Cooking Oil: A Home Fire Hazard in Alberta, Canada

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Abstract

This paper begins with a brief statistical analysis to establish the significant contribution of cooking equipment fires to fire losses and injuries in Canadian homes. Due to lack of comprehensive fire loss data for Canadian homes, further analysis is focused on Alberta data. The most frequent ignition scenario, based on a top-down analysis of Alberta home fires, was the ignition of overheated cooking oil in pots, deep-fat fryers, or pans heated on stove tops. These fires also accounted for the majority of home fire injuries. Fire characteristics of cooking oils, which point to the importance of maintaining oil temperatures below their flash points, and thermostatically controlled deep-fat fryers as the best available solution to the problem are discussed.

Introduction

"Our passion for fried foods shows up in our fire statistics," was how one fire service spokesperson recently described cooking oil fires as a significant part of Alberta, Canada's, fire problems. Few people realize that cooking oil heated to high temperatures can release flammable vapors that can ignite. Cooking fires, the majority of which originate when cooking oil ignites, remains the leading cause of home fire injuries. Analysis of Alberta fire loss data over the five-year period from 1988 to 1992 shows that cooking equipment accounts for 30% of home fires, leading the list of home fire ignition sources. Cooking oil comprised the material first ignited in 69% of all cooking-equipment-related fires. The most frequent ignition scenario in Alberta homes is "overheated cooking oil in a pot or pan on a stove stop."

Three approaches are taken in this report. The first is a statistical analysis of fire loss data to establish the significance of cooking oil fires and to characterize the problem in Alberta homes. The second is a discussion of the characteristics of cooking oils that make them fire hazards. And the third is a discussion of prevention and suppression measures to minimize the incidence of, and danger from, cooking oil fires.

Statistical Analysis of Fire Loss Data

The data bank of the Alberta Fire Commissioner's Office provided fire loss data for statistical analysis. Under the Regulations of the Safety Codes Act,[1] provincial legislation in Alberta requires every fire that causes death, injury, or property damage, except forest fires, to be reported to the fire commissioner. Fire loss data are collected by the Fire Commissioner's Office on a province-wide basis using standardized incident, casualty, investigation, crime, and smoke detector and alarm reports, in conjunction with the *Alberta Fire Statistics Reporting Manual.*[2] During the period of this study, fires were reported by municipal fire departments (73%), insurance companies/adjusters (40%), Alberta government fire investigators (9%), police (3%), and private individuals and corporations (1%). Where necessary, media and other reports were used as supplemental information. Alberta fire loss data presented in this article are not, therefore, a sample but represent all reported fires.

The *Alberta Fire Statistics Reporting Manual* is based on the *Manual of Uniform Practices for Collecting and Tabulating Fire Loss Statistics in Canada*, developed in 1963 by the Association of Canadian Fire Marshals and Fire Commissioners. This reporting system is similar to, and compatible with, NFPA 901,[3] *Standard Classification for Incident Reporting and Fire Protection Data.* However, there are some differences between the two reporting systems. For example, the five elements that describe an incident's origin in NFPA 901 correspond with elements in the *Alberta Fire Statistics Reporting Manual* as follows:

- "Equipment Involved in Ignition" in NFPA 901 corresponds to "Source of Ignition" in the manual;
- "Form of Heat of Ignition" in NFPA 901 corresponds to "Fuel or Energy Associated with Igniting Object" in the manual;
- "Form of Material" in NFPA 901 has no equivalent in the manual;
- "Type of Material" in NFPA 901 corresponds to "Material First Ignited" in the manual; and
- "Ignition Factor" in NFPA 901 corresponds to "Act or Omission" in the manual.

Cooking oil as material first ignited is the main focus of this article. Cooking oil is defined in the *Alberta Fire Statistics Reporting Manual* under "Material First Ignited" in the section on "Flammable Liquids, Combustible Liquids," as "cooking oil, fat—includes butter, lard, margarine." Foods other than cooking oil or fat are not assigned a specific code but are categorized in the manual under "Material First Ignited" in the section "Miscellaneous." In NFPA 901, separate codes are assigned for cooking oil, fat, or grease, and foods other than fat or grease under "Type of Material."

Fire statistics for Canada were extracted from the annual *Fire Losses in Canada*[4] reports published by the Association of Canadian Fire Marshals and Fire Commissioners. The reports are compiled from information supplied by the provincial and territorial fire marshals and fire commissioners, Indian and Northern Affairs Canada, and Statistics Canada.

Key words: Canada, Alberta, cooking equipment, cooking oil, fire injuries, smoke point, flash point, fire hazard, fire statistics, prevention.

Data Analysis

First, fire losses in Canada were analyzed by ignition source to establish the significant contribution of cooking equipment to fires. Then fire data from selected provinces were compiled to show that most cooking equipment fires occur in one- and two-family dwellings, apartments, and mobile homes. Finally, fire loss data for Alberta homes were subject to a top-down analysis to subdivide the data into leading areas of fire origin, their major ignition sources, and materials first ignited to reveal the importance of cooking oil as a fire hazard. Also analysed were factors such as act or omission, initial detection, time and day of week, extent of fire spread, actions taken, methods of control, and fire casualties in relation to cooking oil fires in Alberta homes. Statistical analyses of Alberta fire loss data were carried out using Statistical Analysis System (SAS)[5] software.

Cooking Equipment Fires in Canada

Table 1 provides an overview of the fire losses in Canada for the five-year period from 1988 to 1992, and Table 2 lists the major sources of ignition in these fires. During this period, cooking equipment consistently led the list of known sources of ignition in 13% of all Canadian fires.

Table 3 shows the extent of losses from cooking equipment fires in Canada. Losses from cooking equipment fires, expressed as a percentage of all fire losses in Canada between 1988 and 1992, have remained remarkably stable—fires (13%), civilian deaths (9 to 11%), civilian and firefighter injuries (33 to 40%), and dollar losses from property damage (6%). Table 4 compares all major sources of ignition in Canadian fires and points to cooking equipment fires as the single largest source (30%) of civilian fire injuries and the second or third known source of ignition in civilian fire deaths. Cooking equipment fires were the third or fourth known source for dollar losses from property damage.

