State of Fire Research and Safety

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ABSTRACT

A review is made of available international statistics on the costs and losses due to fire. Estimates are also made on the level of fire research carried out by different countries. Views are presented on strategies for reducing the losses and costs by fire. An example is given to illustrate a rational use of test data to predict fire growth on materials.

INTRODUCTION

"It takes a disaster to make one cautious" wrote Eddie Foy as he recounted his experiences on the afternoon of December 30, 1903. Eddie Foy was a well-known entertainer appearing at the Iroquois Theater in Chicago, Illinois on that day. He had brought his son Bryan, aged six, to watch the performance of Mr. Bluebeard. The audience was packed with women and children enjoying the Christmas week. During the performance, fire occurred and quickly spread. In eight minutes, 1825 people sought to escape; 602 did not succeed. The building was of fire resistant construction and modern for its day. What went wrong? Some said the fire-blocking stage curtain malfunctioned, exits were poorly marked, there was no fire alarm box, and sprinklers should have been provided for the stage [1]. Should these factors have been obvious before the fire? Perhaps not. "It takes a disaster to make one cautious."

Disastrous fires continue to take their toll. In 1983, a theatre fire in Italy killed 64 people, a hotel fire in Turkey claimed 35 lives, and a discotheque fire in Spain killed 79. In the skies over the USA, a fire in a commercial passenger aircraft resulted in 23 fatalities.

Current (1981) USA fire statistics suggest that 7600 deaths due to fire will occur per year. Assuming no substantial change in this death rate ($34/10^6$ persons), about one in 400 persons will die by fire in your lifetime (75 years). You are likely to have known one.

Could these disasters have been prevented? Can we reduce our risk of death due to fire? Do we fully understand what causes a fire catastrophe? Is fire safety an exact science? Let's explore our state of fire safety and its science and technology.

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Technology is the state of knowledge applied to the production of goods
and services in a particular field. Technology is an important ingredie
in the economic health of a company, industry or nation. Economic growt
depends on technological change, i.e., advances in knowledge that are
applied to the market place. Although new scientific discoveries
contribute to and promote technological change, it is the dissemination
knowledge that contributes to its application.

The technology of fire safety is governed principally by its response to
needs in the market place and our environment. In the production of mar
products, issues of fire safety play a role in their design and structui
Components of building codes and standard test methods mandate the
technological requirements for meeting standards of fire safety. These
are usually inflexible requirements that limit the application of new
knowledge to fire safety design or new understanding to fire resistance.
The technology (both generic and proprietary) for fire safety is set by
the criteria of "pass the test" or "meet the requirements".

The technological level of a nation, with its complex array of
technological changes, can place a burden on the processes for setting
fire safety requirements. Moreover, the inability of the fire safety
technology to cope with technological changes in the market place can
limit or inhibit such changes. It is not uncommon to have new products
applications come along only to be misread by the current fire test meth
of record.

The level of technological development of the United States appears to b
at least twice that of other developed countries of the world (Figure 1)
[2]. Thus, it would appear that the level of fire safety technology mus
be equal to this challenge. Unfortunately, this is probably not the cas
since we place our emphasis on "rule making" to settle issues as opposed
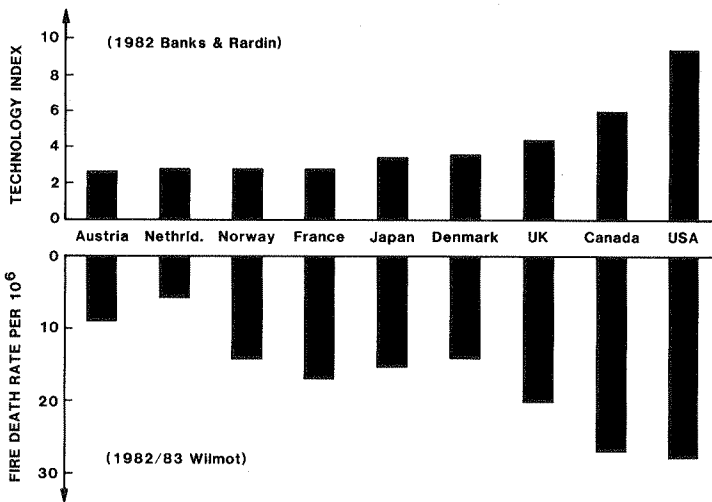to performance standards based on new knowledge.

