#3374

Computer Analysis of Smoke Transport during a Hotel Fire

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INTRODUCTION

It is an accepted fact that approximately 80% of fire deaths result from smoke inhalation. Nearly two-thirds of the deaths occur away from the room in which the fire originated. Victims may become incapacitated by heat, visible smoke, and/or toxic species within fire-generated, high-temperature gases long before death from the effects of one or more known lethal combinations of combustion byproducts occurs.

In a fire, smoke is considered to be the major killer. According to the American Society for Testing and Materials (ASTM), smoke is defined as a complex mixture of airborne liquid, solid particulates, and gas evolved under pyrolysis or combustion. Smoke is highly dependent on combustion conditions, and its toxicity often cannot be attributed directly to inhalation of one or more specific chemicals from known or suspected toxic fuels. Considerable information, however, has been developed for key constituent materials containing carbon (Kaplan et al. 1983).

All fire-generated materials contain some highly toxic carbon monoxide (CO) and relatively less toxic carbon dioxide (CO_2) during the combustion process. The relative amounts of CO and CO_2 are highly dependent on the amount of air or oxygen (O_2) present, and these combustion byproducts can be produced in high enough concentrations to create a toxically hazardous environment (Burgess et al. 1979; Grand et al. 1981). Smoke toxicity is an important factor to consider in improvement of life safety during fires. To accurately assess the threat of fires to human life, the features of the fire and building, the rate at which smoke is produced, losses of that smoke, and the susceptibility of occupants all must be considered.

In this analysis, the progression of a large hotel fire and concentrations of accompanying high-temperature toxic gases were closely simulated by the use of two state-of-the-art computer simulation programs. The results of these computer simulations are substantiated by eyewitness accounts of the actual events on a time reference basis. Only the fires in a restaurant and a bar were simulated because it was believed that these two areas alone generated enough fire-related toxic gases at high temperatures to fatally permeate the upper floors. For identification purposes, the term "toxic gases" refers primarily to CO and secondarily to CO_2.

The description of each computer simulation program used in this analysis and the results of the computer analysis are presented in the following paragraphs.

COMPUTER SIMULATION PROGRAMS

Two state-of-the-art computer simulation programs developed by the Center for Fire Research of the National Engineering Laboratory, National Institute of Standards and Technology (formerly National Bureau of Standards) (Babrauskas 1979; Jones 1984), were used for simulating the progression of fire and related smoke and toxic gas concentrations. The necessary data for these computer simulation programs were extracted from appropriate information in our project files pertaining to a large hotel fire. These data contained information on the building dimensions of the hotel and the types of material present prior to the fire, therefore enabling us to estimate the thermophysical properties, compartment geometry, location of openings, etc., required as input to the computer simulation programs.

The description of each computer simulation program used is as follows:

NBS/COMPF-2 Program Description

This program was developed by Babrauskas (1979) and is used to calculate post-flashover characteristics in a single room (compartment) based on fire-induced ventilation through a single door or window. The flashover of a room is defined as the stage when the bulk of the room volume becomes involved in flames. At this stage, the fire poses a serious threat to a structure and its fire barriers (Babrauskas 1979).

NBS/COMPF-2, in this analysis, was used to simulate the mass pyrolysis rate of the available fuel rate for the hotel fire from its inception in the restaurant through its associated post-flashover condition and subsequent spread into an adjacent bar (NFPA 1983). NBS/COMPF-2 was most useful for calculating the fire characteristics in a single compartment treating the post-flashover condition by following the fire progression in a logical sequence from pre-flashover to flashover to post-flashover. Based on fire-induced ventilation through a single opening in a compartment, NBS/COMPF-2 calculated the temperature and mass loss rate of burning fuel as a function of time within the compartment. Unlike previous fire progression meth-

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odology, requiring key assumptions regarding relative positions of the initial fire and other fuel objects within the compartment, NBS/COMPF-2 requires information only about the fuel loading (amount of flammable material) in the compartment.

The fire compartment's geometry and initial fuel loading are the two primary inputs to the NBS/COMPF-2 computer simulation program. In this analysis, the fire in the restaurant and bar was simulated in two separate computer runs, namely: one configuration containing the restaurant as a compartment and another configuration containing the combination of the restaurant and bar as a compartment. The geometry of each compartment was obtained from architectural and/or structural drawings used in the actual construction of the hotel. The fuel loading for each compartment was obtained from a preliminary fuel inventory report. Results of this computer simulation provided approximate rates of fuel mass loss, which were used as input to the subsequent NBS/FAST computer simulation program.

NBS/FAST Program Description

This program was developed by Jones (1984) and is used to determine the concentration levels of smoke and its associated toxic constituents present in the effluent hot gases. In this analysis, NBS/FAST was used to simulate smoke and toxic gas migration from the ground-level fire area to the upper floors of the hotel (refer to Figure 1). NBS/FAST, especially suitable for high-rise building applications, determined the concentrations and temperature profiles of fire-generated smoke and high-temperature toxic gases. It also calculated the temperature and associated toxicity levels of fire-generated, high-temperature gases traveling under pressure outward and/or upward through elevator shafts and other structural openings. The primary element of this model is a compartment that is divided into upper and lower layers (or zones). Basic equations of this model describe the mass, momentum, and energy transfer from one zone to another in a fire-driven environment. These equations were arranged in such a way that the physical phenomena affecting the environment are isolated as "source" terms to appear on the right-hand side. These "source" terms are as follows:

- Radiative heat transfer between gas layers and wall, fires, and other objects
- Convective heat transfer
- Flow in plumes
- Flow in vent jets due to buoyancy forces and piston effects (i.e., forced flow due to volumetric expansion during combustion)
- Mixing at vents
- Conductive heat transfer through walls and objects.