Having established the large contribution made by fires originating in cooking equipment to the total fire losses in Canada, we examined the distribution of these fires by property classification. Table 5 provides this distribution for three selected provinces in 1992. Such data were not available in the *Annual Reports of the Fire Commissioner of Canada*. The data in Table 5 clearly show that the majority (80 to 92%) of cooking equipment fires occur in residential properties. A breakdown by type of residence shows that approximately 92% of all residential fires occur in one- and two-family dwellings, apartments, and mobile homes (see Table 6). It is therefore reasonable to conclude that most cooking equipment fires in Canada happen in homes. Due to lack of data, further analysis of cooking equipment fires in Canadian homes was not feasible. The remainder of this report is therefore based on Alberta fire statistics. In a general sense, it is assumed that the causes of home fires in Alberta are representative of the rest of Canada.

TABLE 1
Fire Losses in Canada, 1988-1992[4]

	1988	1989	1990	1991	1992
Fires	70,624	67,182	67,556	68,150	65,999
Deaths	498	500	461	388	401
Injuries	3,630	3,763	3,841	3,476	3,874
$ Losses	924,572,533	1,119,579,909	1,226,027,172	1,239,716,205	1,241,390,000

TABLE 2
Fires in Canada by Major Sources of Ignition, 1988-1992[4]

Sources of Ignition	Percent of All Fires				
	1988	1989	1990	1991	1992
Cooking equipment	13	13	13	13	13
Electrical distribution - equipment	10	11	11	10	10
Heating equipment	11	10	10	9	10
Smoker's material	6	7	6	6	5
Matches and lighters used for lamps, candles, tapers	5	5	5	8	6
Appliances and equipment	5	5	4	4	4
Smoker's material or open flame, unclassified	7	5	5	2	7
Other known *	8	9	9	9	8
Miscellaneous	18	19	19	19	18
Undetermined	17	16	18	20	19
Total	100	100	100	100	100

* The "other known" category includes sources which accounted for less than 3% of all fires.

TABLE 3
Fire Losses Related to Cooking Equipment in Canada, 1988–1992[4]

	1988	1989	1990	1991	1992
Fires	8,946 (13%) **	8,855 (13%)	8,845 (13%)	8,752 (13%)	8,272 (13%)
Deaths*	42 (9%)	54 (11%)	42 (9%)	36 (10%)	37 (10%)
Injuries:					
Civilians	665 (28%)	638 (26%)	700 (29%)	639 (30%)	847 (32%)
Injuries:					
Firefighters	83 (7%)	95 (7%)	85 (7%)	131 (10%)	88 (7%)
$ Losses	55,559,762	68,322,231	88,031,970	72,257,739	74,899,225
% Losses	6	6	7	6	6

*Only civilians have died in cooking equipment fires.

**Numbers in brackets show cooking equipment fire losses as a percent of all fire losses in Canada.

Fires in Alberta and Alberta Homes

Between 1988 and 1992, a total of 39,182 fires, 228 fire deaths, 2,172 fire injuries, and $569 million in property damage occurred in Alberta. Homes accounted for 27% of all fires, 66% of fire deaths, 58% of fire injuries, and 33% of dollar losses from property damage in these fires (see Table 7). These statistics show that Canadians are in the greatest danger from fire in the home, as are those in the rest of North America. During the period of this study, home fires as a percentage of all fires were consistently higher in Canada (41%) than in Alberta (27%). This difference is primarily due to a large percentage of fires outdoors and in transportation properties in Alberta.

Areas of Fire Origin

The kitchen is the primary area of fire origin in one- and two-family dwellings (35%) and apartments (32%). Kitchen fires (19%) rank second only to structural area fires in mobile homes. Fires in the kitchen accounted for the largest fraction of fire injuries in all three types of homes (see Table 8). The kitchen is the number one site for home fires and fire injuries and the number three site in home fire deaths and property damage in the U.S.[5]

Sources of Ignition

Sources of ignition in kitchen fires in the three types of homes are listed in Table

TABLE 4
Fire Casualties by Major Sources of Ignition in Canada, 1990–1992[4]

Sources of Ignition	1990 Injuries FF*	1990 Injuries Civ	1990 Deaths FF	1990 Deaths Civ	1991 Injuries FF	1991 Injuries Civ	1991 Deaths FF	1991 Deaths Civ	1992 Injuries FF	1992 Injuries Civ	1992 Deaths FF	1992 Deaths Civ
Cooking equipment	85	700	-	42	131	639	-	36	88	847	-	37
Electrical distribution equipment	142	161	-	25	135	103	-	22	135	139	-	24
Heating equipment	84	174	-	34	98	177	1	22	84	179	-	30
Smoking material	129	404	-	100	117	281	4	85	79	306	-	68
Matches and lighters not for smoking	79	209	-	26	131	224	1	31	82	263	1	63
Appliances and equipment	32	82	-	5	21	77	-	9	22	61	-	3
Smoker's material or open flames, unclassified	87	64	1	15	9	15	-	4	85	163	-	30
Other known	73	132	-	9	82	111	-	18	70	127	2	15
Miscellaneous	141	218	4	48	125	157	-	28	102	168	-	25
Undetermined	449	308	-	152	524	319	2	125	474	400	1	91
Total	1,301	2,452	5	456	1,373	2,103	8	380	1,221	2,653	4	386

* FF = firefighters, Civ = civilians

9. Cooking equipment ranks first on this list, accounting for 89% of kitchen fires in one- and two-family dwellings, 93% of kitchen fires in apartments, and 80% of kitchen fires in mobile homes. More than two-thirds of kitchen fires in U.S. homes begin in appliances or other equipment related to cooking, primarily stoves and ovens.[5]

Materials First Ignited

Cooking equipment fires in all three types of homes were analyzed by the materials first ignited. The resulting data are presented in Table 10. Cooking oil leads the list of the most common materials ignited in cooking equipment fires in kitchens, accounting for 66% of kitchen fires in one- and two-family dwellings, 75% of kitchen fires in apartments, and 65% of kitchen fires in mobile homes.

