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AN ANALYSIS OF UNITED STATES FIRE FATALITY STATISTICS

A fire risk index is described that correlates the widely varying fire fatality record among the states of the United States with ignition factors (principally cigarettes and faulty heating devices) and potentiating factors (alcohol consumption, income deficiency, occupancy density, housing defects, and lack of education) that worsen the consequences of unwanted fires.

INTRODUCTION

The fire fatality statistics for individual states of the United States* show a substantial spread in the fatality rate, ranging from a low of 0.9 per hundred thousand population in Hawaii to a high of 10.7 in Alaska (Table 1). It would be desirable to have a model that explains why such large differences exist and to what factors they can be related, using the detailed Maryland fire fatality study[1] as a guide.

All fires are ultimately traceable to mostly unplanned initiating events (ignition) and to specific fuel arrays that permit a small fire source to grow in size. Unwanted fires may be caused by deliberate or thoughtless human actions (arson, suicide, misused ignition sources), by design faults (fuel leaks, overheating), or by natural events (lightning).

The observed fatality rates should, in principle, correlate with the dominant ignition factors that describe human errors, design faults, and other contributing factors. In addition, for every initiating event several "potentiating factors" may be present that can lead to an increase in the number of fires with fatal outcomes. Such potentiating factors include: (a) *high levels of alcohol consumption* that, by causing errors of judgment, would give rise to a larger number of unplanned fire initiations than in their absence and would also prevent affected persons from reaching safety or helping others to escape; (b) *high density of building occupancy* that would put a larger number of persons at risk for any given fire event (although tempered by the benefits of mutual help); (c) *low educational levels* that would produce a larger number of misjudgments in the carrying out of effective fire prevention and suppression measures; (d) *poor housing stock* that would give rise to a higher rate of fire-causing equipment malfunctioning and, because of lower building standards in housing construction, would lower the ignition requirements for fire starts; (e) *low income levels* that limit the purchase of warning devices or of furnishings designed to resist ignition; and (f) *inadequate supervision of children, the aged, and the bedridden* that would preclude effective and timely rescue.

By appropriate selections and weightings of the relevant ignition and potentiating factors, a correlation should be possible with the reported fatality record. The Maryland fire fatality study[1] has provided the basis for selecting the specific ignition and potentiating factors that are likely to influence the overall fire record. Seven such variables have been identified (see below).

ANALYSIS

The correlation of various factors influencing the fatal outcomes of fires with the base values determined in the Maryland study is carried out in the following manner:

A "fire risk index" is defined as the product of two terms, expressing the relative probabilities of ignition and the magnitude of the potentiating factors that will modify the frequency by which an ignition event will escalate to a fire fatality. They, in turn, are the weighted sums of individual terms, each representing a specific factor that is related to ignition frequency or the severity of the resulting fire.

Based on the data identifying the principal causes of ignition in the state of Maryland,[1] the Ignition Index (X) is composed of ignition sources from substandard house-heating devices (A), from cigarettes (B), and a miscellany of other ignition causes (C) such as vehicle collision fires, substandard cooking devices, etc.. Values for the parameters A and B are available for each state (Fig. 1 and Table 2) from a variety of sources.[3] C is considered to be a constant. In addition, data on five potentiating factors (alcohol consumption, income deficiency, occupancy density, housing defects, and education) are listed in Fig. 2 and Table 2.

*Averaged over the period 1954-1972 to eliminate fluctuations that may amount to ±30% from year to year, especially in regions where the number of fatalities is small. The essential invariance of the fatality record in the 1954-1972 period is noteworthy and is indicative of a constant set of scenarios that are responsible for the causes and consequences of fires with fatal outcomes.

No one parameter is sufficient by itself to correlate the observed fire fatality ranking order and magnitude among the different states. Rather, a combination of properly weighted factors must be used to obtain a satisfactory correlation, calculated as follows:

Fire risk index = (Ignition Index X) · (Potentiating Index Y),

where $X = (A' + 3B + C)$,

$Y = 10(D) + 2(E) + F + 0.1(G) + H$,

and

A = Heating factor
A′ = Modified heating factor [(A) · (I)] (Fig. l)
I = Heating degree-days
B = Smoking factor (Fig. l)
C = Constant (i.e., 2)
D = Alcohol consumption factor (Fig. 2a)
E = Income deficiency factor (Fig. 2b)
F = Occupancy density factor (Fig. 2c)
G = Housing defect factor (Fig. 2d)
H = Education factor (Fig. 2e)

