ANALYSIS OF THE HAPPYLAND SOCIAL CLUB FIRE WITH HAZARD I

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BACKGROUND

In the early morning hours of March **25,1990** a tragic fire took the lives of **87** persons at **a** neighborhood club in the Bronx, New York. A few days later, the New **York** City Fire Department requested the assistance of the Center for Fire Research (CFR) in understanding the factors which contributed to this high death toll and to develop a strategy that might reduce the risk of a similar occurrence in the many similar clubs operating in the city. It was not the purpose of the CFR work to examine cause and origin, nor criminal or negligent actions which may or may not have taken place before or after the incident.

In responding to this request, CFR staff visited the fire scene on March **29** to obtain information needed to perform an analysis with the HAZARD **I** Fire Hazard Assessment Method.' Physical measurements taken on site along with floorplan drawings and newspaper accounts provided the only data on which this analysis was based. No material samples were taken and no testing was performed.

THE BUILDING

The floorplan drawings obtained from the New York Fire Department are shown in Figure **1.** Wall finish throughout the interior of the building was 316-inch wood paneling. The ceilings were low density fiberboard tiles in the first floor entry and bar, and gypsum board elsewhere. The fiberboard tiles were installed on furring strips under the floor joists and the paneling was on furring strips over plaster. Note the partial sprinkler system on the second floor.

THE FIRE

From information reported in the media and observations of the CFR staff during **an** on-site investigation, the ignition scenario for this fire was as follows. One dollar's worth (about three quarters of a gallon) of gasoline was poured on the floor of the entryway and ignited.* The door from the entryway to the street was believed to be open and the **door** from the entryway to the bar was believed to be closed. The fire quickly spread to the combustible interior finish within the entry area **and,** at some point someone opened the **door** from the bar to the entryway to go out.[3] This opened a path for fire to spread from the entryway into the first floor bar area.

At some point before or after this interior door was opened, an employee and a patron escaped through the service entrance which was reportedly closed4 It is undear whether these doors were left open or closed and reopened after the fire department arrived. The fire department entered through the front doors and quickly brought the fire under control4 Of the seven sprinkler heads on the second floor, four opened, two did not, and one was missing at the time of the site visit, but water stain patterns on the ceiling indicated that it had been in place and activated during the **fire.**[5] Based on damage observations made at the scene, the hollow core door at the base of the front stairway was believed to be closed through most of the fire.

THE VICTIMS

Newspaper accounts indicate that 68 of the **87** victims were recovered from the second floor where they succumbed to toxic smoke6 The remainder of the bodies were recovered from the first floor **(11** from the rear restroom),[6] each having some bums in addition to smoke inhalation. There were at least three survivors and possibly a **few** more.[3]

THE APPROACH

Given the limited scope of the CFR involvement, the HAZARD I[1] software was used to develop an approximate reconstruction of the fire events. The details of the building arrangement and construction, and the ignition sequence described above, were entered into the HAZARD **I** routines. A series of computer runs were made examining the possible ventilation conditions associated with which doors to the exterior might have been open, and when they might

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1. Bukowski, R. W., Peacock, R. D., Jones, W. W., and Forney, C. L, HAZARD **I** - Fire Hazard Assessment Method, NIST Handbook **146,** Natl. Inst Stand. Tech., Gaithersburg, MD **20899 (1989).**
2. "Portrait of Suspect in Social Club Blaze Emerges," New York Times, March **26,1990.**
3. "No Escape in Bronx," New York Times, March **26,1990.**
4. Personal Communications, Hodgens, J. J., Assistant Bureau Chief, NY Fire Department.
5. Observed by CFR staff during on-site visit, March **30, 1990.**
6. "Dream Turns into Nightmare", USA Today, March **26,1990.**

have been opened. This is critical in understanding the fire development since this fire quickly became ventilation controlled. This is the point that the burning rate becomes controlled by the availability of air necessary for combustion rather than by the rate at which fuel is vaporized. Both the computer reconstruction of the fire events and the limited extent of burning in the building[5] support this position. Thus, the burning rate was influenced more by ventilation than by fuel characteristics (e.g., type, quantity, exposed area). The combination of door openings predicting results which best match the observed damage conditions would be assumed to represent the likely conditions during the fire.

The next step was the examination of potential mitigation strategies that could have influenced the outcome of this fire. Initially, four possible approaches were identified:

- Provide a complete automatic sprinkler system.
- Install a door at the base of the rear stairs to prevent combustion products from travel to the second floor.
- Install a second means of egress from the second floor.
- Upgrade all interior finish materials to noncombustible materials that would not contribute to the fire.