It was of interest to verify the involvement of foods other than cooking oil,

TABLE 5
Distribution of Cooking Equipment Fires by Property Class in Three Canadian Provinces, 1992

	Province					
	Alberta		British Columbia		Manitoba	
Property Classification	# of fires	(%)	# of fires	(%)	# of fires	(%)
Residential	549	80	611	89	415	92
Assembly	38	6	35	5	14	3
Special (outdoor/transport)	70	10	2	0	-	-
Institutional	7	1	6	1	7	2
Mercantile	7	1	4	1	5	1
Storage	4	1	3	0	5	1
Business	1	0	5	1	-	-
Miscellaneous	5	1	24	3	5	1
Total	688	100	690	100	451	100

Data sources: Fire Commissioner's Offices in British Columbia and Manitoba

TABLE 6
Residential Fires in Canada, 1988–1992[4]

Type of Residence	1988	1989	1990	1991	1992
One- and two-family dwellings	21,423	20,917	20,616	20,957	19,797
Apartments	7,056	5,928	6,035	5,949	6,043
Mobile homes	1,039	1,081	1,239	1,074	1,015
All other residences	2,234	2,230	2,414	2,504	2,341
Total	31,752	30,156	30,304	30,484	29,196

grouped in "other/undetermined/unknown" in Table 10, as materials first ignited in cooking equipment fires in Alberta homes. Since foods other than cooking oil are coded under "Material First Ignited" in the "Miscellaneous" section as "Unclassified (describe)," original fire reports on paper with this coding and description were separated and counted manually. Results showed that foods other than cooking oil comprised only 6% of all materials first ignited in cook-

TABLE 7
Fires in Alberta and Alberta Homes, 1988–1992

	Fires		Deaths		Injuries		$ Losses	
	No.	%	No.	%	No.	%	Amount	%
One- and two-family dwellings	7,038	18	91	40	639	29	131,159,438	23
Apartments	2,526	6	30	13	529	24	34,474,664	6
Mobile homes	844	2	29	13	88	4	21,704,193	4
All other property classes	28,774	73	78	34	916	42	381,158,041	67
Total (Alberta)	39,182	100	228	100	2,172	100	568,496,336	100

ing equipment fires. Approximately 84% of all materials first ignited on kitchen stoves and ovens in U.S. homes were identified as food or grease.[5] A recent report indicates that unattended cooking fires in U.S. homes most often involve cooking oil or grease.[6]

For the remainder of the report, analysis of fire loss data from all three types of homes focused on cooking oil as the material first ignited by cooking equipment in kitchens in Alberta homes. The term "cooking oil" includes not only oils—corn, soybean, and vegetable—but also fats such as lard, tallow, butter, and margarine.

To characterize cooking oil fires, fire loss data were analysed by type of cooking equipment, acts or omissions, initial detection of fire, time of day and day of week, extent of fire spread, action taken, and methods of control of fire and fire casualties.

Types of Cooking Equipment

From a total of 2,081 cooking oil fires reviewed, fires associated with stove-top burners accounted for 93% (see Table 11). These stove-top fires were in deep-fat fryers or pots (62%), pans (29%), and other circumstances (2%). Only 1% of cooking oil fires occurred in portable, electric deep-fat fryers. The most damaging types of cooking oil fires began in deep-fat fryers or pots heated on stove tops and inflicted the most deaths (70%), injuries (67%), and dollar losses (72%).

Fuels or sources of energy for cooking equipment involved in cooking oil fires (data not shown) were electricity (96%), fuel gases (1%), and other fuels (3%). The ratios of the incidence of cooking oil fires and resulting fire deaths, injuries, and property damage associated with electric and gas appliances were 96, 8, 25, and 30. This may be due to the larger percentage of electric cooking appliances in Alberta households. According to *Statistics Canada Catalogue Number 64-202, Household Facilities and Equipment,*[7] 839,040 households had electric stoves and conventional ovens in 1992, while another 63,840 households had gas

TABLE 8
Areas of Fire Origin in Alberta Homes by Property Class, 1988–1992

	One- and two-family dwellings			
	Fires	Deaths	Injuries	$ Losses
Areas of origin				
Kitchen	2,444	11	182	22,472,881
Structural areas	1,090	6	70	24,316,360
Other/undetermined/unknown	1,021	16	94	34,011,169
Living room	760	34	106	17,733,808
Bedroom	681	15	97	16,216,774
Laundry area	413	1	28	4,030,978
Heating equipment room	302	5	49	9,020,998
Means of egress	124	0	10	2,129,348
Chimney, flue pipe, gas vent	203	3	3	1,779,877
Total	7,038	91	639	131,712,193
	Apartments			
	Fires	Deaths	Injuries	$ Losses
Kitchen	813	5	194	7,694,107
Structural areas	182	0	6	100,070,198
Other/undetermined/unknown	316	1	45	5,025,277
Living room	347	13	124	5,227,683
Bedroom	422	9	105	4,456,900
Laundry area	162	0	27	909,852
Heating equipment room	66	0	14	692,463
Means of egress	213	2	13	748,767
Chimney, flue pipe, gas vent	5	0	1	22,383
Total	2,526	30	529	34,847,630
	Mobile Homes			
	Fires	Deaths	Injuries	$ Losses
Kitchen	163	7	24	4,738,216
Structural areas	247	1	16	4,459,934
Other/undetermined/unknown	137	1	6	4,517,503
Living room	79	9	14	2,115,880
Bedroom	83	10	11	2,498,108
Laundry area	31	0	0	781,651
Heating equipment room	65	0	3	1,451,090
Means of egress	29	1	13	1,016,365
Chimney, flue pipe, gas vent	10	0	1	135,246
Total	844	29	88	21,713,993

TABLE 9
Kitchen Fires in Alberta Homes by Sources of Ignition, 1988–1992

	One- and two-family dwellings			
	Fires	Deaths	Injuries	$ Losses
Sources of Ignition				
Cooking equipment	2,183	8	165	16,949,959
Appliances and equipment	89	0	1	735,373
Other/undetermined/unknown	70	1	4	2,266,050
Match/lighter, not with smoking materials	32	0	5	893,598
Smoking materials	30	0	1	759,828
Electrical distribution equipment	25	1	1	355,844
Heating equipment	15	1	5	512,229
Total	2,444	11	182	22,472,881
	Apartments			
	Fires	Deaths	Injuries	$ Losses
Cooking equipment	755	3	155	3,918,929
Appliances and equipment	6	0	0	34,089
Other/undetermined/unknown	18	1	13	138,427
Match/lighter, not with smoking materials	12	0	0	61,872
Smoking materials	15	1	25	3,516,067
Electrical distribution equipment	6	0	0	21,581
Heating equipment	1	0	1	3,142
Total	813	5	194	7,694,107
	Mobile Homes			
	Fires	Deaths	Injuries	$ Losses
Cooking equipment	130	6	21	3,406,180
Appliances and equipment	5	0	0	288,904
Other/undetermined/unknown	12	0	0	562,429
Match/lighter, not with smoking materials	7	0	0	76,355
Smoking materials	4	1	1	133,133
Electrical distribution equipment	2	0	2	208,515
Heating equipment	3	0	0	62,700
Total	163	7	24	4,738,216

TABLE 10
Materials First Ignited in Cooking Equipment Fires in Alberta Home Kitchens, 1988–1992