The equations are formulated as a set of differential equations (nonlinear, first order, and linear parabolic) (Jones 1984). The "implicit predictor-corrector" and "successive over-relaxation" techniques are utilized for solving these equations. NBS/FAST performs a complex set of calculations on pressure and upper high-temperature layer species buildup following the movement (or flow) of high-temperature gases from the compartments through openings (i.e., doors, etc.) between adjacent spaces that are treated as a series of interconnecting compartments.

The hotel's building geometry was translated into a simplified yet complete format (refer to Figures 2 and 3) suitable for the NBS/FAST computer simulation program. Only the principal (high- and low-rise) elevator shafts (refer to Figure 4) extending from the casino lobby were considered as principal pathways for high-temperature gases moving into the upper-level tower corridor areas. From 7:15 a.m. to 7:20 a.m. (approximate time of ignition of the bar),

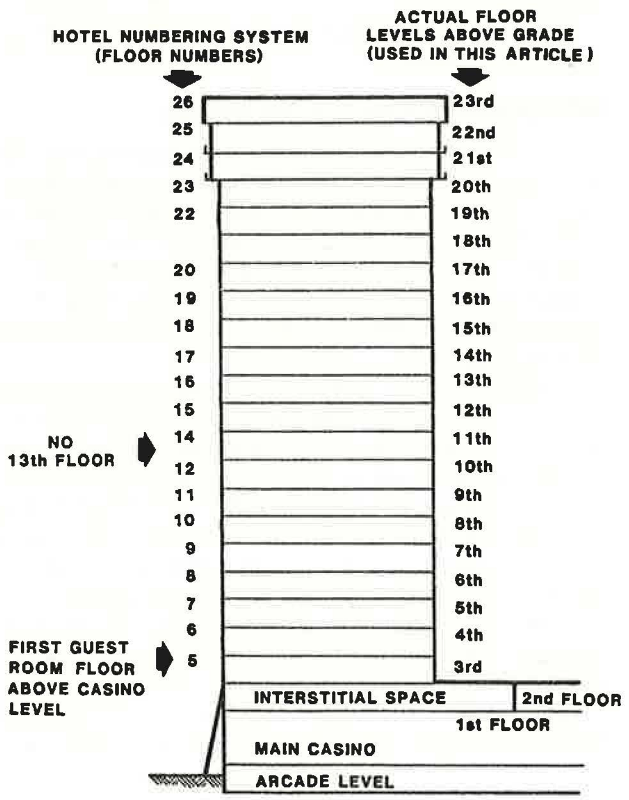

Figure 1 *Hotel tower floor locations*

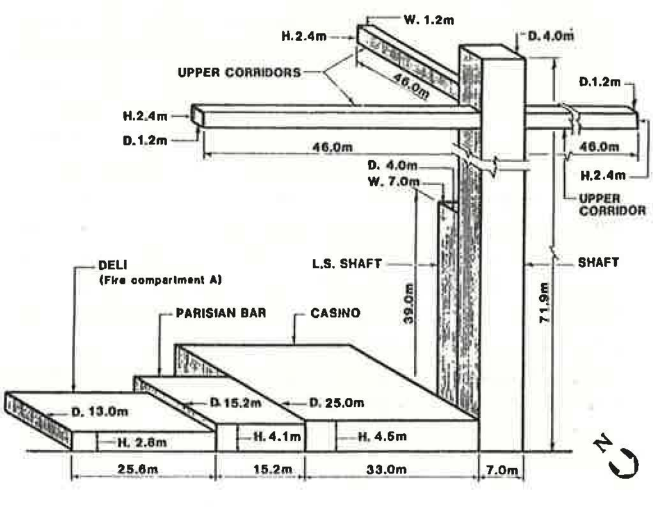

Figure 2 *Dimensional configuration of fire compartment A and related building spaces*

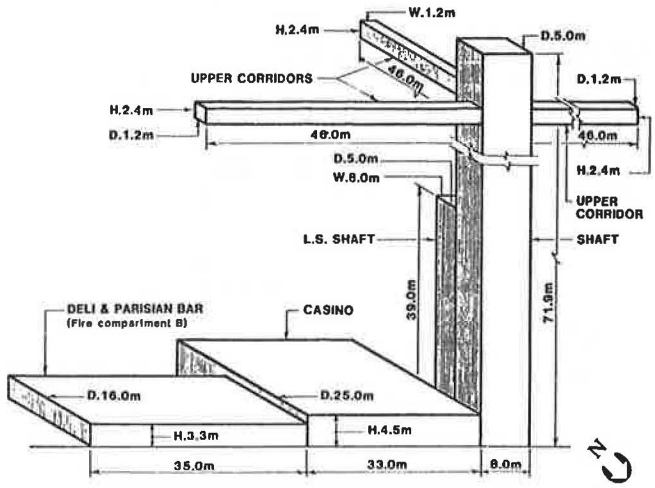

Figure 3 *Dimensional configuration of fire compartment B and related building spaces*

eight compartments with the restaurant (fire compartment A) as the fire source were used (refer to Figure 2).

After 7:20 a.m., a seven-compartment model was used with the combined area of the restaurant and the bar (fire compartment B) as the fire source (refer to figure 3). However, the results of this simulation can be used to estimate probable conditions within the adjacent hotel guest rooms.

The rapid spread of high-temperature gases from the ground-level fire area to the upper-level corridors can be examined by the use of a gas flow mechanism. Flow through the two fire compartment (A and B; refer to Figures 2 and 3, respectively) doors is governed by the pressure differential across the openings. In dealing with the velocity streamline construction at the openings, NBS/FAST considered the flow caused by buoyancy forces and piston effects, which are particularly important during the early stages of a fire. During combustion, the flow may be forced by volumetric expansion rather than by a density differential (buoyancy) between two gases.