Table 1

FIRE FATALITIES IN THE UNITED STATES[2]

	1954	*1956*	*1958*	*1960*	*1962*	*1964*	*1966*	*1968*	*1971*	*1972*	*Average*	*Per Capita* $\times 10^5$
1 Alaska	-	-	-	19	31	33	68	25	31	30	33.4	10.7
2 Mississippi	169	181	222	235	219	198	211	203	123	134	189.5	8.4
3 Arkansas	130	124	191	186	152	140	154	130	95	136	142.8	7.3
4 South Carolina	140	137	207	224	154	190	175	180	142	150	170.1	6.4
5 Alabama	230	181	253	257	263	209	244	223	198	174	223.2	6.4
6 Louisiana	189	187	247	241	228	256	249	227	137	176	213.4	5.8
7 West Virginia	85	64	126	129	123	95	133	79	79	100	101.3	5.7
8 District of Columbia	44	39	31	47	32	49	41	39	47	40	40.9	5.4
9 Georgia	228	216	266	263	274	255	265	293	246	236	254.2	5.4
10 Maine	52	61	54	61	46	50	46	54	53	58	53.5	5.3
11 Oklahoma	94	105	156	138	140	153	134	108	108	166	130.2	5.0
12 Tennessee	135	143	202	230	207	159	214	211	168	176	184.5	4.6
13 Kentucky	178	128	184	179	155	103	192	188	155	126	163.8	5.0
14 North Carolina	204	182	249	251	215	243	253	290	230	248	236.5	4.6
15 Virginia	203	182	276	228	212	194	219	218	212	188	213.2	4.5
16 Missouri	178	196	204	212	225	206	242	196	187	188	203	4.2
29 Maryland	112	149	94	111	166	131	185	150	129	128	135.5	3.4
42 South Dakota	20	14	16	20	18	18	33	23	20	12	19.4	2.9
43 Ohio	281	300	336	308	317	304	317	322	277	282	304.4	2.8
44 New York	427	401	474	594	529	551	615	414	407	468	489.0	2.7
45 Rhode Island	20	23	15	30	27	32	30	22	27	20	25.1	2.6
46 Iowa	57	58	77	67	96	82	75	89	60	68	72.9	2.5
47 California	362	456	402	468	475	553	580	542	521	492	485.1	2.3
48 Wisconsin	70	108	106	118	99	85	93	88	112	107	98.3	2.2
49 Colorado	46	50	41	41	46	57	51	41	52	40	46.5	2.1
50 Utah	13	24	32	24	28	17	13	21	41	16	22.7	2.1
51 Hawaii	-	-	-	7	6	6	14	4	8	4	7.0	0.9

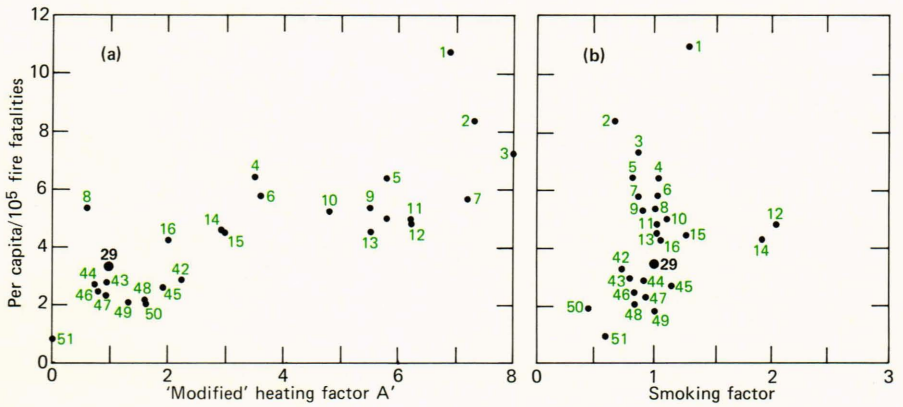

Fig. 1—Fire Ignition Indexes. (a) "Modified" heating factor (adjusted for heating degree-days) as a function of per capita $\times 10^5$ fire fatality rates for 16 states with the worst (1-16) and 10 states with the best (41-51) fire fatality records, normalized to Maryland (29); (b) smoking factor as a function of fire fatality rates.