	One- and two-family dwellings			
Materials First Ignited	Fires	Deaths	Injuries	$ Losses
Cooking oil/fat	1,432	4	139	11,757,156
Other/undetermined/unknown	384	1	18	2,336,386
Plastics	85	0	2	406,638
Insulation, electric	85	0	0	521,079
Clothing and fabric	68	2	4	416,552
Wood/paper products	64	1	2	488,585
Furniture	24	0	0	444,160
Interior structure:				
Floor/wall/ceiling covering	18	0	0	69,132
Flammable gases	4	0	0	68,282
Other flammable/combustible liquids	8	0	0	30,883
Gasoline	4	0	0	76,227
Mattress and bedding	2	0	0	7,723
Structure: Floor/ceiling/roof	2	0	0	288,174
Garbage, trash	1	0	0	11,433
Tar, asphalt	2	0	0	27,549
Total	2,183	8	165	16,949,959
	Apartments			
	Fires	Deaths	Injuries	$ Losses
Cooking oil/fat	565	3	117	2,880,519
Other/undet./unknown	89	0	23	372,638
Plastics	31	0	9	109,638
Insulation, electric	18	0	1	176,866
Clothing and fabric	20	0	3	23,702
Wood/paper products	22	0	0	300,804
Furniture	4	0	1	12,058
Interior structure:				
Floor/wall/ceiling covering	2	0	0	38,804
Flammable gases	1	0	0	2,100
Other flammable/combustible liquids	-	-	-	-
Gasoline	-	-	-	-
Mattress and bedding	1	0	0	1,000
Structure: Floor/ceiling/roof	1	0	1	300
Garbage, trash	1	0	0	500
Tar, asphalt				
Total	755	3	155	3,918,929

TABLE 10 (cont.)
Materials First Ignited in Cooking Equipment Fires in Alberta Home Kitchens, 1988–1992

	Mobile Homes			
	Fires	Deaths	Injuries	$ Losses
Cooking oil/fat	84	3	6	2,421,413
Other/undetermined/unknown	13	0	0	356,119
Plastics	6	2	2	52,286
Insulation, electric	3	1	1	83,371
Clothing and fabric	7	0	2	117,806
Wood/paper products	4	0	0	49,889
Furniture	3	0	0	109,000
Interior structure:				
Floor/wall/ceiling covering	2	0	1	31,500
Flammable gases	6	0	8	147,796
Other flammable/combustible liquids	-	-	-	-
Gasoline	2	0	1	37,000
Mattress and bedding	-	-	-	-
Structure: Floor/ceiling/roof	-	-	-	-
Garbage, trash	-	-	-	-
Tar, asphalt	-	-	-	-
Total	130	6	21	3,406,180

stoves and ovens. Based on these statistics, the rates of cooking oil fires per 100,000 households in Alberta are 238 for electric and 58 for gas-fueled stoves and ovens. Thus, the rate of cooking oil fires involving electric cooking equipment is four times that of gas-fueled cooking equipment.

Studies of fat-pan fires, expressed per 100,000 households in the U.K., also found a 4:1 ratio between electric and gas appliances.[8] Possible reasons for the relative safety of gas appliances were the visibility of the flame and the sound of a gas burner, which make the user more aware of danger; a higher degree of heat control; the rapid loss of residual heat after the appliance is switched off; and less confusion with controls. Two other explanations in favor of gas appliances were that any oil spilled will fall through the flame, rather than onto a flat electric element, and that the user can adjust the flame size to the size of the pot or pan. In electric stoves, the pot or pan may not entirely cover the heating surface. Initially setting a burner on high to heat the cooking oil more quickly and leaving it unattended may also contribute to the high fire incidence of electric cooking equipment.

TABLE 11
Cooking Oil Fires by Types of Cooking Equipment, 1988–1992

Types of Cooking Equipment	Fires	%	Deaths	%	Injuries	%	$ Losses	%
Stovetop burner (deep fat fryer/pot)	1,289	62	7	70	176	67	12,248,141	71.8
Stovetop burner (fire in pan)	601	29	3	30	78	30	3,868,466	22.7
Oven of stove/range	111	5	0	0	1	0	234,550	1.4
Stovetop burner (other circumstances)	38	2	0	0	1	0	229,010	1.3
Deep-fat fryer (electric, portable)	16	1	0	0	4	2	317,531	1.9
Fry pans/grills not on stove	16	1	0	0	1	0	103,200	0.6
Other cooking unit, portable	7	0	0	0	1	0	56,149	0.3
Chafing dish/fondue	2	0	0	0	0	0	1,654	0.0
Food warming appliances (microwave/electric kettle)	1	0	0	0	0	0	387	0.0
Total	2,081	100	10	100	262	100	17,059,088	100.0

Acts or Omissions

The elements of human behavior commonly associated with cooking oil fires are categorized under acts or omissions. As shown in Table 12, these indicate that 79% of cooking oil fires were the result of overheating cooking oil. Other common acts or omissions of lesser significance were distractions or being pre-occupied (7%); ignorance of the hazard (4%); falling asleep, either unimpaired (2%) or impaired by alcohol, drugs, or medication (2%); and accidents (2%).

The inherently hazardous task of cooking with hot oil using traditional cooking equipment is compounded by a variety of unsafe human behaviors that increase not only the risk of fire but also the risk of injury, death, and spread of fire to adjacent combustibles. Fire statistics point to overheating as the predominant act or omission, but the code prevents documentation in fire reports of other actions, such as unattended cooking or distractions, that may have led to the overheating. Confirming the fact long known from U.S. data,[9] a recent study of 10 U.S. communities concluded that unattended cooking was involved in 63% of the residential cooking fires reported.[10] Studies in the U.K.[8] with respondents who had actually experienced fat-pan fires indicate that unattended cooking was the primary cause (50%). About 10% said they "forgot to turn off heat." Examples of reasons given in the U.K. studies for unattended cooking were helping a neighbor, attending to the needs of a child or sick person, visiting the bathroom, or bringing in the laundry as rain started. Narrative descriptions from Alberta fire reports can add to this list activities such as answering the phone, leaving the kitchen to answer the doorbell, or being busy with other kitchen activities while the oil was heating on the stove. It appears that overheating, the prelude to a cooking oil fire, usually occurs when the cook's attention is diverted from the task of cooking by unexpected external demands or forgetfulness, or when the cook badly underestimates the time necessary to reach ignition temperature.[11]