For each strategy, the ability to mitigate the life loss was evaluated and the retrofit cost estimated. Cost is an important determinate of whether any strategy is realistic since high costs may result in a reluctance by building owners to comply with code mandates.

THE ANALYSIS

The room dimensions and estimated fire characteristics for the interior finish materials were entered into HAZARD 1. FPETOOL[7] was employed to make estimates of the burning rate of the gasoline and the combustible ceiling and walls of the entryway. The resulting potential energy release rate profile for the gasoline alone and in combination with the ignited combustible material are shown as "GASOLINE FIRE" and "TOTAL POTENTIAL FIRE" in figure 2a. The difference between the potential rate of heat release and the rates of heat release predicted by HAZARD I for the cases analyzed (except the gasoline fire) results from the impact of the limited air supply. The rate of heat release estimated by HAZARD I for the *case* where the only combustible material was the gasoline is identical to the potential rate of heat release of the gasoline. This was because the available air supply was sufficient to freely bum all of the gasoline.

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7. Nelson, H. E., FPETOOL - Fire Protection Tools for Hazard Estimation, NISTIR 4380, Natl. Inst. Stand. Tech., Gaithersburg, MD, 20899, (1990).

The execution of HAZARD I requires specific input data. In addition to the potential rate of heat release, the data listed in Table 1 was used. The area of the gasoline fire is a judgment estimate as no specific data exist on exactly how the reported gasoline pour[2] occurred. The value used represents a circular pool about 3 feet in diameter. The area of interior finish is approximately that burned in the fire as estimated by CFR staff.[5] The other values are generic values typical for gasoline and plywood or fiberboard interior finish materials.

The predicted conditions within the building for the incident (labeled *base fire)* and for each mitigation strategy are presented in the figures 2 through 5. Data for a single variable (e.g., temperature, oxygen concentration) are presented in each figure consisting of a graph for each room with a curve for each case examined. All graphs for a given variable use the same scale for easy comparisons.

With these as input data, the FAST model was utilized to examine the room temperatures and gas concentrations predicted in the various spaces within the Club as a function of whether and when the doors to the service entrance and those to the entryway were open. The results of these calculations are presented next.

SERVICE ENTRANCE

The analysis assumes that the exterior service entry door and the door between the service entry and the bar room were initially closed. At some point early in the fire, the two uninjured survivors exited through these doors, probably leaving both open.[3] Since there were no automatic closers on either door, it is assumed that in the rush they did not delay to close the doors behind them. There was fire damage to the service corridor and the exterior of the building above that door,[5] so these two doors were certainly open for some time during the fire. Since the volume of the service corridor is small compared to the remaining volume of the building, the question of interest is whether both remained open after they were used for escape or whether either was closed.

The calculations show that the obtained conditions are much less sensitive to the position of these doors than to the doors to the entryway. The HAZARD I computations indicate that the service entrance doors have a noticeable effect on increasing burning in the bar room but only a minor effect on burning in the entryway. Thus it was assumed that the service entrance doors were open throughout the incident.

ENTRYWAY

The assumed sequence of events has the exterior door open throughout and the interior door initially closed. At some time after the gasoline was ignited, a person opened the interior door, saw the fire, and ran out through the flames (sustaining serious bums but surviving) leaving the door open.[3,4] The fire damage to the entryway was severe and there was also fire damage to the building exterior over this door.

Simulations with the exterior entryway door closed showed rapid fire starvation due to lack of oxygen, even if the service entrance doors were both open. Since this is inconsistent with the physical evidence, the analyses were based on the *case* where the exterior entryway door was open throughout the incident[5]

The injured survivor confirmed that the inner door was initially closed.[3,4] But it is of interest to determine at what point in the fire development he opened that door. It is assumed that if he ran through the *entryway* while the gasoline was burning, he would have picked up burning gasoline on his shoes, and would have received bums to his legs. He did not.[4] Thus, it was assumed that he moved through the entryway after the gasoline burned out - by our estimates, about 90 seconds ("s").

The FAST model was used to examine the impact of the inner door being opened at 60 s, 120 s, and 180 s. The primary effect of this door being opened at different times is to shift the point at which the fire's effects began to spread into the building. As discussed above, the door was probably not opened before 90 s. If the door was opened as late as 180 s, the finish in the entry could have begun to burn out. Thus, to be more conservative, we assumed for calculation purposes that the inner door was opened at about 120 s after the gasoline was ignited.