Figure 1. Country technology level and annual fire deaths.

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One measure of the level of fire technology is the great reliance placed on specifications required by standard tests and codes. Indeed, disparities among "national" fire propagation test methods [3] clearly illustrate our lack of unanimity in how to decide a material's fire behavior. These disparities surely add to confusion in the international market place and add to the cost of foreign trade for the products affected.

Another measure of the level of fire technology is the knowledge base of the field. In 1983 about 150 technical articles by USA authors appeared in six technical journals. Yet, no fundamental textbooks exist for the field in the USA. In Japan, at least two texts exist; one for the fire science program at the Science University of Tokyo; the other at Yokohama National University in the curricula of engineering safety. In the USA, the NFPA Handbook provides a chronicle of the fire technology in practice. It provides much useful information on the many subjects related to fire safety; but little in the way of theory in order to develop understanding or flexible design practices. This is consistent with a recent survey of fire protection engineers (SFPE) which indicated preference to design by using the "code" rather than by analytical methods [4].[1] Of the 2800 SFPE members, about 350 new engineering graduates are needed by the field each year. Of those graduates, only about 25% come from college degree programs in fire protection engineering. Hence, the 75% that mostly come from other engineering disciplines must learn the field in practice.

The practice of fire safety technology involves knowledge from many disciplines. This contributes to its lack of an organized science base of knowledge. The field involves human behavior, heat and mass transfer, toxicity, detection, suppression, structural behavior, risk, and probably education should also be added. It is interesting to recite from a description of a new program begun at the National Bureau of Standards on fire safety [6].

> In a joint undertaking with the National Fire Protection Association and the Underwriters Laboratories, the Bureau aimed at a thorough study of the behavior and safety of building materials in various types of construction under all possible fire conditions. The study would furnish architects, builders, State and city building bureaus, and insurance interests with fundamental engineering data long needed but nowhere available.

> But so broad became the scope of the investigation that it soon involved almost everyone of the scientific and engineering laboratories of the Bureau. It included high-temperature measurements, fire tests, and thermal conductivity studies by the Heat Division; solution of composition and construction problems by the Chemistry and Structural Materials Divisions; electrical wiring and safety code studies by the Electrical Division; and the behavior of structural materials under heat as a special study in the Weights and Measures Division.

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[1] In a more recent survey [5], this preference reversed. Also, the book, An Introduction to Fire Dynamics, by Dougal Drysdale was published (1985).

This was the program directed by Simon Ingberg that began in 1914. It w
prompted by the concern that the USA property loss was ten times that of
any European country. Also, the NBS Director noted in Congressional
testimony that "The greatest (fire) losses are in the cities having fire
laws and regulations." Sixty years later, a Presidential Commission on
Fire declared: "One basic need is to strengthen the grounding of knowled
about fire in a body of scientific and engineering theory, so that real
world problems can be dealt with through predictive analyses" [7].

Perhaps it is fair to say that the practice of fire safety is an under-
developed technology. Its state could be particularly burdensome to an
advanced technology and its consequences could be economically costly.

COSTS OF FIRE

The costs of fire comprise the money spent in the implementation of fire
protection and control measures, insurance administrative costs and
claims, plus the personal costs in terms of deaths and injuries. One
could also include the cost of medical treatments as a direct result of
fire injuries and the indirect costs of displacement, relocation, lost
production and psychological effects.