TABLE 12
Cooking Oil Fires by Acts or Omissions, 1988–1992

Acts or Omissions	Fires	%	Deaths	%	Injuries	%	$ Losses	%
Overheated cooking oil	1,640	79	6	60	210	80	13,580,841	79.6
Distracted, preoccupied	147	7	0	0	15	6	1,194,627	7.0
Ignorance of hazard	83	4	0	0	6	2	407,805	2.4
Act or omission/other/unknown	49	2	0	0	0	0	244,756	1.4
Human failing, accident	48	2	0	0	4	2	387,916	2.3
Asleep	39	2	0	0	6	2	311,292	1.8
Asleep (suspect alcohol/drugs/medicine)	39	2	1	10	15	6	532,132	3.1
Impaired (suspect alcohol/drugs/medicine)	14	1	3	30	6	2	197,744	1.2
Fuel, spilled accidentally	8	0	0	0	0	0	36,698	0.2
Temporary loss of judgement	6	0	0	0	0	0	46,088	0.3
Child playing with	3	0	0	0	0	0	45,110	0.3
Arson/set fire	3	0	0	0	0	0	72,172	0.4
Combustible placed too close to heat	1	0	0	0	0	0	1,707	0.0
Electrical short circuit	1	0	0	0	0	0	200	0.0
Total	2,081	100	10	100	262	100	17,059,088	100.0

Initial Detection and Time of Occurrence

Statistical analysis (data not shown) revealed that the majority (85%) of cooking oil fires were detected initially by someone in the vicinity of the fire. This is to be expected, since people are generally close to cooking equipment when food is being prepared and would thus be in a position to notice a pot or pan on fire. Most of the deaths, injuries, and property losses occurred in these fires. In cooking oil fires that were detected initially by smoke alarms (13%), the oil was probably left unattended, and the cook was away from the kitchen.

Analyzed by day of week, cooking oil fires were fairly evenly distributed throughout the week. When analysed by time of day, the study found that such

TABLE 13
Cooking Oil Fires by Extent of Fire, 1988-1992

Extent of Fire	Fires	%	Deaths	%	Injuries	%	$ Losses	%
Confined to part of room/ area of origin	933	45	1	10	115	44	4,767,810	27.9
Confined to object of origin	446	21	0	0	39	15	711,246	4.2
Confined to room of origin	434	21	2	20	55	21	4,452,839	26.1
Confined to floor level of origin	130	6	2	20	22	8	1,480,478	8.7
Confined to building of origin	128	6	5	50	27	10	5,420,378	31.8
Extended beyond building of origin	4	0	0	0	4	2	217,614	1.3
Not applicable, for example outside area/vehicle	4	0	0	0	0	0	1,668	0.0
Extent of fire unknown	2	0	0	0	0	0	7,055	0.0
Total	2,081	100	10	100	262	100	17,059,088	100.0

fires occurred most frequently between 4:00 and 8:00 p.m., when many people prepare their evening meals. Thirty-three percent of all home cooking oil fires, 20% of associated fire deaths, 39% of associated injuries, and 35% of property damage occurred during this period. However, cooking oil fires late at night, between midnight and 6:00 a.m., caused the majority (50%) of deaths.

Extent of Fire Spread

The extent of fire spread is the actual extent of burning or charring. As Table 13 shows, only 21% of the cooking oil fires reported were confined to the object of fire origin. These fires resulted in no deaths and did the least amount of property damage, at $1,595 per fire.

The majority of cooking oil fires spread beyond the object of origin to the immediate area (45%), to the room of origin (21%), the floor of origin (6%), the building of origin (6%), and beyond building of origin (less than 1%). The dollar loss per fire increased as the extent of fire spread increased. Most of the deaths (50%) from cooking oil fires occurred in fires in which fire spread was confined to the building of origin, and injuries were highest when fires were confined to the area of origin. Such injuries generally resulted when householders tried to fight the fires themselves (data not shown).

Further analysis of the extent of fire spread in relation to the type of cooking equipment showed that fires were confined to the object of origin in only 16% of fires in deep-fat fryers heated on the stove top and in 21% of fires in pans heated on the stove top. It appears therefore that the initial stages of fire development

TABLE 14
Cooking Oil Fires by Action Taken to Extinguish, 1988-1992

Action Taken	Fires	%	Deaths	%	Injuries	%	$ Losses	%
Extinguished by occupant	694	33	1	10	128	49	2,519,888	14.8
Action taken-unknown, undetermined	709	34	1	10	18	7	3,199,776	18.8
Extinguished by fire department	478	23	7	70	82	31	10,504,519	61.6
Burned out—no extinguishment attempted	153	7	1	10	20	8	500,364	2.9
Action taken—unclassified	47	2	0	0	14	5	334,541	2.0
Total	2,081	100	10	100	262	100	17,059,088	100.0

in both these sources are largely uncontrolled. The danger of fire spread and injury is greater with stove-top-heated deep-fat fryers due to the larger quantities of cooking oil used in deep frying. The casualty figures in Table 11 bear this out: 70% of fatalities and 67% of injuries in cooking oil fires occurred with deep-fat fryers or pots.

Action Taken and Method of Control

The majority (33%) of cooking oil fires were extinguished by the occupant, and these fires inflicted half the injuries (see Table 14). The 23% of cooking oil fires extinguished by fire departments resulted in 70% of the fatalities, one-third of all injuries, and 62% of dollar losses. A further 7% of cooking oil fires burned out on their own, without any attempted extinguishment. These fires resulted in 2 deaths (10%) and 20 (8%) injuries.

Two-thirds of the methods occupants used to extinguish cooking oil fires were classified as "makeshift." Makeshift firefighting is action taken to control or extinguish fires by methods other than the use of fire extinguishers; these include smothering the fire by covering it or by dousing it with baking soda, snow, sand, or water from a garden hose or vessel. Fires in which these methods were used resulted in the largest number (91% or 71%) of fire injuries.

Casualties

A profile of the 10 civilian cooking oil fire fatalities in Alberta is provided in Table 15. Six of the victims were adult males, one was a 13-year-old female, and three were children aged 1, 3, and 5 years. Examination of fire and casualty reports indicate that, except for the children, the victims themselves were doing the cooking that led to the fires. There were no firefighter fatalities.