BASE FIRE SCENARIO (HAZARD I CASE - BASE FIRE)

The simulations presented thus far were used to identify the likely positions of the exterioor doors, and therefore the ventilation conditions present in the building during the incident. On this basis the following conditions were assumed for the balance of the study.

- the exterior door to the entryway was open throughout,
- the door from the entryway to the bar was initially dosed, but was opened at about 120 seconds (after ignition of the gasoline), and
- both doors to the service entrance were open throughout the incident.

Under these base conditions, occupants of the second floor room were predicted to have been physically incapacitated by toxicity (a combination of high carbon monoxide and low oxygen in the presence of CO_2) at about 5 minutes; a result that is consistent with the number of victims that died without apparent attempts to escape. At that time, predicted temperatures on the second floor were still low. Further, as has been demonstrated experimentally,[8] the operation of a sprinkler at the top of a stairs would cool the gases even further but with no effect on the CO, CO_2, or oxygen. Prediction of such *effects* of sprinklers is beyond the current capabilities of the models used in this analysis.

MITIGATION STRATEGIES

Once the base scenario was derived, the potential benefits of the four, previously identified mitigation strategies could be examined. These are presented in the following sections.

AUTOMATIC SPRINKLERS

While the building had a partial sprinkler system on the second floor, it played only a minor role in this fire since it was so far removed from the actual fire. If the building had been protected by a complete (operational) sprinkler system, the fire likely would have been extinguished in the entryway. While it is not currently possible to demonstrate this with the models, there are test data[9] for a very similar condition, a gasdine spill in the entryway to an apartment, in which rapid extinguishment was achieved. There are routines in FPETOOL[7] that estimate the activation time of sprinkler heads. The FPETOOL routine FIRE SIMULATOR indicates that a traditional sprinkler head in the entryway would have activated in about 7 seconds following ignition of the gasoline.

DOOR AT BASE OF REAR STAIRWAY (HAZARD I CASE - REAR STAIRWAY DOOR)

The principal avenue of smoke/gas travel impacting the second floor occupants was the rear stairway. If this stair had been cutoff by the addition of a door with an automatic closer at the bottom, this path would havv been reduced to whatever leakage might have existed around that door. However, this solution would have required that the occupants "ride out the fire,' and that the fire department could respond and extinguish it before any structural failure.

To examine this strategy, a (dosed) solid wood door at the first floor entry to the stair was assumed. An effective crack width of 1/2 inch (1.3 *cm)* was assumed over the height of the door to represent the gap to the frame. The simulation run for these conditions showed a reduction in the

8. Cooper, L. Y. and O'Neill, J. G., Fire Tests of Stairwell Sprinkler Systems, NBSIR 81-2202, Natl. Inst. Stand. Tech., Gaithersburg. MD, 20899, (1981).
9. DiCicco, P., Full-scale Fire Tests *on* Row-frame Residential Buildings, ***Symposium on Fullscale Fire Tests in Research and Development,*** Armstrong World Industries, Lancaster, PA, (1974).

predicted temperatures within the rear stairway and the second floor (figure 1, d & e), as expected. The temperature of the first floor bar (figure lc) was also lower, as less flow up the stairs reduced the ventilation rate through the front door reducing the oxygen (fig 4, a & c) and the burning rate (fig 2, a & c) in both the entry and the bar. The CO levels upstairs (fig 5e) were significantly lower and the levels on the first floor (fig 5c) were reduced due to the lower burning rate.

SECOND EXIT
(HAZARD I CASES - FIRE ESCAPE AND ENCLOSED EXIT STAIRWELL)

The third mitigation strategy involved the addition of an independent, second exit from the upper floor. This would likely be located in the front (street) side as either an exterior, open fire escape with a drop down ladder, or as an interior, enclosed exit stairway descending in the service entry area.

The difference between these two is more than just the additional cost of the latter. Opening a second floor door to a fire escape would have changed the ventilation pattern in the building, possibly resulting in a significantly increased flow up the rear stairs to the second floor, making occupant survivability worse. Thus, both arrangements were examined with the model. The results of the predictions showed similar results with respect to each of the examined parameters. In both cases, opening of the egress door on the second floor results in increased flow up the back stairs with an attendant increase in the temperature (fig le) and CO levels (fig 5e), and decrease in the oxygen on the second floor (fig 4e). However, these effects were somewhat greater in the case of the fire escape than for the enclosed exit stair since its direct opening to the outdoors allows more flow.