These effects were shown to be present in eyewitness accounts of a heavy pressure buildup prior to an apparent explosion at 7:20 a.m. This was caused by high-temperature gases that were forced almost instantaneously through the elevator shaft to the upper-level corridors, filling the corridors within three minutes after 7:15 a.m., as shown in Figure 5 for representative floor 13.

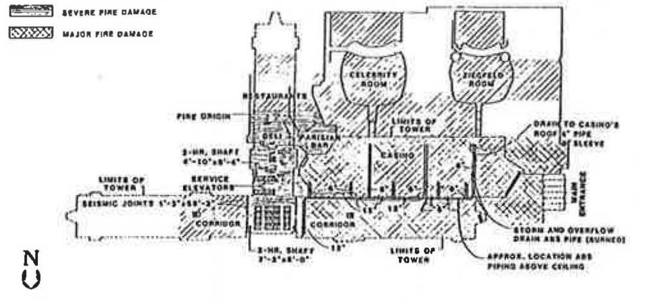

Figure 4 *First floor plan (no scale)*

The required input data for above calculations are as follows:

- Compartment dimensions
- Dimensions of openings
- Thermophysical properties of compartment walls
- Fire production curve (from NBS/COMPF-2)
- Fuel properties for partial combustion
- Fractional production rates of species (smoke and gases).

Required input for NBS/FAST was obtained from information pertaining to the fire, including the building architectural and structural drawings, information on dimensions, and types of material present below the ceiling line prior to the fire.

COMPUTER ANALYSIS RESULTS

Table 1 summarizes the variations of temperature and concentration level of species (smoke and gases) on the upper floors of the hotel from 7:15 a.m. to 7:40 a.m. In this table, the concentrations of these species obtained in ppm (parts per million) by the use of the NBS/FAST computer simulation program are converted to percent volume for CO, CO_2, and smoke. The concentration level of O_2 is obtained by subtracting the amount of smoke, toxic gases, and nitrogen from the total volume of breathable air in the corridors. It is evident from Table 1 that the corridors of each upper floor were already filled with toxic gases (CO and CO_2) by 7:18 a.m., due to rapidly expanding gases. Table 1 also shows that the CO levels were at 0.03%, with temperatures ranging from 111°F to 114°F at 7:25 a.m. Constantly increasing temperatures and CO concentration after 7:25 a.m. ensured death for the other victims.

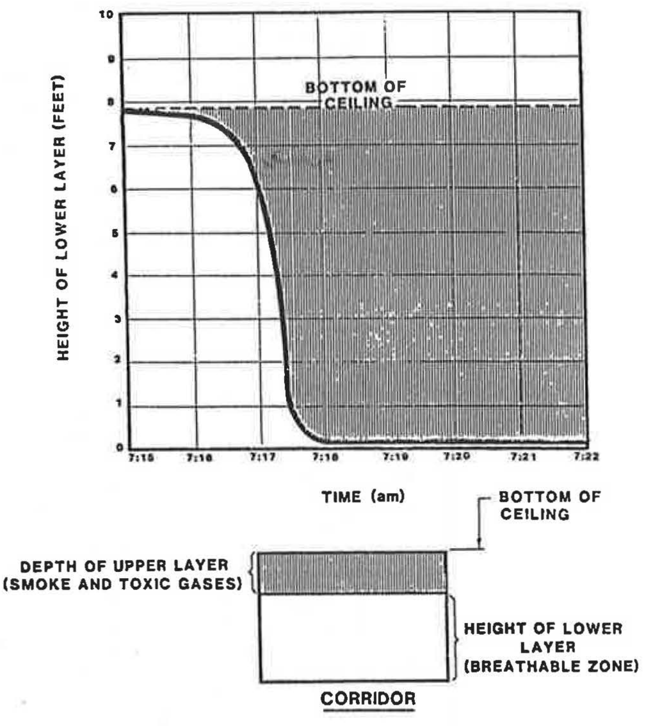

Figure 5 *Height of lower layer in corridors of 13th floor vs. time (generated from NBS/FAST)*

TABLE 1

Variation of Temperature and Species (Smoke and Gases) Levels
Floors 13 to 23 (7:15 to 7:40 a.m.)

Generated from NBS/FAST computer runs and converted to volume percentage. Volume oxygen = total fire compartment volume = smoke volume = CO volume = CO_2 volume = nitrogen volume