There were 262 injuries in these fires; 17 of the victims were firefighters and

TABLE 15
Civilian Fatalities in Cooking Oil Fires, 1988–1992

Casualty Condition	Casualty Action	Age	Sex
Impaired	•Unknown	27	male
	•Received delayed warning	28	male
	•Loss of judgement/panic	63	male
Unknown	•Unknown	23	male
		3	male
		19	male
Asleep	•Received delayed warning	5	female
		29	male
Awake, alert	•Injured while trying to escape	13	female
Too young to react	•Injured while trying to escape	1	male

245 were civilians. The majority of injuries to firefighters (65%) and civilians (67%) were minor (see Table 16). Thirty-five percent of firefighter injuries and 29% of civilian injuries were light. A small proportion (3%) of civilians was seriously injured; no firefighters were seriously hurt.

Of the 245 civilians injured, 60% were males and 40% were females. Seventy percent of the casualties were awake and functioning normally at the time of the fire, while 10% were asleep and 6% were impaired by alcohol, drugs, or medication. Two percent were children who were too young to react properly or had been left unattended. Fifty-five percent of the casualties entered or remained on the premises to fight the fire, 11% entered or remained to save property, and 7% experienced loss of judgment or panic. A recent study, based primarily on a survey of 10 urban communities in the United States, found that 64% of people in the home did not try to fight a cooking fire that erupted in the kitchen or left the area when such a fire broke out. Of the 36% who attempted to suppress the fire, nearly half reportedly used improper methods.[10]

The narrative descriptions provided on fire reports were examined to gain further insight into the types of actions occupants took to put out the fires and to relate these to injuries they sustained. These showed that people most commonly tried to carry the pot or pan away from the stove to dispose of it or to pour the oil down the sink; threw water, snow, sand, or baking soda on the flames; and used a fire extinguisher improperly, causing the fire to spread to nearby combustibles. The most dangerous actions, which led to serious burns, resulted when the victims carried the pot or pan of flaming oil or threw water or snow at the flames. Some examples extracted from fire reports are presented below.

TABLE 16
Injuries in Cooking Oil Fires, 1988–1992

Status of Casualty	Type of Injury: Minor	Light	Serious	Total Injuries
Firefighter	11	6	-	17
Civilian	165	72	8	245
Total	176	78	8	262

According to the Alberta Fire Statistics Reporting Manual, a minor injury is one that does not require hospitalization for more than 24-hours or absence from work of more than one full day. A light injury is one that requires hospitalization of 24 to 48 hours and/or absence from work for a period of two to 15 days. A serious injury is one that requires hospitalization for more than 48 hours and/or an absence from work of more than 15 days. Firefighter injuries may occur in the process of fire fighting or as a result of accidents on the way to or from a fire scene.

- A 41-year-old male in a single-family dwelling put a pan of oil on the front left element of an electric stove to make fries. While he was cutting the potatoes, the lid blew off, alerting him to the fire. He tried to put the lid back on, but the fire did not go out, so he carried the pan outside. In the process, he received first-degree burns to his left thumb, wrist, and forearm, and damaged the living room carpet. Fire also damaged the kitchen cupboards, wall, ceiling, and stove exhaust fan.
- A 22-year-old woman left a pot of oil she was heating for popcorn unattended on an electric stove in her apartment, and the oil burst into flames. Grabbing the pot, the woman carried it into the apartment hallway, where the intense heat of the flames caused her to drop it on the floor. The hot oil spilled on her right hand, causing second-degree burns, and a small fire damaged the hallway carpet.
- A 38-year old man in a single-family dwelling put a pot of burning oil in the kitchen sink and opened the water tap. The oil flared up, setting the curtains on fire. The victim suffered second-degree burns to his left hand.
- The female occupant of an apartment was intoxicated and fell asleep after placing a pan of cooking oil on an electric stove. A neighbour smelled smoke and woke her. The fire was confined to the pan, and the occupant suffered smoke inhalation.
- An 85-year-old women in a senior citizen's lodge became unconscious in the living room after placing a pot of oil on the electric stove. Upon regaining consciousness, she realized that her apartment was on fire. She got off the floor and moved the pot to the sink, burning herself on the arms and forehead. She crawled out of the apartment under thick smoke.
- A tenant of a one-story house was heating cooking oil in a pot on the right rear

TABLE 17
Selected Civilian Cooking Oil Fire Injuries by Condition and Action of Casualties

Condition	Female (%)	Male (%)	Action	Female (%)	Male (%)
Impaired	0	100	Firefighting	41	59
Asleep	22	78	Saving property	43	57
			Rescuing	8	92

element of an electric stove when the phone rang. As she answered the phone, she turned the control knob to what she thought was the off position. In reality, she inadvertently turned it to the high setting. A short time later, she noticed smoke coming from the kitchen. She carried the pot of burning oil outside and threw water on the flaming kitchen cupboards before calling the fire department. No injuries were reported.

- A 58-year-old man received second-degree burns over 28% of his body and suffered smoke inhalation when a pot of cooking oil overheated on an electric stove top. The fire spread from the kitchen to an attic and into an attached garage. Total property damage to this two-story home was estimated at $150,000.

As with all home fires, men appear more prone—1.5 times more prone—to cooking oil fire injuries than females. Reasons for this can be seen in the conditions and actions of the casualties (see Table 17). During fires, more males than females were asleep or impaired by alcohol, drugs, or medication. Men also entered or remained to fight the fire, save property, or rescue someone more frequently than women.

Based on 1988 population data for Alberta, the average annual fire injury rate for cooking oil fires was 4.1 per 100,000 population during the five-year period from 1988 to 1992. Regardless of gender, people in three age groups appeared more susceptible to cooking oil fire injuries. Those 16 to 30 years old had age-specific annual fire injury rates of 6.4; those 41 to 45 years old had age-specific annual fire injury rates of 7.4; and those 56 to 60 years old also had age-specific annual fire injury rates of 7.4.

As pointed out earlier, cooking fires are the leading cause of fire injuries in Alberta homes. Data in Table 9 confirm this statement. The majority (72%) of cooking fires involve cooking oil as the material first ignited (see Table 10). The U.S. home fire experience also shows that cooking fires inflict the highest number of injuries.[9]

TABLE 18
Smoke Points of Common Cooking Oils[14,15]

Oil	Smoke Point (°C)
Soybean	224
Canola	224–230
Corn	220
Sunflower	230
Peanut	232
Cottonseed	229

Fire Characteristics of Cooking Oils

According to NFPA 321, *Basic Classification of Flammable and Combustible Liquids,*[12,13] cooking oils belong to Class IIIB combustible liquids, which have flash points above 93°C. Cooking oils have several fire characteristics that contribute to their fire hazard. Those relevant to this discussion are smoke point, flash point, fire point, and ignition temperature. Since these fire characteristics have been determined under controlled laboratory conditions, they are inadequate in predicting actual fires. However, insight useful in evaluating actual fires can be gained from an understanding of these simplified situations.