A comparison of fire deaths per capita is plotted against the country's
technology index. These data for 1982/83 came from Wilmot [8] who lists
15 countries with only Hungary exceeding the USA death rate. Figure 1
suggests the relationship between technology and fire losses previously
posed by Banks and Rardin [2]. The highest death rate for Hungary might
be contrasted with the fact that it has the highest standard of living
among the Eastern European countries which is suggestive of its technolo
level. Although the level or change in technology might be correlatable
with fire statistics, it does not suggest causative factors but does
suggest the interplay of more variables in an advanced technological
environment.

Some of the monetary costs due to fire and fire safety are shown in Figu
2 in comparisons based on the Gross Domestic Product (GDP) for various
developed countries [9]. (The GDP is essentially the Gross National
Product (GNP) minus the input of foreign investment). These costs are
broken down into the cost of the property lost, the cost needed to prov:
fire service operations, the cost of meeting the fire protection needs o
the facility and the administrative costs of the fire insurers. Despite
variations in these individual costs among the countries listed, it is
significant that the total costs are nominally at 1 percent of their GD:
The cost of research and development for fire safety might be viewed as
indicator of potential reduction in the "costs" of fire. An informal
survey (1985) for the USA found $15 million for basic fire research whi
contributes to new fundamental knowledge; $80 million for special testi
standards and education; and roughly $150 million for product developme
to meet fire safety requirements. These results suggest that less than
percent of the USA fire costs ($37.4 billion, 1983 [10]) used for fire
safety research, development and standards with only 0.05 percent appli
to research. This compares to typical values of 2-3 percent of a
developed country's GDP applied to research and development [1].

A measure of a country's interest in fire safety research can be deduce
by the staff employed relative to its population. As with direct costs
these staff figures are also subject to interpretations of research
activities versus other activities. In compiling this measure, shown i
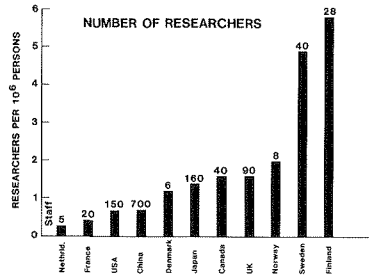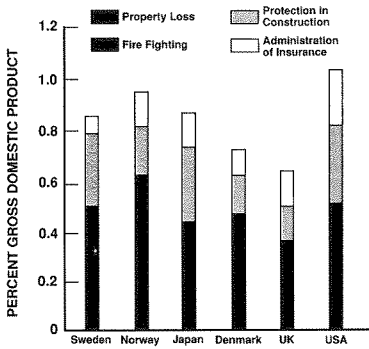
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COST OF FIRE

Figure 2. Country costs of fire.   Figure 3.   Country relative number of fire researchers.

Figure 3, I tried to identify the technical staff of well-known institutions engaged in research programs. These numbers represent the pool from which advances in fire safety knowledge can spring. Whether one considers this effect to be adequate or not, is not the total issue, since the transfer of new knowledge into practice is just as critical. The Building Research Board of the National Research Council reported, "The technology base needed to solve fire problems is now evolving. Owner-operators (of buildings) and design professionals have received little education in the use and benefits of this technology base and there is an urgent need for fire protection professionals to translate fire research into terms understandable by designers and the owner-operators they serve" [12]. Thus, in addition to deficiencies in fire research levels, there is perhaps a greater deficiency in the mechanisms and resources for transferring the fire science knowledge base to the users.

PROSPECTS FOR REDUCING FIRE COSTS

The goal of effective management in fire safety should be to minimize the costs and losses due to fire. Implicit in the term losses are the deaths and injuries associated with fire. Let us examine some major aspects of the costs and losses in order to project some potential indication for their reductions.