The heating factor, A, refers to the use of substandard heating devices (such as room heaters without flues, fireplaces, stoves, and portable heaters) as the principal supply of home heating. It has been modified, A′, by relating it to the local climate, which sets the frequency and length of usage of these devices. The local climate is expressed as "heating degree-days," defined as the number of days per year where the average local temperature is below 65°F multiplied by the absolute magnitude of the average temperature difference below 65°F. The weighting for the various factors was selected to give an optimal correlation.

DISCUSSION

The results for the 16 states with the worst fatality records and the 10 states with the best fire fatality records (with Maryland as the baseline) are shown in

Table 2

INITIATING AND POTENTIATING FACTORS[3]
(NORMALIZED TO MARYLAND)

	Per Capita Fatalities ($\times 10^5$)	*Adjusted Heating* (A')	*Heating Degree Days* (I)	*Smoking* (B)	*Alcohol Consumption* (D)	*Income Deficiency* (E)	*Occupancy Density* (F)	*Housing Defect* (G)	*Education* (H)
1 Alaska	10.7	6.8	9007	1.18	1.19	1.3	3.06	3.90	0.71
2 Mississippi	8.4	7.6	2300	0.9	0.62	3.5	2.36	5.52	1.21
3 Arkansas	7.3	8.0	3354	0.91	0.55	2.8	1.56	4.22	1.23
4 South Carolina	6.4	3.5	2598	1.01	0.72	2.4	1.92	4.22	1.29
5 Alabama	6.4	5.8	2500	0.87	0.58	2.5	1.73	3.84	1.21
6 Louisiana	5.8	3.6	1465	1.04	0.76	2.6	2.26	2.61	1.19
4 West Virginia	5.7	7.2	4500	0.9	0.58	2.2	1.42	4.14	1.19
8 District of Columbia	5.4	0.6	4211	1.01	1.95	1.7	1.91	0.58	0.94
9 Georgia	5.4	5.5	3095	0.95	0.73	2.1	1.70	3.0	1.21
10 Maine	5.3	4.8	7498	1.08	0.84	1.4	1.17	3.5	0.94
11 Oklahoma	5.0	6.2	3695	1.04	0.61	1.9	1.14	1.61	1.0
12 Kentucky	5.0	6.2	4645	1.7	0.62	1.3	1.66	4.73	1.31
13 Tennessee	4.6	5.5	3227	0.92	0.60	2.2	1.52	3.36	1.19
14 North Carolina	4.6	2.9	3218	1.61	0.65	2.0	1.59	3.55	1.29
15 Virginia	4.5	2.95	3900	1.16	0.74	1.5	1.25	3.05	1.08
16 Missouri	4.2	1.97	5161	1.04	0.74	1.5	1.28	2.20	0.94
29 Maryland	3.4	1.0	4729	1.0	1.0	1.0	1.0	1.0	1.0
42 South Dakota	2.9	2.2	7838	0.86	0.72	1.9	1.04	3.09	0.78
43 Ohio	2.8	0.94	5500	0.94	0.70	1.0	1.03	1.18	0.98
44 New York	2.7	0.70	6000	0.93	0.93	1.1	1.19	0.73	0.92
45 Rhode Island	2.6	1.9	5972	1.1	0.99	1.1	0.94	0.70	1.11
46 Iowa	2.5	0.79	6700	0.93	0.68	1.2	0.92	1.70	0.87
47 California	2.4	0.90	2000	0.93	1.07	1.1	1.23	0.48	0.79
48 Wisconsin	2.2	1.58	7400	0.87	1.08	1.0	1.12	1.64	0.96
49 Colorado	2.1	1.3	6000	0.98	1.0	1.2	1.08	1.14	0.77
50 Utah	2.1	1.6	6000	0.60	0.54	1.1	1.66	0.71	0.71
51 Hawaii	0.9	0	0	0.71	0.95	1.3	3.1	1.27	0.81