FLOOR	SPECIES (% Vol) & TEMP.	Times (a.m.) 7:15	7:18	7:20	7:25	7:30	7:35	7:40
23	CO	--	0.0003	0.01	0.04	0.05	0.05	0.06
	CO_2	--	0.001	0.40	0.45	0.64	0.63	0.73
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.004	0.1	0.4	0.6	0.6	0.6
	T(°F)	81	88	87	115	126	132	174
22	CO	--	0.0003	0.01	0.03	0.05	0.05	0.05
	CO_2	--	0.004	0.12	0.44	0.6	0.6	0.7
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.004	0.1	0.4	0.5	0.6	0.6
	T(°F)	81	88	92	114	120	128	164
21	CO	--	0.0004	0.01	0.03	0.05	0.05	0.05
	CO_2	--	0.005	0.12	0.44	0.6	0.6	0.7
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.005	0.1	0.4	0.5	0.5	0.6
	T(°F)	81	82	89	114	120	128	164
20	CO	--	0.0003	0.01	0.03	0.05	0.05	0.05
	CO_2	--	0.004	0.13	0.4	0.6	0.6	0.7
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.003	0.1	0.4	0.5	0.5	0.6
	T(°F)	81	87	85	112	118	127	161
19	CO	--	0.0003	0.01	0.03	0.05	0.05	0.05
	CO_2	--	0.004	0.12	0.4	0.6	0.6	0.6
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.003	0.1	0.4	0.5	0.5	0.6
	T(°F)	81	86	86	111	117	128	160
18	CO	--	0.0003	0.01	0.03	0.05	0.05	0.05
	CO_2	--	0.003	0.12	0.4	0.6	0.6	0.65
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.003	0.1	0.4	0.5	0.6	0.6
	T(°F)	81	86	88	111	118	129	161
17	CO	--	0.0003	0.01	0.04	0.05	0.06	0.06
	CO_2	--	0.003	0.14	0.5	0.7	0.7	0.8
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.003	0.1	0.4	0.6	0.6	0.7
	T(°F)	81	85	92	120	129	140	179
16	CO	--	0.0002	0.01	0.03	0.04	0.05	0.05
	CO_2	--	0.003	0.13	0.42	0.6	0.6	0.6
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.003	0.1	0.4	0.5	0.5	0.6
	T(°F)	81	85	89	111	118	128	162
15	CO	--	0.0002	0.01	0.03	0.04	0.05	0.05
	CO_2	--	0.003	0.13	0.41	0.6	0.6	0.64
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.002	0.1	0.4	0.5	0.5	0.6
	T(°F)	81	82	96	112	119	130	162
14	CO	--	0.001	0.01	0.03	0.04	0.05	0.05
	CO_2	--	0.02	0.13	0.4	0.6	0.6	0.6
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.01	0.1	0.4	0.5	0.5	0.6
	T(°F)	81	80	95	111	119	128	161
13	CO	--	0.0001	0.01	0.03	0.04	0.05	0.05
	CO_2	--	0.002	0.13	0.41	0.6	0.6	0.6
	O_2	21	20.9	20.8	20.8	20.7	20.7	20.7
	Smoke	--	0.002	0.1	0.4	0.5	0.5	0.6
	T (°F)	81	83	95	112	120	129	163

TABLE 2
Visibility on Floors 13 to 23 (Meters)

	Time (a.m.)				
FLOOR	7:20	7:25	7:30	7:35	7:40
23	8	3	2	2	2
22	7	3	2	2	2
21	8	3	2	2	2
20	8	3	2	2	2
19	8	3	2	2	2
18	8	3	2	2	2
17	8	2	2	2	2
16	8	3	2	2	2
15	8	3	2	2	2
14	8	3	2	2	2
13	8	3	2	2	2

TABLE 3
Optical Density of Smoke per Unit Path Length (Meters)

Generated from NBS/FAST

	Time (a.m.)						
FLOOR	7:15	7:18	7:20	7:25	7:30	7:35	7:40
23	--	0.006	0.169	0.578	0.811	0.795	0.671
22	--	0.006	0.157	0.568	0.764	0.789	0.812
21	--	0.007	0.161	0.565	0.759	0.785	0.801
20	--	0.005	0.172	0.56	0.747	0.781	0.782
19	--	0.004	0.167	0.55	0.739	0.785	0.773
18	--	0.004	0.169	0.55	0.739	0.788	0.773
17	--	0.004	0.186	0.63	0.84	0.895	0.901
16	--	0.004	0.171	0.545	0.735	0.775	0.769
15	--	0.004	0.171	0.531	0.726	0.767	0.761
14	--	0.002	0.17	0.522	0.718	0.748	0.748
13	--	0.003	0.173	0.528	0.724	0.756	0.757

The obscuring properties of smoke can impair visibility, reduce the chances of escape, and increase the time occupants are exposed to fire-generated toxic gases. Table 2 shows the range of visibility (in meters) from 7:20 a.m. to 7:40 a.m. for the upper floors. The visibility values in Table 2 are based on the optical density of smoke (FRCA 1982) per unit path length generated from NBS/FAST, as shown in Table 3.

The depth of the lower layer in corridors for the upper floors as a function of real time was calculated by the use of the NBS/FAST computer simulation program. Figure 5 shows a plot of this computer simulation for floor 13 as a representative floor. It can be seen from Figure 5 that the lower layer rapidly approaches zero at about 7:16 a.m., implying that, even if occupants in these corridors were to lie on the floor, they still would have been forced to breathe toxic gases and smoke.

NBS/FAST also calculated the depth of the increasing upper layer (measured from the underside of the ceiling surface) that contained potentially toxic CO and smoke. This is also illustrated in Figure 5. A plot of CO concentration levels in the upper layer (in ppm and percent volume) as a function of real time for floor 13 is shown in Figure 6. This plot is representative of the upper floors and was generated from NBS/FAST. The highest variation occurred on the 17th floor, at 15% above the average (refer to Figure 7). Variation in CO concentration is attributed to the difference in floor height from the actual location of the fire.

When a fire spreads, the layers of gas in a room (or compartment) separate into two distinct zones: the upper zone and the lower zone. The upper zone contains the

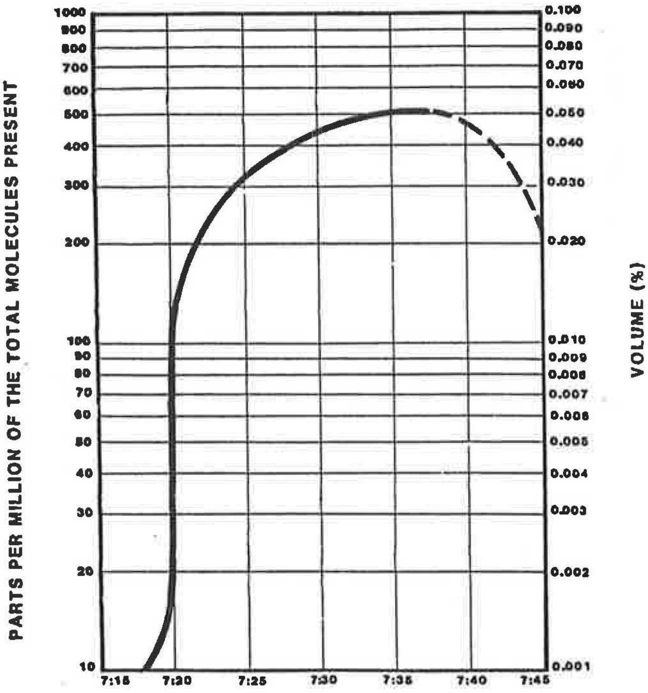

Figure 6 *Plot of carbon monoxide concentration levels (upper layer) vs. time on 13th floor (generated from NBS/FAST)*

dangerous fire-generated smoke and potentially toxic high-temperature gases at a higher temperature than the lower zone. NBS/FAST makes use of this well-known phenomenon. The higher the temperature, the more lethal

