate; PP = polypropylene; PS = polystyrene; PU = polyurethane; PVC = polyvinyl chloride; SB = styrene-butadiene; SBR = styrene-butadiene rubber.

[b] F = flamed; M = melted; D = dripped; S = smoldered; S.E. = self-extinguished; F→S = flamed then smoldered.

[c] B = black; W = white; G = gray; N = none visible; H = high density; L = low density.

[d] Not measured due to lack of sufficient sample or test not performed at this time.

[e] Abbreviated version of ASTM test method for ignition properties of plastics was used.

The data shown in table 11 are presented at this time more as an example of the type of testing being performed than as a set of specific results. As more laboratory data are developed, the test methods as well as the results will be analyzed. An important part of this analysis will be the relationships between these data and the field data obtained through the questionnaire form.

6. USE OF THE DATA

By the nature and scope of this study, there are many variables to be considered both from the field investigations and from the laboratory tests. The data presented in the preceding tables are merely intended to illustrate the breadth of information being collected. As more accident cases are processed, it should be possible to analyze the contributions made by many of the variables in the fire incidents and the manner in which these variables interact. It is expected that patterns will emerge from these analyses which will help characterize the hazards, both demonstrated and potential, surrounding the use of synthetic polymeric materials in residences.

These data will supplement other information sources such as the National Fire Incident Reporting System (NFIRS) [19] and large scale fire test data to define problem areas and provide some details regarding actual accident sequences not found in the other sources. The plastics fire incident data may also demonstrate a need for more specific information after potential hazards are identified.

As far as the product behavior is concerned, three basic questions need to be answered from the field and laboratory data:

1. What type of exposure did a product receive?
2. What was its response behavior and thus its contribution to the overall fire incident?
3. What defines or characterizes a product's susceptibility to ignition, sustained combustion, smoke production, etc.?

Defining the important exposure, response and susceptibility variables for each product or accident situation will be the first step in any hazard assessment. This may include some of the variables listed in tables 1 and 10 and others as appropriate. For example, exposure parameters may include type of heat source, heat flux levels, and the absence or presence of direct flame contact. The responses may take the form of smoke density, flame spread, heat release rate, ignition and self-extinguishment. More important perhaps is the idea of characterizing a product's susceptibility to involvement in a fire which could include material properties such as composition, density and thermal conductivity, design parameters such as configuration and construction; flammability properties such as ease of ignition and heat of combustion, and environmental factors such as location in a room,

ventilation and usage. Note that the latter suggests human involvement which can be critical in the initiation of certain fire incidents, for example, smoking in bed or unattended cooking in the kitchen. Human behavior is also an important determining factor in the ultimate extent of the fire and personal injuries incurred as a result of extinguishment attempts and actions aimed at rescue or escape.

Justification of new standards, test methods or changes in design and application of materials and products must be based on a realistic assessment of the problem. It is intended that the data being collected in the present study will provide a greater understanding of fire incidents that involve plastics and point out solutions to the problems uncovered.

7. ACKNOWLEDGMENTS

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APPENDIX - SYNTHETIC POLYMER FIRE ACCIDENT CASE STUDY QUESTIONNAIRE FORM

OMB No. 41-R2802; Approval Expires June 30, 1976

NBS-782 (6-74) U.S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

SYNTHETIC POLYMER FIRE ACCIDENT CASE STUDY

Contractor's Name

NOTICE: All information which would permit identification of the individual will be held in strict confidence, and will be used only by persons engaged in and for the purposes of this study.

Contractor's Case No.:

I. INCIDENT AND CASE IDENTIFICATION

1. Name of Investigator *(Last, First, Initial)*

2. Date of Report

3. (A) Date of Fire *(Mo./Day/Yr.)*

(B) Day of Week

- ☐ Monday
- ☐ Tuesday
- ☐ Wednesday
- ☐ Thursday
- ☐ Friday
- ☐ Saturday
- ☐ Sunday
- ☐ weekday
- ☐ weekend
- ☐ unknown

4. Time of Fire *(Indicate earliest time known)*

- ☐ specific time _____
- ☐ 12:01 a.m. - 6:00 a.m.
- ☐ 6:01 a.m. - Noon
- ☐ 12:01 p.m. - 6:00 p.m.
- ☐ 6:01 p.m. - Midnight
- ☐ unknown

5. Is this time, the

- ☐ time fire started
- ☐ time fire first noticed
- ☐ time fire reported to fire department
- ☐ other *(specify)* _____

6. City or Town

7. State

8. Date of 1st Interview *(Mo./Day/Yr.)*

9. What sources of information were used to investigate this fire incident? *(Indicate all that apply)*

- ☐ Newspaper
- ☐ NEISS
- ☐ Person directly involved
- ☐ Fire department
- ☐ Witness or bystander
- ☐ Insurance Co.
- ☐ Other *(specify)* _____