The smoke point of a fat or oil is the temperature at which a thin, continuous stream of bluish smoke first appears when it is heated under standard conditions. Smoking represents the release of volatile, gaseous products from the decomposition of overheated oils and fats. Acrolein, an aldehyde formed from dehydration of glycerol, volatilizes at these high temperatures to produce a sharp odor and irritates the mucous membranes. The decomposition products may also give food an unpleasant flavor. For these reasons, it is considered desirable to use fats or oils with relatively high smoking temperatures (215° to 230°C) for frying. Table 18 provides the smoke points of some commonly used oils and fats. Apart from the variation among different products, the smoke points are influenced by additional factors. With repeated and prolonged use, the smoke points of fats and oils decrease. Containers that are shaped in such a way as to produce a comparatively large surface area will also lower the smoke points.[15,16,17]

The flash point of a liquid is determined by slowly raising the liquid's temperature until it gives off vapors in the right proportion with air to form a flammable mixture of vapor and oxygen. If an ignition source is applied at the surface, a flame will flash through this vapor/air mixture. The lowest temperature at which this happens is the flash point. The flame does not continue to burn at the flash point when the ignition source is removed.

TABLE 19
Flash Points of Common Flammable and Combustible Liquids[14,19]

Liquid	Flash Point (° C)	Ignition Temperature (°C)
Gasoline	–43	280
Diesel fuel oil	37-54	
Kerosene	43–72	210
Lubricating oil	148–230	
Paraffin wax	200	
Peanut oil	282	445
Olive oil	225	343
Sesame oil	255	
Soybean oil no.1	220	445
Tallow	265	
Lard oil	260	
Coconut oil	287	
Corn oil	321	393(crude)
Sunflower oil	320	
Cotton seed oil	321	343(crude)
Palm oil (Palm Butter)	162	
Canola oil	275–290	315

Because it indicates the degree of safety of a material, the flash point is one of the most important fire characteristics of liquids. It is directly related to a liquid's volatility, or ability to generate vapors. Since it is the vapor of the liquid, not the liquid itself, that burns, vapor generation becomes the primary factor in determining the fire hazard. At its flash point, a liquid continuously produces flammable vapors at the right rate and volume to produce a flammable atmosphere if an ignition source is brought into the mixture.[2,13,18] Flash points for a number of cooking oils are given in Table 19.

At a temperature slightly higher than the flash point, the flame will persist long enough to establish continuous burning. This is called the fire point. If the temperature of a liquid is quickly raised above its flash point and its fire point, perhaps even above its boiling point, it reaches its autoignition temperature, at which it burns without an external ignition source.[18,20] The autoignition temperatures of a number of cooking oils fall into the range of 300° to 450°C (see Table 19).

Flammable liquids with low flash points, such as gasoline, which has a flashpoint of -43°C, continually give off vapors at room temperatures that can burn or explode, depending on the confinement of the mixture. Cooking oils have high flash points and do not evolve flammable vapors at ordinary temperatures (see Table 19). The usual temperature range for frying foods in cooking oil is between 140° and 190°C,[21] clearly below the flash point of most cooking oils. The first point of fire danger with cooking oil begins when it is heated above its flash point. From that point on, it will present the same degree of fire and explosion risk, at least in the immediate vicinity of the liquid, as a flammable liquid such as gasoline. In this context, it is of interest to note that vegetable oils were used during the energy crisis of the 1970s[22,23] as alternate fuels, either by blending them with diesel oil or burning them neat.

A number of complex chemical reactions occur during frying that cause cooking oil to degrade. The main degradation products are the result of hydrolysis and oxidation reactions. Vegetable oils are more prone to degradation than animal fats, and the accumulation of more volatile degradation products, such as free fatty acids, lowers the flash and fire points of cooking oils.[21] Thus, the fire danger may worsen when cooking oil is reused in frying.

The main variables that determine the time it takes a heated cooking oil to reach its autoignition temperature are the type and temperature of the heat source, the type and volume of the oil, and the type of container. Technical data from the U.K. dating back to 1969[8] indicate that a chip-pan half to two-thirds full of cooking oil takes 8 to 16 minutes on a gas cooker and 17 to 21 minutes on an electric hot plate to reach a temperature of 205°C. It takes a further 6 to 10 minutes on a gas cooker and 9 minutes or more on an electric hot plate to reach the autoignition temperature. These times are probably too long and not directly applicable to present-day cooking equipment.

When cooking oil vapors burn, the liquid temperatures are in the range of 300° to 450°C or more. If water, which has a boiling point of 100°C, is introduced, it first sinks, then becomes superheated and explodes to steam, expanding at a ratio of about 2,000 to 1. Australian research shows that this steam explosion throws out enough flaming oil to fill the average kitchen with a ball of fire. In a test using corn oil, the explosion filled a 4 by 2.5 m kitchen and burst through the open window. There was no significant difference in behavior among different types of oils or fats when water was thrown into them.[24] Using other materials containing water, such as sand or earth, to extinguish cooking oil fires or attempting to fry wet foods in very hot oil can also lead to steam explosions.

Looking at the fire characteristics of cooking oil in the context of the statistical findings leads to several conclusions.

A cooking oil fire is ignited by heating the oil above its flash point. Above this temperature, the oil continuously produces flammable vapors, which can then be ignited by flames from a gas stove burner.[25] The vapors can also be ignited if they come in contact with a heated surface such as a hot (1,000°C) electric stove element.[25] A premixed, moving flame originating at the element flashes back to the overheated cooking oil, further heating it and producing more flammable vapors. According to the National Fire Protection Association's *Flammable and Combustible Liquids Code Handbook*,[13] studies show that vapors require varied durations of exposure to hot surfaces before they actually ignite. A general rule is that hot surfaces need to be about 204°C above the autoignition temperature of the vapor for ignition to occur.

Heated cooking oil vapors can also autoignite if the oil is rapidly heated well past its fire point and perhaps even its boiling point. Dougal Drysdale, author of *An Introduction to Fire Dynamics*,[26] provides the following description: "Relatively nonvolatile combustible liquids, such as cooking oils and fats, may be heated sufficiently for spontaneous ignition to occur. Careful observation shows that the flame starts in the plume of hot volatile products, well clear of the liquid surface, then flashes back to give immediately an intense fire, as the liquid is already close to its boiling point."