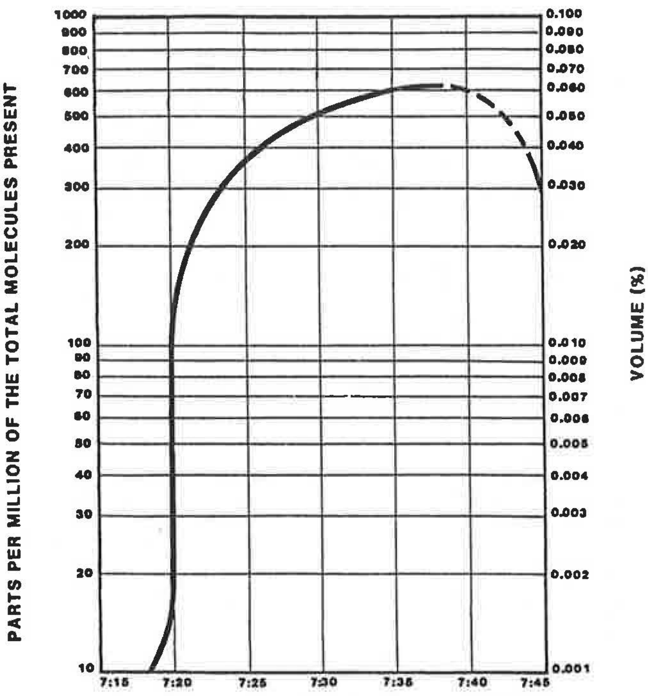

Figure 7 *Plot of carbon monoxide concentration levels (upper layer) vs. time on 17th floor (generated from NBS/FAST)*

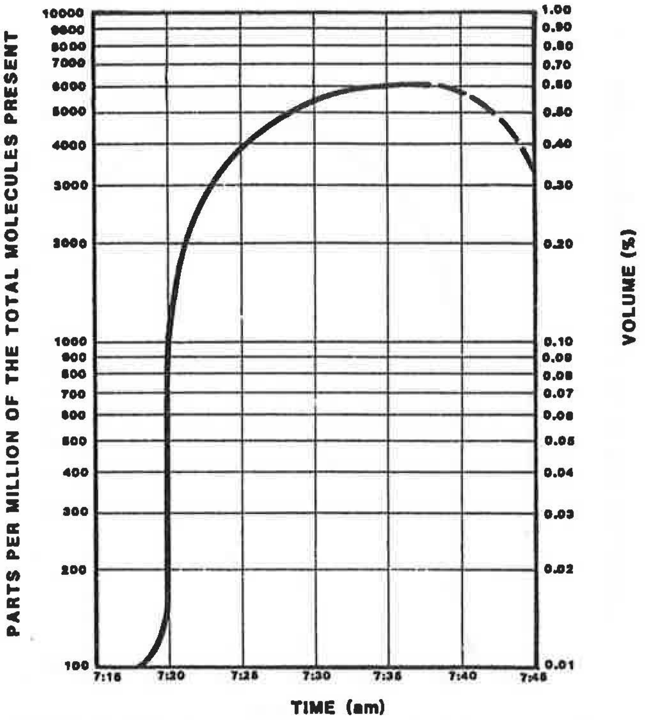

Figure 8 *Plot of smoke concentration levels (upper layer) vs. time on 13th floor (generated from NBS/FAST)*

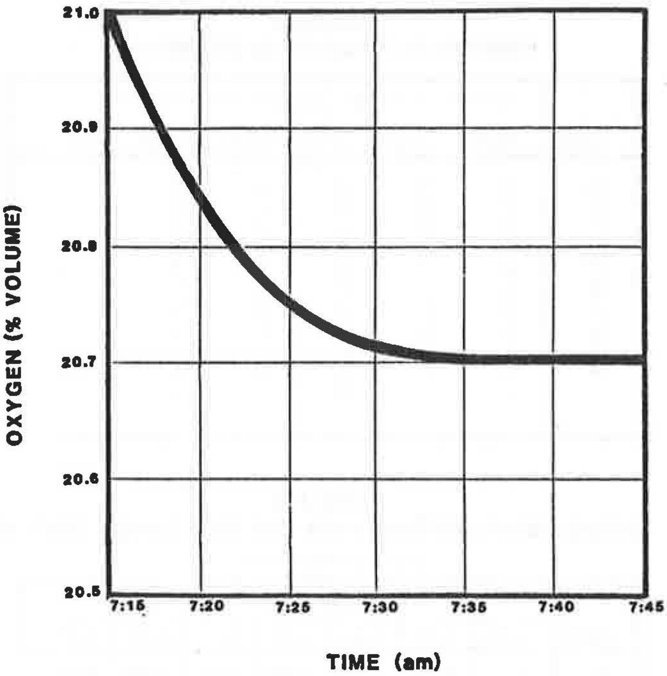

Figure 10 *Plot of oxygen depletion (upper layer) vs. time on 13th floor (values given in Table 1)*

the upper zone becomes. Therefore, the varying distribution of victims can be explained by the varying temperatures on the upper floors. Figure 5, a plot of the height of the lower layer in corridors vs. real time for floor 13, is generated from NBS/FAST and shows a sharp decrease in the height of the lower layer on various upper-level corridors at approximately 7:18 a.m. This observation indicates that, by 7:18 a.m., all of the occupants were completely exposed to the dangerous upper zone.