The USA has the highest number of fire deaths per capita of any developed country in the world. Based on data for 1981, the death rate was 33.1 per million persons -- a significant drop from 1971 when it was at 43.7 [13]. A study by Gomberg, et al. [14] derived a 41% reduction in the fatality rate for residences with smoke detectors. In 1981, 66 percent of the homes had detectors, compared to virtually very little in 1971. Based on these facts one can estimate the death rate in 1981 solely due to the detector impact on life safety [13]. Since about 80 percent of deaths occur in residences, a 41 percent reduction will be applied uniformly to the 1971 death rate, i.e., it is assumed that all deaths occur in residences and people are evenly distributed over residences:

1981 Estimated Death
Rate Due to Detector   =   43.7 [(1-0.41) (0.66) + (1.) (0.34)] = 31.9
Intervention

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This value compares favorably with the actual statistic of 33.1; moreover a value of 34.2 would have been estimated if we accounted for the fact that only 80% of the fire deaths occur in residences. This follows by taking the residential (80%) portion of the death rate to be 31.9 and the (20%) remainder at the 1971 level of 43.7. Indeed, if one assumed all deaths could be mitigated by detectors, then the death rate might reach a minimum based on detector intervention of 25.3 per million person. This minimum for the USA is still greater than the fire death rates of most industrialized nations. Also, the prevalence of home smoke detectors in other countries is not as great as in the USA. Hence, although the technology of reliable detectors and their current low price appear to have contributed greatly to the USA death rate reduction, it would appear that other unique but unknown factors inflate the USA fire death rate compared to other industrialized nations.

A reduction in the potential for fire growth, its mitigation, and its control bear on the loss of life, the occurrence of injury, and the damage to property. Property loss in unreported fires has been estimated at $45 per fire [14]. This might result for a fire involving less than 1 square meter of material, or less than 300kW of energy. For a fire much bigger, the opportunity for a non-professional to extinguish it is poor, and the potential for such fires to quickly and fully involve a typically sized residential room is very high. Once a fire spreads beyond a room the chance that it will become a large fire is much greater; e.g., Thomas [16 reports the number of large loss fires (perhaps greater than $100,000 today) is related to the cube of the number of fires which left the room of origin. Furthermore, fully involved compartment fires generate a considerable amount of carbon monoxide threatening life at sites remote from the fire origin. Hence, confining fire growth to less than 1 square meter of material could be a desirable goal.

It has been estimated that a combination of smoke detectors and a standard sprinkler could reduce the fire death rate by 58% [14]. Recently, Budnic [17] suggested a figure of 73% if fast-acting "residential" sprinklers were used instead of the standard sprinklers. Whereas detectors are realizing widespread use, the cost of sprinklers, especially in residences, has inhibited their widespread use. Efforts to reduce this cost or to improve the technology of residential suppression systems is needed to effectively impact the fire losses. It might be contemplated that very little fire research has been directed at suppression -- perhap 15% at most.

Of course while a suppression system could limit a fire's growth in the early stages, ignition and flame spread resistant materials could improve fire safety significantly. It is not necessarily just the development of new materials that is essential, but it is the proper measurement of fire hazard and risk that these materials impart to their environment. Improved measures of fire hazard analysis can have significant reductions in product development costs as well as in the costs of fire protection i construction.

The cost of fire protection in construction is estimated at $9 billion (1983). much of this cost is due to prescribed requirements by the building codes. Yet most codes have discretionary provisions which allow for the use of alternative but equivalently safe designs and construction practices. Because of the high reliance by the practicing engineers and architects on the codes, these alternatives are not usually exercised, especially since a creditable equivalency level must be demonstrated. Former Secretary of HEW (now HHS), Joseph A. Califano, Jr., stated that i