II. GENERAL LOCATION OF FIRE

10. (A) What is the general classification of the property, building or structure where the fire occurred? *("X" appropriate boxes to indicate the general property category and then the specific type if known)*

- ☐ Private Dwelling or Duplex
  - ☐ year-round use (1 family)
  - ☐ year-round use (2 family)
  - ☐ other *(specify)* _____
  - ☐ no other information available
- ☐ Townhouse or Rowhouse
- ☐ Apartment, Tenement or Flat
  - ☐ specify type _____
  - ☐ no other information available
- ☐ Rooming, Boarding or Lodging House
  - ☐ 4 to 8 roomers, boarders
  - ☐ other *(specify)* _____
  - ☐ no other information available
- ☐ Dormitory
  - ☐ school, college or university
  - ☐ fraternity or sorority
  - ☐ other *(specify)* _____
  - ☐ no other information available
- ☐ Hotel, Inn or Lodge *(Interior entry only to individual units)*
  - ☐ year-round use
  - ☐ transient
  - ☐ other *(specify)* _____
  - ☐ no other information available
- ☐ Motel or Motor Hotel
- ☐ Mobile Home or Trailer
  - ☐ mobile home
  - ☐ travel trailer
  - ☐ camper
  - ☐ other *(specify)* _____
  - ☐ no other information available
- ☐ Institution For the Aged
  - ☐ specify type _____
  - ☐ no other information available
- ☐ Institution For Care of the Young
  - ☐ children's home, orphanage
  - ☐ other *(specify)* _____
  - ☐ no other information available
- ☐ Institution For Care of the Handicapped, Sick or Injured
  - ☐ hospital
  - ☐ sanatorium
  - ☐ institution for deaf, dumb or blind
  - ☐ other *(specify)* _____
  - ☐ no other information available
- ☐ Other Residential Occupancy
  - ☐ children's treehouse, playhouse
  - ☐ shelter (includes storm, tornado, bomb or fallout)
  - ☐ other *(specify)* _____

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Figure A-1. General information section of plastics fire incident questionnaire form.

Contractor's Case No. ______ NBS Case No. ______

PRODUCTS INVOLVED IN THE FIRE

By location of item at the time of the fire

SHEET ____ OF ____

AREA OR ROOM	ITEM			WHAT HAPPENED TO ITEM IN FIRE			IDENTIFYING THE ITEM		CONSTRUCTION AND COMPOSITION				LABEL INFORMATION	SAMPLE SENT NBS	
	TYPE	PRE-FIRE CONDITION	AGE	ORDER OF INVLMT	BURNING CHARACTERISTICS	CONDITION AFTER FIRE	MANUFACTURER	MODEL AND SERIAL NO.	NO. LAYERS OR COMPONENTS	COMPONENT I.D.	COMPOSITION	CONSTRUCTION		YES	NO
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	

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Figure A-2. Chart for recording information about products involved in plastics fire incidents.

NBS Case No. _____

PERSONS INVOLVED IN THE FIRE Sheet _____ of _____

1. Name	2. Age	3. Education
4. Address	5. Previous fire training or experience	
6. Pre-fire health/physical condition	7. Location at time of ignition	
8. Activity at time of ignition	9. How did person first become aware of fire?	
10. Immediate reaction to fire after becoming aware	11. Extinguishment attempt	
12. Difficulties in escaping	13. Most significant obstacles encountered	
14. How did person escape from fire?	15. Adverse physical reactions	
16. Injury disposition	17. Nature of injury	
18. Parts of body injured	19. Location where injury/death occurred	

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Figure A-3. Chart for recording information about people involved in plastics fire incidents. (Names and addresses (item Nos. 1 and 4) are deleted from this form and all other related documents immediately upon their receipt at NBS to assure the confidentiality of the persons providing information for this study.)

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15. SUPPLEMENTARY NOTES

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

The growing use of plastics has, in recent years, produced an increased concern over the potential flammability of plastics materials and products. In order to assess some of the real-life hazards associated with fire incidents involving plastics, a data base of residential fire accidents is being developed. The data consist of detailed case history reports based on a questionnaire form developed at the National Bureau of Standards and laboratory tests of samples retrieved at the fire scene. The major criteria for a fire incident to be included in the data base are that (1) an identifiable plastic product played a significant role in the fire and (2) the sequence of events can be partially reconstructed. Information is collected about the building environment in which the fire occurred, the products and the persons involved in the incident, the fire development and extinguishment. The field data are being coded and computerized. Sample tabulations of field and laboratory data from the first 25 accident cases are shown.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Accident analyses; fire hazards assessment; flammability tests; hazard analysis; human behavior; plastic fires; plastics; product safety; residential fires.

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