A representative plot of CO_2 and smoke concentration levels in the upper layer as a function of real time for

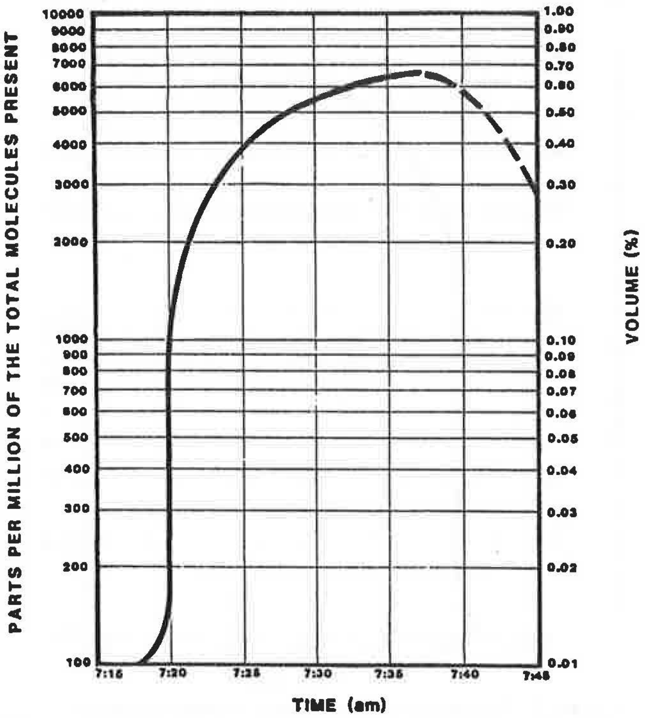

Figure 9 *Plot of carbon dioxide concentration levels (upper layer) vs. time on 13th floor (generated from NBS/FAST)*

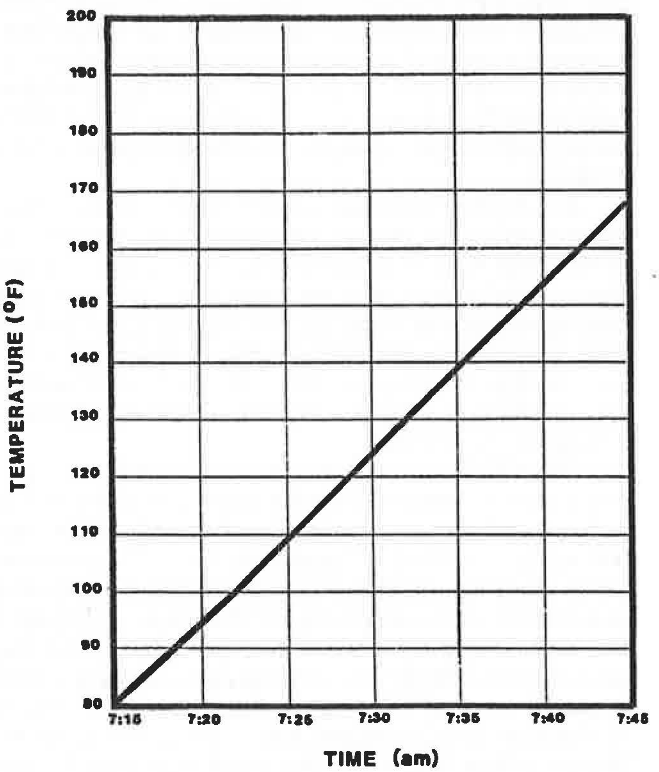

Figure 11 *Plot of temperature (upper layer) vs. time on the 13th floor corridor (temperature rise attributable only to restaurant and bar fire compartments)*

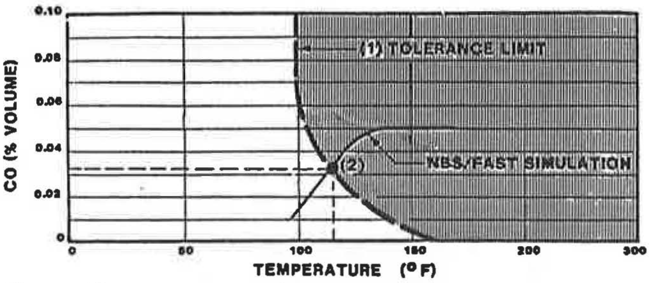

Figure 12a *Carbon monoxide vs. temperature; 13th floor (7:15 a.m. to 7:20 a.m., restaurant fire compartment; 7:20 a.m. to 7:45 a.m. restaurant and bar fire compartment).*
(1) Tolerance limit obtained by interpolating literature data (Carlos J. Hilado); (2) estimated lethal dosage: 0.032% at 114°F

LETHAL DOSAGE

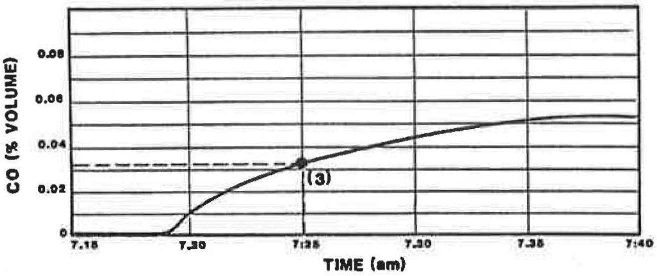

Figure 12b *Carbon monoxide vs. real time; (3) probable time of death, 7:25 a.m.*

floor 13 is shown in Figures 8 and 9. These plots are also generated from NBS/FAST output and show that these concentration levels are also rising.