The FPETOOL routine EGRESS estimates that it would take between 2 and 5 minutes to evacuate the 87 second floor occupants using a single exit, depending on the width of the exit stairs. The 2 minute evacuation time is for a 44 inch wide stair and the 5 minute time is for 22 inch wide treads. These are the minimum widths permitted by the Life Safety Code[10] for stairways and fire escapes respectively. The amount of delay between the time of fire initiation and when most of the occupants would start to evacuate then becomes a crucial unknown. To reach safety the occupants would have to be able to egress before being incapacitated at about 290 s (by toxicity). That is within about 3 minutes after the inner door of the entryway is opened. A narrow fire escape would have likely resulted in a constriction at the top tread that would have prevented some of the occupants from escaping even if evacuation started as soon as the fire burst into the bar room. Wider stairs would improve the situation but the degree of success would depend on the speed of start-up of evacuation. In the case of a 44 inch wide stair the combination of the HAZARD I data and the EGRESS routine indicate that it would have been necessary for the occupants *to start* evacuation within about 3 minutes of ignition (1 minute after the inner **door** was opened.)

If the additional means of egress was combined with the door for the back stairs, sufficient egress time would be available for all occupants, but notification to begin evacuation becomes an even more important issue in the absence of an automatic fire alarm system.

NONCOMBUSTIBLE INTERIOR FINISH
(HAZARD I CASE - GASOLINE FIRE)

The last strategy involves the replacement of the combustible ceiling and walls with noncombustible interior finish materials. This would have the effect of limiting the fire to the original gasoline spill. If run with the same assumption that the inner door from the entryway was closed until after the gasoline bums out, then the conditions in the rest of the building remain at ambient throughout the incident. Thus, we examined this case as if this door was open from the point of ignition, resulting in the prediction of elevated conditions in the building during the first 120 s not present in the other scenarios due to the closed door between the entryway and bar.

When this scenario was run in the model, the results indicated that temperatures (fig 1), CO (fig 5), and oxygen concentrations (fig 4) remained tolerable throughout the fire. Only a person in the entryway would have experienced lethal conditions, from bums. With both doors to the entryway open, the gasoline fire had sufficient air to bum out without producing flames out either door, so ignition of furniture in the bar would be unlikely. But if the fire had involved the contents of the bar (e.g., if the fire was started in the bar), some life loss would be likely, even with noncombustible finish.

COST ESTIMATES

Rough estimates of the retrofit costs of each of these mitigation strategies were made using typical construction cost handbooks to assist in evaluating the degree to which each would be realistic to enforce on such clubs. The estimates developed[11] were:

Automatic Sprinklers - $8000
Door for Rear Stairway - $300

10. Life *Safety* Cock, NFPA Standard **101-1988,** National Fire Protection Association, Quincy, MA, 1988.

11. Dodge Manual for Building Construction Pricing and Scheduling, Dodge Building Cost Services, McGraw-Hill Publishers, New York, NY, (1979).