order to insure proper fire safety, "...HEW's staff had proposed several hundred pages of detailed, plank-by-plank, nail-by-nail specifications for construction and remodeling of hospitals and nursing homes". ..."Instead, at an estimated savings of $1 billion from the cost of complying with the HEW staff proposal, we ordered a simple code drafted that would require hospitals and nursing homes to provide equivalent fire safety protection, but left them the flexibility to determine how [18]". This "simple code" was the Fire Safety Evaluation Systems (FSES) developed by Nelson and Shibe [19]. It is based on equivalency with the NFPA Life Safety Code. The estimated optimum savings in cost compared to implementing the Life Safety Code is 50 percent [20]. Since the FSES has been based on existing fire protection technology; i.e., wisdom and experience, the potential for improving cost reductions further by analytical design methods is enormous. Thus, the recognition and ability to take advantage of flexibilities in the fire codes are beneficial objectives. The Japanese government has recently funded a five-year program to develop design and evaluation methods for building fire safety [21]. Perhaps this will be a first step for a flexible performance fire safety code.

Three other aspects of fire safety and fire consequences could also be improved. First, one research goal from America Burning (p.136) [7] sought to increase fire control capability by more effective extinguishing methods. Perhaps improved cost efficiency could be achieved by the fire services if this goal were realized. Second, liability claims associated with fire are increasing and their costs to society and industry sap more constructive pursuits. Scientific data and analytic methods could positively mitigate these issues, and make more sound the lessons learned. Third, common international understanding of fire safety principles, based on accepted scientific methods, could go a long way for reducing trade barriers and costs of foreign compliance on materials and products.

A RATIONAL APPROACH TO MATERIAL FIRE SAFETY

A scientific approach to fire safety analysis should improve the use of material test data and help to harmonize fire safety requirements. There is a lack of consensus on the tests to use for evaluating the flammability of interior finish materials. The disparity in results from various international test methods underscores this lack of consensus [3]. As an example, let us examine the prospect of predicting fire growth over a wall lining material in a room subject to a small ignition source. An actual experiment will be examined. Our analysis will be simplified for clarity in illustrating the governing physics. Its ultimate generalization offers the prospect of a rational approach for interior finish fire hazard analysis.

Ignition

The room fire experiment is displayed in Figure 4. The only combustible in the room is a T-section of polymethylmethacrylate (PMMA) of 12.7 mm thickness over the back wall. The ignition source is a line burner diffusion flame 0.15 m high and 0.30 m high as shown in Figure 5. This offers a potential vertical spread region and ceiling jet region that would be indicative of "wind-aided" or concurrent gas flow and flame
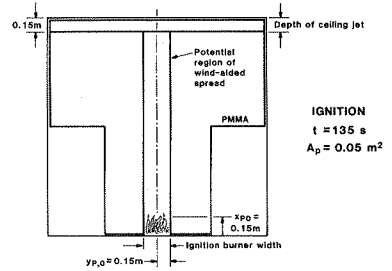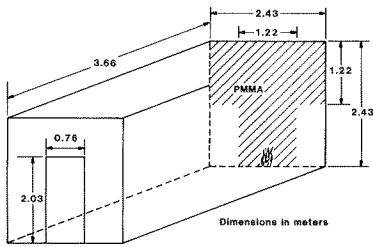
Figure 4. Room wall fire experiment. Figure 5. Ignition of PMMA wall.

spread. The ceiling jet thickness was estimated from the solution by
Alpert [22] as 0.06 of the room height. The time to ignite is estimated
for the diffusion flame heat flux of 25-30 kW/m^2 [23] by the formula:

$$t_{ig} = \frac{\pi}{4} \left(\frac{k\rho c (T_{ig} - T_i)}{\dot{q}''} \right)^2$$

(

where $k\rho c = 1.02$ $(kW/m^2 K)^2 s$,
$T_{ig} = 378°C$,
$T_i = 25°C$,
and $\dot{q}'' = 25-30$ kW/m^2

following the test data of Harkleroad and Quintiere [24]. The calculate
time is 135 ± 25 s compared to observed ignition estimated at 94 s. The
initial pyrolysis area, A_p, is calculated as 0.05 m^2 based on the burner
flame exposure. The objective is to compute the growth of A_p in time an
its influence by and to the room.