Figure 10 shows a representative plot of O_2 depletion (in percent volume) in the upper layer as a function of real time for floor 13. This depletion is due to the displacement of air by the fire-generated smoke and gases traveling through elevator shafts. As can be seen from Figure 10, the O_2 level was reduced from its normal volume percentage of 21 at 7:15 a.m. to a volume percentage of 20.7 at 7:33 a.m., and this depletion was almost identical for all upper floors. The average temperature on all of the upper floors was 95°F by 7:20 a.m. and rose at a constant rate of 5°F per minute until it reached approximately 170°F by 7:45 a.m. A representative plot of this temperature increase in the upper layer as a function of real time is shown in Figure 11.

The lethal dosage of toxic gases at a given temperature for any of the upper floors is estimated on the basis of the results obtained from the NBS/FAST computer simulation program (refer to Figures 12A and 12B). Also shown in Figure 12B is the percent volume of CO_2 as a function of real time for floor 13.

As shown in Figure 12A, the intersection of the rising indoor temperature curve (obtained from NBS/FAST) and the tolerance limit curve (Hilado 1976) represents a lethal amount of CO in percent volume. The tolerance limit curve is obtained by interception of the experimental data lines with the zero-time axis, as shown in Figure 13. Therefore, any value of CO as a function of temperature on the

TABLE 4
Comparison of NBS/FAST Computer Program Results and Reported Time-Line Observations

TIME	REPORTED OBSERVATIONS	RESULTS FROM NBS/FAST COMPUTER PROGRAM
7:12 to 7:13 a.m.	Heavy Pressure	Intense combustion resulted in rapid volumetric pressure expansion of gases which caused the observed heavy pressure (see Figure 14).
7:20 a.m.	8 Foot Smoke Layer In Casino	The depth of smoke from the ceiling was about 9 feet (see Figure 15).
7:20 to 7:21 a.m.	Fire Intensified	Parisian Bar Ignition. Presence of fuel, air supply and a very large undivided area allowed for extremely rapid fire spread and heavy smoke production (see Figure 8).
After	Varying Distribution Of Casualties	Variation of temperature at 7:21 a.m. altered the minimum lethal dosages.

tolerance limit curve is hypothetically lethal (refer to Figure 12A).

Figure 12B shows the increasing percent volume of CO as a function of real time. This graph is obtained by combining the plots of CO vs. real time and temperature vs. real time (refer to Figures 6 and 11, respectively) for floor 13. For example, referring to Figure 12A, the occupants of floor 23 were exposed to a CO concentration of 0.03% at a temperature of 112°F. By the use of this CO concentration of 0.03%, in Figure 12B, the time of death is estimated to be 7:25 a.m.

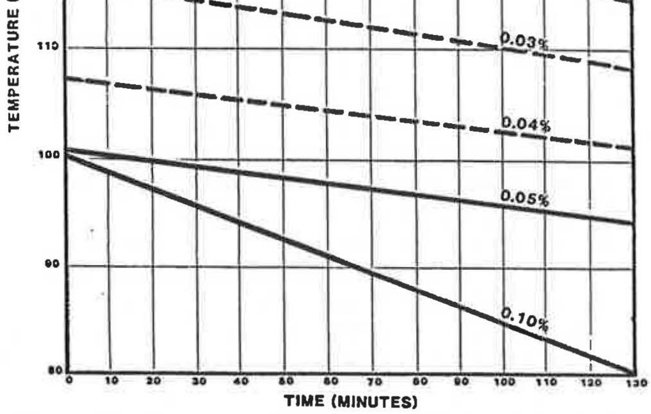

Figure 13 *Temperature vs. time elapsed before victim deaths at various carbon monoxide levels (% volume). Dashed lines obtained from* Smoke and Products Combustion *edited by Carlos Hilado. See Table 4 for more details.*

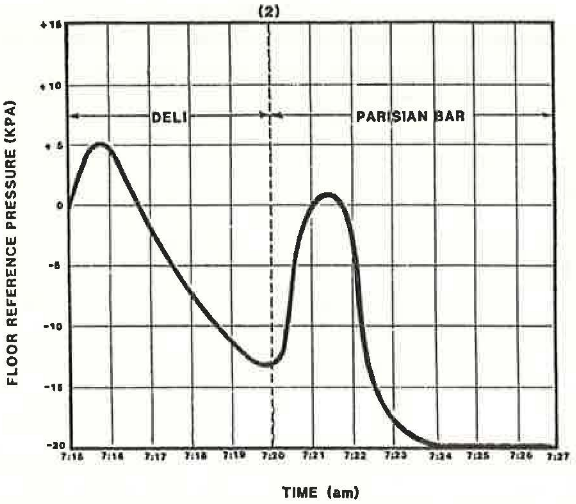

Figure 14 *Pressure variation in the restaurant and bar (generated from NBS/FAST). (2) At 7:20 a.m. the fire spread to the bar.*