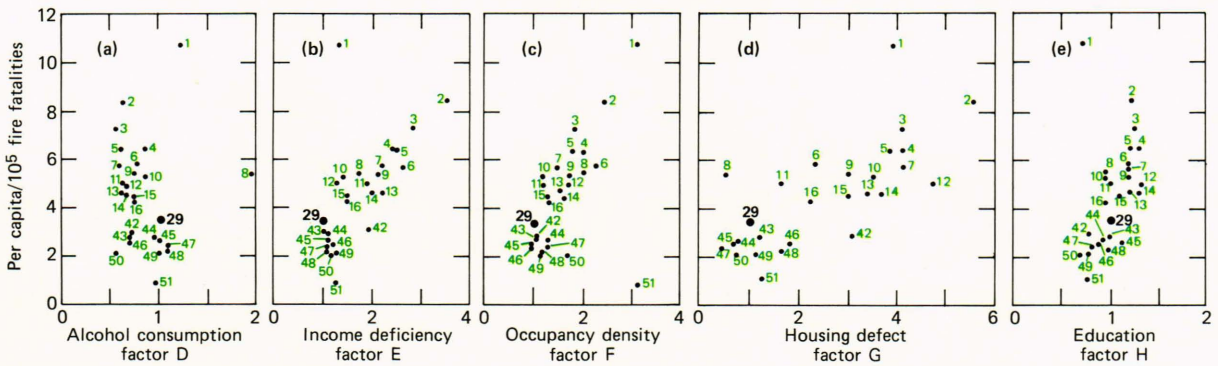

Fig. 2—Fire Potentiating Indexes. (a) Alcohol consumption, (b) income deficiency, (c) occupancy density, (d) housing defect, and (e) education as functions of per capita ($\times 10^5$) fire fatality rates. The numbering scheme used is the same as in Fig. 1.

Fig. 3. The fire risk index correlates reasonably well with the fire fatality data over the range of 0.9 to 10.7 fatalities per hundred thousand population.

The implication of this correlation is that the magnitude of the fire fatality records of the various states can be expressed in terms of a number of physical and social factors that make up the ignition and potentiating indexes. Although these factors do not have a bearing on any specific fire, they are descriptive of the likelihood of persons in specific states becoming fire fatalities. In some locations, factors that promote fire deaths are counterbalanced by others that diminish them. For example, a combination of low ignition and potentiating factors leads to a low overall fatality rate in Utah. High values of ignition factors (brought about by many substandard heaters in Arkansas), of potentiating factors (such as high alcohol consumption in the District of Columbia), or a combination of several factors (such as substandard heaters, high occupancy density, and income deficiency in Mississippi) account for the observed high fatality rates.

The correlations indicate that substandard home heaters, when in frequent use, are responsible for the observed high fatality rates. While this specific cause is relatively small in Maryland (accounting for less than 15% of all fatalities), it tends to have a major influence in most of the 16 states with high fatality records. (The poor fatality record of the District of Columbia is mainly caused by a combination of high values of potentiating factors such as alcohol consumption, occupancy density, and income deficiency.)

Smoking (as an ignition factor) and drinking to excess (as a potentiating factor) are fairly uniformly distributed throughout most, but not all, of the states (Figs. 1b and 2a). They are expected, therefore, to make a nearly constant contribution to the fatality record of each state (but note should be taken of the high alcohol consumption in the District of Columbia and its low value in Utah and in many southern states, such as Arkansas). The magnitude of the "modified" heating factor, on the other hand, varies widely among the states as do some of the potentiating factors such as income deficiency, housing defects, and occupancy density.

It was reported recently (Fourth Annual Conference on Fire Research, October 22, 23, 24, 1980, National Bureau of Standards, Washington, D.C.) that a preliminary analysis of fire fatality data from six states in the Southeastern quarter of the United States with high rates of fire fatalities showed that "... heating fires are the major cause of death in the high rate states ..," and that "smoking is the second leading cause in the high rate states and the major cause in the low rate [control] states."

Additional parameters would have to be introduced to correlate the more subtle fatality trends,[1] such as the daily and seasonal variation, the predominance of male over female victims, the low incidence in suburban as compared to urban or rural areas, or the large risk to black children in urban settings. However, even with the limited available data, many of these observations can be understood qualitatively. For example, the number of households in which mothers with children under 6 years of age are part of the labor force and, therefore, are not always present for supervision or rescue, may hold a clue for the large risk to urban black children. The percentage of black women with young children currently at work outside the home is nearly three times that of white women.