Upward Flame Spread

Upward flame spread is considered along the wind-aided direction,
vertically upward and along the ceiling jet. The pyrolysis front, x_p, i
estimated from the experiments of Orloff, de Ris and Markstein for PMMA
[25]:

$$\frac{dx_p}{dt} = 0.004 \, x_p$$

(

with x_p in m and t in s. The effects of external heating and oxygen
depletion are not included in Eq.(2), but in hindsight Eq. (2) will be
shown adequate for the early stage of fire growth since these effects ar
found to be small. Furthermore, in general, one must first determine if
spread will occur following ignition, but this is not an issue for PMMA.

Mass Loss Rate

Once pyrolysis begins following ignition, the mass flux, $\dot{m}''$, must be
computed. The resultant energy release is a direct measure of the fire
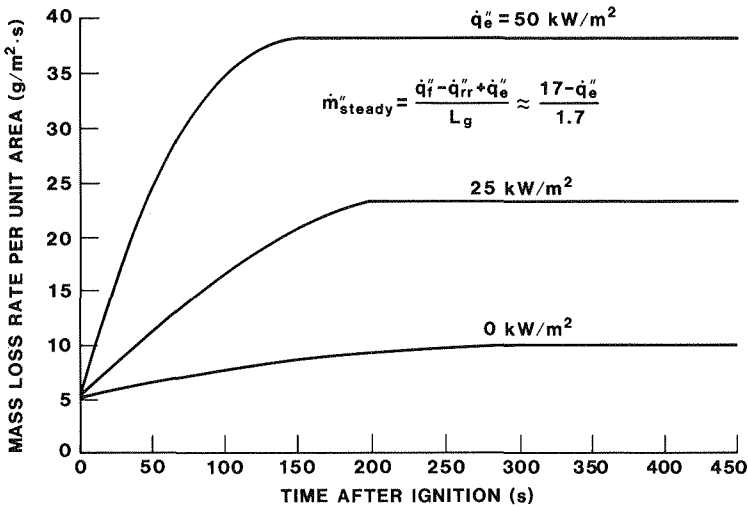hazard potential. Figure 6 shows a sketch of the mass loss behavior as .

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Figure 6. Burning vertical PMMA under external radiant heating.

function of time. For PMMA we can assume steady burning after 300 s of fire growth. Figure 6 follows from the experimental results of Walton and Twilley [26]. The steady result, sufficient for our analysis, can be given as

$$\dot{m}''_{ss} = \frac{\dot{q}''_f - \dot{q}''_{rr} + \dot{q}''_e}{L_g} \quad (g/m^2\text{-}s) \tag{3}$$

where the heat of gasification, $L_g = 1.7$ kJ/g, the reradiation loss, $\dot{q}''_{rr} = 10$ kW/m^2, and the flame heat flux, $\dot{q}''_f = 27$ kW/m^2. The external radiative heat flux is $\dot{q}''_e$. In general, the transient burning of a material must be included in a complete hazard analysis.

Lateral and Downward Flame Spread

Spread orthogonal to the wind-aided direction is in the direction opposite to the air entrainment. The spread is lateral during the vertical ascent of the flame, and downward once the flame has progressed along the ceiling jet. This extent of spread, y_p, is estimated for no external heating effects as

$$\frac{dy_p}{dt} = 0.12 \text{ mm/s } [24] \tag{4}$$

Figure 5 shows the initial value of y_p.

Pyrolysis Area

For this example of PMMA, the pyrolysis area, Ap, can easily be calculated by using Eqs.(2) and (4) as follows: $2 \, x_p \, y_p$. This assumes that burnout does not occur over our period of interest. Again, in hindsight, this

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assumption is satisfactory based on a nominal burning time of 1500 s for this PMMA wall burning under initial ambient conditions.