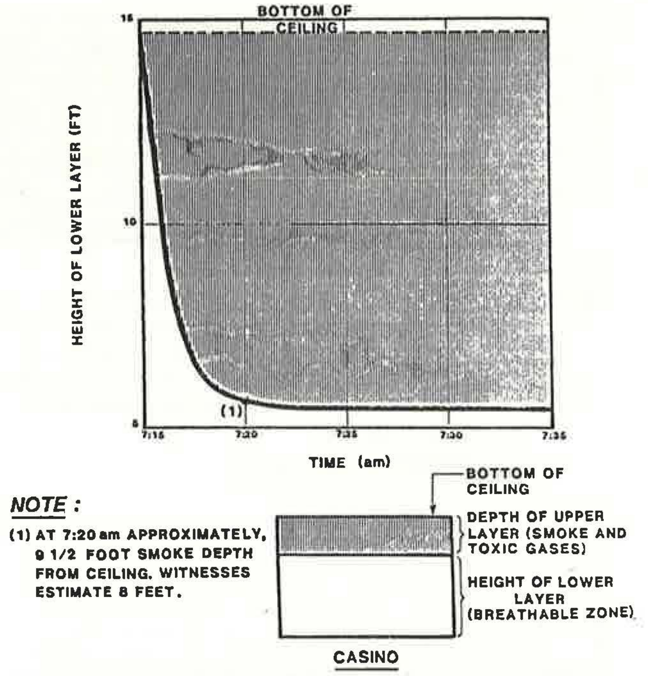

Figure 15 *Height of lower layer vs. time for casino (generated from NBS/FAST)*

To substantiate that NBS/FAST has accurately simulated the actual events, the output describing physical conditions on the upper floors as a function of time was compared with eyewitness accounts shown in the time line (refer to Table 4 and Figures 8, 13, 14, and 15). This time line is generally recognized as one of the most accurate multi-witness accounts of the actual events. Comparisons included victim distribution, rapid spread of high-temperature gases, effects of rapid smoke/CO buildup, smoke-impaired visibility, combustion byproducts, and room conditions. Table 4 summarizes the correlations between the NBS/FAST computer simulation program results and confirmed time line and shows that it in fact simulated the actual conditions accurately.

SUMMARY

Concern about the toxicity of fire smoke, the need to measure the toxicity of smoke from burning materials, and the control of smoke transportation have been unanimously recognized. Due to the presence of smoke and highly toxic substances, fires today are much more harmful than in the past. Therefore, in the design and remodeling of a building, the fuel loading as well as the toxicity level of these fuels must be seriously considered.

Use of the NBS/FAST computer simulation program provided useful information to research efforts on the toxicity of certain lethal compounds extracted from the burning materials. It was shown how rapidly expanding smoke and high-temperature gases under pressure traveled up the shafts, exposing occupants on the upper floors to toxic fumes shortly after 7:18 a.m., at which time the lower "breathable" layer had almost disappeared. This is substantiated by the time line and, furthermore, asphyxiation can be concluded as the cause of death for some occupants on all upper floors. The first victims on the upper floors were dead between 7:24 a.m. and 7:25 a.m., as concluded by the analysis using NBS/FAST.

Based on the results and close correlations between the computer modeling and observations, it became apparent that ABS and PVC piping in a few selected locations above the ceiling line could not have contributed to fatalities on the upper floors of the hotel. This follows from the fact that the casino ceiling remained essentially intact until about 7:45 a.m. Therefore, the contents of the casino ceiling could not have ignited before 7:25 a.m.

Eyewitness accounts of heavy pressure prior to the explosion at 7:20 a.m. confirm the findings of NBS/FAST. This heavy pressure was caused by high-temperature gases that were instantaneously forced through elevator shafts to upper-level corridors within three minutes after 7:15 a.m. The probable "time of death" for the victims, established from computer analysis, is believed to be conservative because not all of the available vertical shafts, stairwells, and other structural openings to the upper-floor corridor areas were considered as additional pathways in transportation of smoke.

It has been demonstrated that, at least within this fire, a lethal combination of toxic gases was generated from burning fuels in the restaurant and bar only. Some additional fuels in the casino area located below the finished ceiling level were probably partially involved in the spread of the fire and would have contributed to even higher toxic concentration levels on the upper-level corridor floors. Thus, the peaks in the curves representing CO, CO_2, and smoke do not reflect a complete site condition at the hotel. Our findings also indicated that the smoke and high-temperature toxic gases resulted in the large number of fatalities within 10 minutes of the initial outbreak of the fire in the restaurant at 7:15 a.m.

PROGRESS TOWARD BETTER SMOKE CONTROL

In the last decade, we have made substantial progress—through building codes—in installing fixed fire protection systems in public structures such as hotels, hospitals, and educational facilities (Jervis 1987). Among these are smoke detectors and automatic sprinklers, which have reduced deaths, injuries, and property damage.

Today, transportation of smoke still presents a major problem in a fire. According to investigators, lives could have been saved in a hotel fire in San Juan, PR, if the hotel had had a traditional sprinkler system located within 10 ft of the area where the fire originated (Hatfield 1987). Within 10 minutes after the fire began in new furniture cartons in a ballroom, flashover took place. A few minutes later, the lobby was engulfed in flames and the glass partition between the casino and lobby was broken. This sent a smoke wave and flames to the casino, trapping many occupants (Hatfield 1987). According to experts, investigations will force major code-making organizations to further update their codes dealing with toxic smoke. Currently, the National Fire Protection Association (NFPA) does not require mandatory sprinkler systems; instead, it allows fire-resistant materials and enclosed stairwells as alternatives (Hatfield 1987).

Smoke detectors, sprinklers, and other fire protection measures have not yet completely eliminated fires due to other variables. One of these variables is the interior furnishings (used in many buildings) that can be easily ignited, producing heat, smoke, and combustible toxic gases that collect at the ceiling, limiting the ability of occupants to escape (Jervis 1987).

According to a report published in 1982 by the NFPA Committee on the Toxicity of Products of Combustion, furnishings and similar contents play a great role in loss of life in fires and these contents are usually the first things ignited (Jervis 1987). An ad hoc subcommittee established by the NFPA in 1983 studied the contribution of furnishings and contents to a fire and concluded that a substantial number of fires resulting in a high number of deaths are in residences (Jervis 1987) in which upholstered furniture and contents play a primary role. Today, there are no strict regulations controlling furnishings and contents. According to the subcommittee, controlling the furnishings and contents can significantly reduce the number of fire-related deaths in the United States.

In conclusion, while it is unrealistic to expect the complete elimination of fires and smoke in furnishings, if fire-resistant rooms can be designed using a systems approach and provisions for fire-hardened furnishings can be built into the fire and building codes (Jervis 1987) (with harsh penalties to violators), a substantial impact on fire and smoke migration, a major killer, may still be possible.

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