Hot cooking oil vapors can also ignite if oil spills or overflows onto the hot element or burner. And oil in deep-fat fryers or pots and pans heated on electric stoves can overheat if the element is turned to its highest setting to heat the oil quickly at the beginning of the cooking process and the setting is not lowered once the oil has reached its frying temperature. The low number of cooking oil fires in thermostatically controlled deep-fat fryers, which cut out at a maximum of 200°C, may reflect their inherent safety features, as well as their low usage in Alberta households, although the actual number used is unknown.

The higher fire risk posed by cooking oil in deep-fat fryers or pots heated on stove tops is probably due to the lack of heat control, which can cause oil to overheat and ignite, or to the large quantity of oil generally used for deep-fat frying. Large quantities of overheated oil that reach flash point can support a large fire, and a large amount of oil is slow to cool after a fire has been extinguished, presenting the possibility of reignition. Large quantities of overheated oil may also spill and spatter more than small quantities. Finally, covering a deep-fat fryer or pot with a lid to make the oil heat more quickly may allow the flammable vapors under the lid to accumulate and ignite.

Introducing water into burning cooking oil can lead to steam explosions, which propel burning oil and vapor from the ignition site, causing the fire to spread and leading to injury and death.

Prevention and Suppression

Successful measures designed to reduce the number of, and danger presented by, cooking oil fires obviously depend upon a thorough understanding of the components of such incidents.

The key to preventing cooking oil fires is keeping oil temperatures below their

flash points. The correct temperature range for frying foods is between 140° and 190°C, far below the flash points of commonly used cooking oils. At the right temperature, the food is well-cooked with a crisp, golden-brown exterior. If the temperature is too low, the food will be soggy. If it is too high, the food will burn. Safe and successful frying entails bringing the oil to the correct temperature and keeping it there during use.

A number of preventive and protective actions can be taken to minimize the hazards of frying in cooking oil. These can be categorized under equipment, technology, product labeling, and human behavior. The conventional stoves installed in the majority of households do not have precise temperature controls. Thermostatic electric deep-fat fryers therefore provide the best available solution to the problem. A thermostatically controlled fryer maintains the correct frying temperature below a factory-set maximum of 200°C, which prevents the oil from reaching its flash point. Given the array of acts or omissions revealed in the statistical analysis, this type of "passive" safety measure appears more promising than attempts to change human behavior. The major shortcoming of thermostatically controlled deep-fat fryers is that they are somewhat expensive.

In the absence of a thermostatically controlled deep-fat fryer, a frying thermometer can be used to read and maintain correct oil temperatures during cooking. With a high frequency of unattended cooking, however, this approach may not be very practical.

A recent study for the U.S. Consumer Product Safety Commission evaluated the pre-ignition environment of gas and electric ranges, with unattended foods placed in pans on burners set to high heat.[6] Phase I of the study concluded that temperature, smoke particulates, and hydrocarbon gases were strong indicators of impending ignition and reviewed detection devices sensitive to these indicators, as well as automatic controls that would respond to a detector signal by shutting off the gas or electricity. These results are promising, in that relatively inexpensive sensor and automatic shut-down/restart technologies that would react to pre-fire conditions are already available. Household kitchen stoves or ranges fitted with smaller-scale automatic fire suppression systems, such as those in restaurant kitchens, may offer an additional strategy.

Proper warning labels on containers of oil and fat used in cooking can alert consumers to the fire hazards associated with them. Such labels already exist, but they are not eye-catching and may not serve their intended purpose.

Public education can focus both on proper frying procedures, as well as the proper actions to take in the event of a cooking oil flare-up.

Conclusions

Fires related to cooking equipment are the major type of fire in Alberta and Canada as a whole. These fires are concentrated in homes, where most cooking takes place. Cooking-related fires are also a major part of the fire problem in the

United States, especially in homes. Statistics for both Canada and the U.S. show that cooking fires are the leading causes of home fire injuries. Most of these fires involve the ignition of overheated cooking oil. The average home-dweller cannot be expected to know that apparently harmless cooking oils can be as flammable as gasoline when heated above their flash points, and this lack of knowledge translates into the large number of cooking oil fires in homes.

All preventive approaches focus on keeping cooking oil temperatures below the oil's flash point. The maximum frying temperature of 190°C is at least 50°C below the flash point of cooking oils and affords a safe margin of operation. A thermostatically controlled deep-fat fryer with a maximum factory set temperature of 200°C offers the best available preventive strategy to combat the cooking oil fire problem. Detectors sensitive to pre-ignition conditions and linked to mechanisms that can safely shut down and restart gas and electric stoves and ranges offer much promise for the future. Fire safety education directed at changing the knowledge, attitudes, and behaviors of the public is the more challenging approach to promoting the safe use of cooking oils, although it could eventually have a favorable impact on fire statistics.

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The Evolution of HAZARD, the Fire Hazard Assessment Methodology

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Abstract

The United States alone spends about $700 billion a year on new and renovated construction. About 20% of this money assures safety from unwanted fires, and this portion includes the cost of insurance to families and businesses. This enormous cost could be reduced by introducing fire safe products to the building and transportation industries, both in the United States and abroad, and by introducing advanced detectors, suppression systems, and firefighting equipment to the fire protection industry. In order to show that these products and mechanisms are safe to use, industries need performance measures. Performance-based fire standards are currently being developed to augment prescriptive standards around the world.

Performance-based standards are intended to provide flexibility in maintaining accepted fire safety levels among competitive products, while ensuring life safety and reducing property loss. At the same time, performance-based requirements should reduce design and construction costs, as well as the cost of maintenance and liability coverage. In order to derive these benefits, evaluation tools are needed. One such tool, HAZARD I, helps users understand the consequences of unwanted fires by making the results of recent fire research available to them. Improvements to the program will include increased applicability, improved usability, the ability to address additional building features, and more accurate treatment of fire behavior and its effects on people and their actions. Many of the improvements made already in the software documentation are based on the experience of fire protection engineers and others who have used the program. User input, combined with other planned program improvements, constitute the first step in the overall goal of a complete Fire Hazard assessment methodology.

Introduction

The United States alone spends about $700 billion a year on new and renovated construction. About 20% of this money assures safety from unwanted fires, and this portion includes the cost of insurance to families and businesses. This enormous cost could be reduced by introducing fire safe products to the building and transportation industries, both in the United States and abroad, and by introducing advanced detectors, suppression systems, and firefighting equipment to the fire protection industry. In order to show that these products and mechanisms are safe to use, industries need performance measures. Performance-based fire standards are currently being developed to augment prescriptive standards around the world.

Key words: fire modeling, building design, fire growth, smoke movement