Room Conditions

The problem we are solving is highly coupled with the fire growth area depending on the room conditions which, in turn, depend on the fire. In the early stage, for this example, this coupling is weak so we will neglect it to some extent. The room upper layer gas temperature (T_g) is estimated by the correlation shown to be adequate for wall fires [27]:

$$T_g = T_i + 6.85 \left[\frac{\dot{Q}^2}{A_o \sqrt{H_o} \, h_k A} \right]^{1/3}$$

(

where A_o is the door area (m)
         H_o is the door height (m)
         A is the room surface area (m)
         h_k is a conductance, 9×10^{-3} kW/m^{2}K selected here

and $\dot{Q}$ is the energy release rate, kW.

$$\dot{Q} = \left\{ \begin{array}{ll} \dot{m} \, \Delta h_c & , \; \phi \leq 1 \\ \dot{m}_a \Delta h_c / \gamma, & \phi > 1 \end{array} \right\}$$

(6

(6

where Eq. (6a) refers to the fuel-controlled case of sufficient air supply, and (6b) is for the ventilation-limited case. The equivalence ratio, ϕ, defines the boundary of these two burning domains:

$$\phi = \frac{\dot{m}_a / \dot{m}}{\gamma}$$

(

here γ is the stoichiometric fuel to air ratio for PMMA, 0.12; Δh_c is th heat of combustion for PMMA, 25 kJ/g; and the air flow rate $\dot{m}_a$ can be estimated from the doorway dimensions and T_g [e.g. 27]. The mass loss rate follows from Eq. (3):

$$\dot{m} = \dot{m}'' \, A_p$$

(

where the external heat flux $\dot{q}_e''$, in Eq. (3) is determined from T_g as purely radiative heat transfer.

The gas concentrations are estimated from ϕ using the results of Beyler for PMMA [28].

Results

The procedure is to compute A_p at a given time, and then compute the roo conditions. For the next time, the previous room conditions are used to estimate the effect of room feedback on the spread process. The results of these computations are shown in Table 1. Certainly they could be refined through a more detailed computer solution, but the order of magnitude of their results is not expected to change. Let us examine

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these results in terms of the actual fire progression in the experiment.
Note, in the Table that ΔA_p is defined as the extent of pyrolyzed area
beyond that due to wind-aided spread alone which would only have been
confined to the band bounded by the dashed-lines in Figure 5. This band
will be retained in subsequent figures to visualize these differences.
Table 1 shows that in the early growth phase through 835 s room feedback
is relatively not significant, but in the next 160 s the oxygen plunges
toward 0% and thermal feedback increases $\dot{m}''$ by 10 times over its initial
value. In the middle of this accelerated growth period of 160 s, the fire
reaches the ventilation limit state $(\phi>1)$ and significant CO is produced
as a result of incomplete combustion within the room. The fire conditions
beyond the room will determine whether subsequent combustion will diminish
this CO concentration. In the early growth period, 35% of the spread is
due to lateral and downward spread modes; and both modes appear to
contribute equally to what might be termed "flashover" at 965 s.

Table 1

Results of Computations for Wall Fire Spread

Time s	A_p m^2	ΔA_p m^2	$\dot{m}''$ $g/m^2 \cdot s$	$\dot{Q}$ kW	T_g °C	m_a g/s	ϕ	Mass Fractions	
								Y_{O_2}	Y_{CO}
135	0.05	0	5	6	48	100	0.02	0.233	0
335	0.12	0.016	6	18	73	200	0.04	0.23	0
535	0.29	0.07	7	50	120	250	0.07	0.22	0
735	0.74	0.24	8	148	220	400	0.12	0.20	0
835	1.14	0.41	8	220	280	450	0.16	0.19	0
935	1.59	0.50	13	515	474	550	0.31	0.15	0
965	3.72	2.18	21	1200	828	650	1.0	0.06	0.02
995	4.47*	2.88	50	1200	828	650	2.8	0	0.05