Since most developed countries have fire fatality losses well below those of even the "best" states in the United States, it would seem worthwhile to ascertain the specific factors that are responsible for these differences. In the fire fatality study of Anderson[4] for parts of Scotland, many qualitative similarities to the Maryland study are apparent that may be accounted for by the similarities in the makeup of the contributing indices in Scotland and Maryland. However, quantitative comparisons among countries

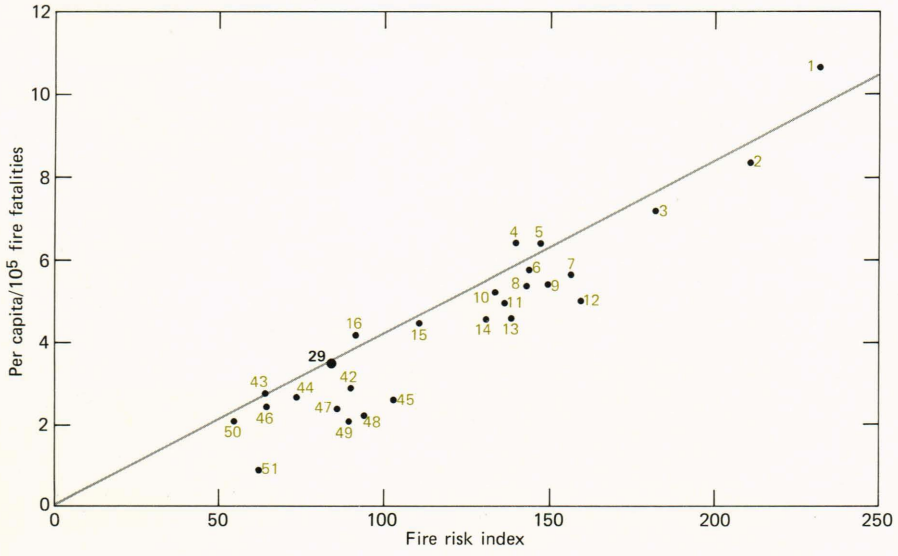

Fig. 3—Correlation of fire risk index with fire fatality rates for 16 states with the worst and 10 states with the best fire fatality records.

with widely different living styles and standards is difficult in view of the differences in measuring social and economic factors that influence fatality rates.

CONCLUSIONS

A complete description of fire deaths must provide explanations for fire fatality rates as a function of the time in which the fatal events occur, the demographic characteristics of the fire victims, and the geographic location of the fires. The following summary lists the principal observations and the most probable causes that account for them.

DAILY VARIATIONS

Observation: Peaking of fatalities in the period from midnight to 6 AM.

Causes: Above average smoking and drinking at night; high building occupancy at night; delayed fire detection and slow arousal from sleep.

SEASONAL VARIATIONS

Observation: Peaking of fatalities during cold weather season.

Causes: Use of defective heating equipment; high building occupancy during cold weather.

ANNUAL CYCLICAL VARIATIONS

Observation: Yearly fluctuations in fatalities.

Cause: Interrelation between weather severity (expressed as heating degree-days) and use of defective heating equipment.

AGE

Observation: Peaking of fatalities for very young and elderly.

Causes: Inability to escape without assistance; misjudgments in the handling of potentially hazardous ignition sources; sensitivity to toxic combustion products.

SEX

Observation: Predominance of male fatalities.

Cause: Excessive alcohol consumption by men.

RACE

Observation: Predominance of black fatalities.

Causes: Income deficiency, housing defects, high building occupancy; inadequate supervision of children in urban and suburban areas.

REGIONS

Observation: High fatality rates in rural and urban areas.

Causes: Income deficiency, housing defects, high building occupancy; defective heating equipment.

STATES

Observation: High fatality rates in diverse states.

Causes: Same as under "Regions." Contributions also from other ignition and potentiating factors; interrelation between weather severity and use of defective heating equipment.

COUNTRIES

Observation: High fatality rates in diverse countries.

Causes: Same as under "States;" other variables such as ownership of defective appliances, differences in effectiveness of fire fighting forces, differences in building codes, and public understanding and differences in health, differences in usage of plastics, paper, and liquid fuels.

This analysis is, at best, a first approximation to the actual state of affairs and is intended primarily to point out broad areas that contribute to fire death risks. Even in Maryland, which represents the most detailed analysis of fire deaths to date, precise information is difficult to obtain from which to evaluate all the many contributory factors, their importance, and their interactions. Additional data are needed to check into the details of the fire fatality correlations and to use them as a predictive tool.