*maximum available

The accuracy of the above analysis is open to question because of its
mathematical approximations and the lack of certainty in the physical
models. However, the phenomenological scope of the analysis is believed
to be complete so that no major effects have been excluded. Subsequent
analysis of the experimental results by Lee [29] can be included to
examine the accuracy. We shall only consider the fire spread extent given
by flame coverage photographs and surface thermocouple measurements.
Figures 7-9 contrast the results computed and the corresponding
experimental state based on nearly equivalent A_p values. For example, in
Figure 7b the pyrolysis zone at 490 s from interpreting Lee's data [29] is
nearly equal to the computed values of $x_p = 1.65$ m and $y_p = 0.7$ at 735 s.
Thus, in all of these comparisons the experimental results are 200-300 s
faster than our estimated results. Certainly, our analysis must be
improved and generalized to other materials, but this illustration does
offer an indication of what is possible.

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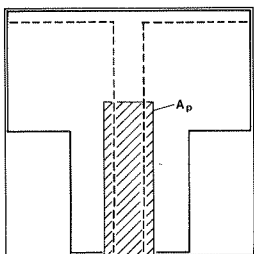
$t = 735\ s$
$A_p = 0.74 m^2$
$\triangle A_p = 0.24\ m^2$
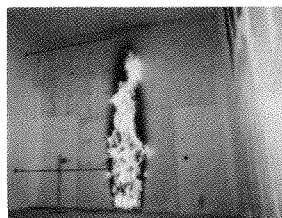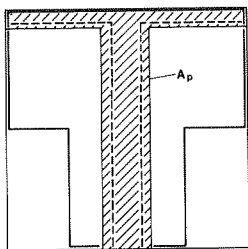$\dot{m}'' = 8\ g/m^2 s$
$\dot{Q} = 148\ kW$
$T_g = 220°C$
$Y_{O_2} = 0.20$

Figure 7a. Predicted results at 735 s.

Figure 7b. Experimental results at 490 s.

$t = 935\ s$
$A_p = 1.59 m^2$
$\triangle A_p = 0.5\ m^2$
$\dot{m}'' = 13\ g/m^2 s$
$\dot{Q} = 515\ kW$
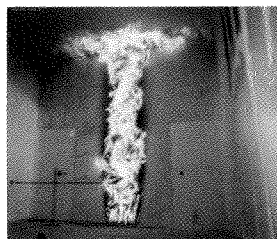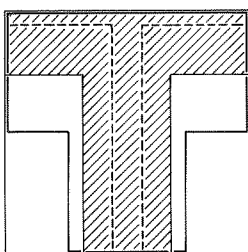$T_g = 474°C$
$\dot{q}''_e = 17\ kW/m^2$
$Y_{O_2} = 0.15$

Figure 8a. Predicted results at 835 s.

Figure 8b. Experimental results at 604 s.

$t = 965\ s$
$A_p = 3.8 m^2$
$\triangle A_p = 2.18\ m^2$
$\dot{m}'' = 21\ g/m^2 s$
$\dot{Q} = 1230\ kW$
$T_g = 830°C$
$\phi = \dfrac{m/m_{air}}{\gamma_{fa}} = 1$
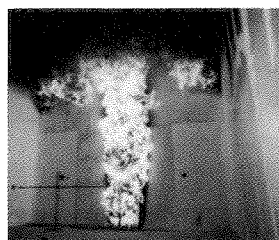$Y_{O_2} = 0.06$
$Y_{CO} = 0.02$

Figure 9a. Predicted results at 965 s.

Figure 9b. Experimental results at 660 s.

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CONCLUDING REMARKS

- We have an opportunity to bring scientific knowledge to bear on the practice of fire safety -- an underdeveloped technology.

- As researchers, we must look for opportunities to translate sound technical advances into practice.

- As practitioners, we must stretch our knowledge base to learn new concepts and approaches for fire safety.

- Fire is costly in terms of lives and goods; the practice of safety must keep pace with technology in the world we live.

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