Most potentiating factors (alcohol abuse, economic, or educational deficiencies) are deeply imbedded in society as general social and economic ills and are difficult to change rapidly. On the other hand, potentially hazardous ignition sources can, in principle, be corrected more rapidly at the technical and design level and their misuse minimized by appropriate regulations and educational efforts. But prevention of large and damaging fires by the installation of warning devices that detect unwanted fires at an early stage may well be the most effective short-term method for reducing fatalities substantially.

REFERENCES and NOTES

[1] W. G. Berl and B. M. Halpin, "Human Fatalities from Unwanted Fires," *Johns Hopkins APL Tech. Dig.* **1**, No. 2, 129-134 (1980); *Fire J.* **73**, 105-123 (1979).

[2] *Vital Statistics of the United States, Vol. II — Mortality*, U.S. Department of Health, Education and Welfare, Health Resources Administration, National Center for Health Statistics, Rockville, Md.

[3] Sources and Comments on Table 2:

PER CAPITA FATALITIES: *Vital Statistics of the United States (1954-1972), Vol. II — Mortality.*

HEATING: U.S. Bureau of the Census, *Census of Housing (1970)*, Table 23, "Heating Equipment."

The data record the percentage of heating equipment used in all year-round residences that consist of room heaters without flues and of fireplaces, stoves, and portable heaters. Such heating devices, in contrast to central furnaces of built-in electric heating units, are potential ignition hazards.

HEATING DEGREE-DAYS: *Statistical Abstracts of the United States*, Table 362, "Normal Monthly and Seasonal Heating Degree Days, 65° Base."

The data provide information on the use of home heating equipment. Each degree of mean temperature below 65°F is counted as one heating degree-day. The frequency of use of heating equipment is related to the absolute values of heating degree days.

SMOKING: *The Tax Burden on Tobacco*, Table 77, "Tax Paid Per Capita Sales (in number of packs) — 1977," Tobacco Tax Council, Richmond, Va. (1977).

The data list the tax paid per capita sales during Fiscal Year 1977.

Cigarette consumption is believed to be a measure of frequency of fire initiations due to smoking.

ALCOHOL CONSUMPTION: M. Keller and C. Curioli, *Statistics on Consumption of Alcohol and on Alcoholism*, Rutgers Center of Alcohol Studies (1976), Table 4, "Apparent Consumption of Alcoholic Beverages and Total Absolute Alcohol in U.S. Gallons per Capita of the Drinking Age Population (1974, aged 14 and over)."

The per capita rate of alcohol consumption is a measure of the number of human errors leading to ignition and to failure to escape from a fire.

INCOME DEFICIENCY: *Statistical Abstracts of the United States*, Table 458, "Percentage of Persons Below Poverty Level" (1969).

This factor lists the percentage of persons whose income is below the "poverty line" income level. It is an indicator of the relative absence of fire-safe furnishings, of fire detection devices, and of fire extinguishment equipment.

OCCUPANCY DENSITY: U.S. Bureau of the Census, *Census of Housing (1970)*, Summary, Table 1, "Housing Characteristics for States, Cities, and Counties. Year Round Housing Units. Percentage with Occupancy of Greater than 1 Person/Room."

This factor lists the fraction of housing units in which the number of inhabitants exceeds the number of rooms. It is an indicator of the numbers of people who live together in a single housing unit.

HOUSING DEFECTS: U.S. Bureau of the Census, *Census of Housing (1970)*, Summary, Table 1, "Year Round Housing Units Lacking Some or All Plumbing Facilities."

This factor lists the fraction of housing units that have partial or no plumbing. It is indicative of relatively poor housing stock, built to designs that do not reflect current fire prevention standards of construction.

EDUCATION: *Statistical Abstracts of the United States*, Table 180, "Years of School Completed. Percentage of High School Graduates (1970)."

The percentage of population with completed high school records is an index of understanding regarding the safe handling of potentially fire-causing materials and devices.

[4] I. S. Symington, R. A. Anderson, J. S. Oliver, I. Thompson, W. A. Harland, and J. W. Kerr, "Cyanide Exposure in Fires," *Lancet*, 91-92 (July 8, 1978).

[5] W. H. Harland and W. E. Wooley, "Fire Fatality Study — University of Glasgow," Fire Research Station Report PD-27 79, Building Research Establishment, Boreham Woods, England.