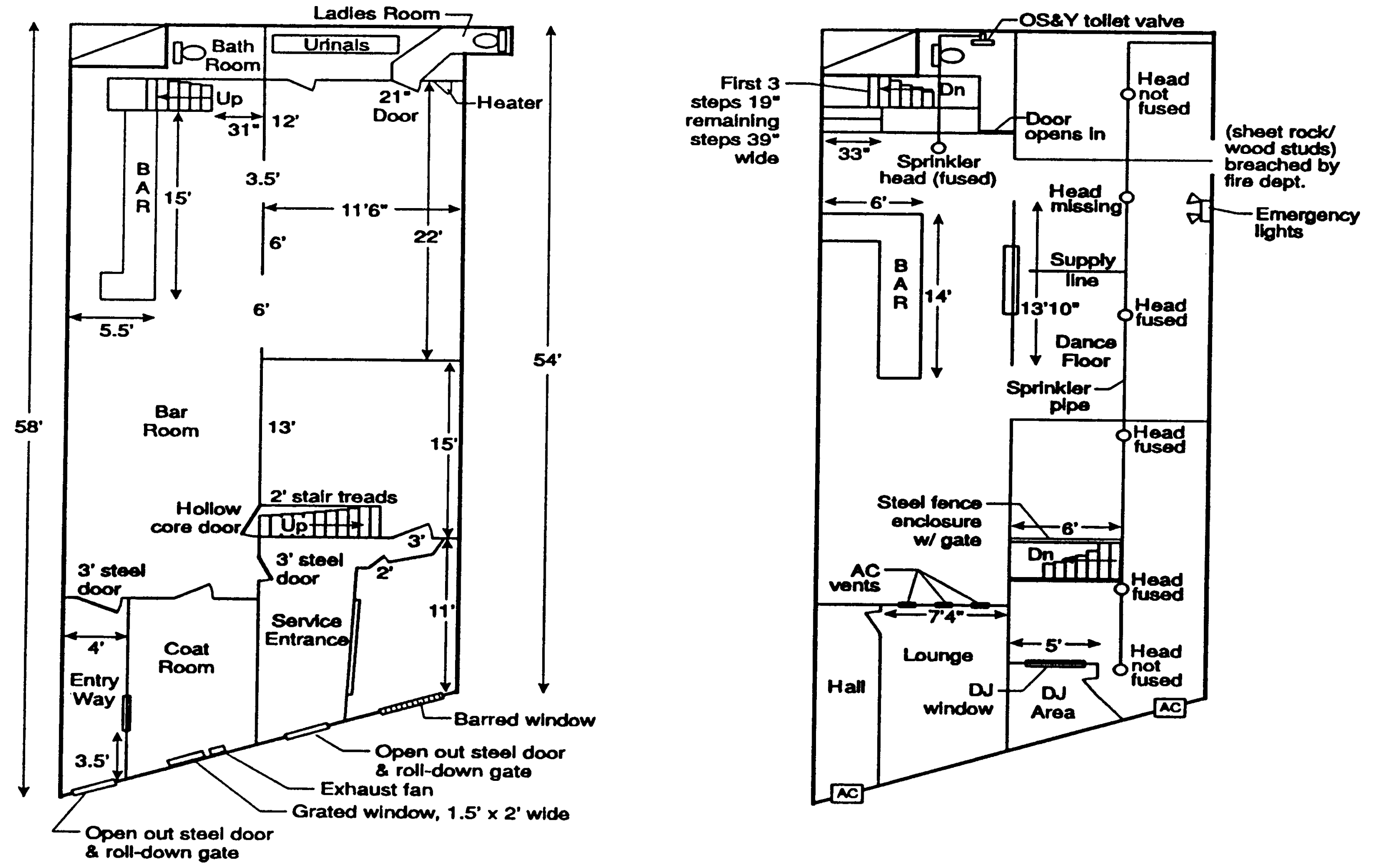

Figure 1 - Floorplan drawings of the Happyland Social Club

Table 2 - Summary of Occupant Tenability

Time (sec) to incapacitation (death)	Base Case Fire	Noncombust-.Interior Finish	Door on Rear Stairway	Fire Escape	Exit Stairway
Entryway					
FLUX	30	30	30	30	30
TEMP2	30	40	30	30	30
FED2	40	NR	40	40	40
FED1	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)
Service Entr.					
FLUX	160	NR	160	160	160
TEMP2	210	NR	240	NR	NR
FED2	290	NR	240	350	380
FED1	NR	NR	NR	NR	NR
1st Floor Bar					
FLUX	140	NR	140	140	140
TEMP2	200	NR	170	200	180
FED2	200	NR	170	210	210
FED1	280 (420)	NR	**200 (230)**	270 (290)	290 (320)
Back **Stair**					
FLUX	200	NR	NR	200	200
TEMP2	NR	***NR***	NR	270	270
FED2	270	NR	NR	260	270
FED1	350 (480)	NR	NR	NR	300 (NR)
Second Floor					
FED2	320	NR	NR	290	300
FED1	390 (520)	NR	NR	340 ***(460)***	360 **(460)**
Exit **Stair**					
FED2	**NA**	NA	**NA**	NA	**340**
FED1	**NA**	NA	**NA**	**NA**	**420 (590)**

FED1 is Fractional Effective Dose based on NIST toxicity model.
FED2 is Fractional Effective Dose based on Purser toxicity model.
TEMP2 is limit for convected temperature based on Purser model for incapacitation.
FLUX is the threshold of 2nd degree burns to exposed skin causing incapacitation.
NR = limiting condition not reached.
NA = not applicable since the exit stairway was not present in other than exit stairway cases.
FLUX and TEMP2 were not applied to the second floor nor the exit stairwell because of the operating sprinkler at the top of the back stairs, which was predicted to activate at 240 s.

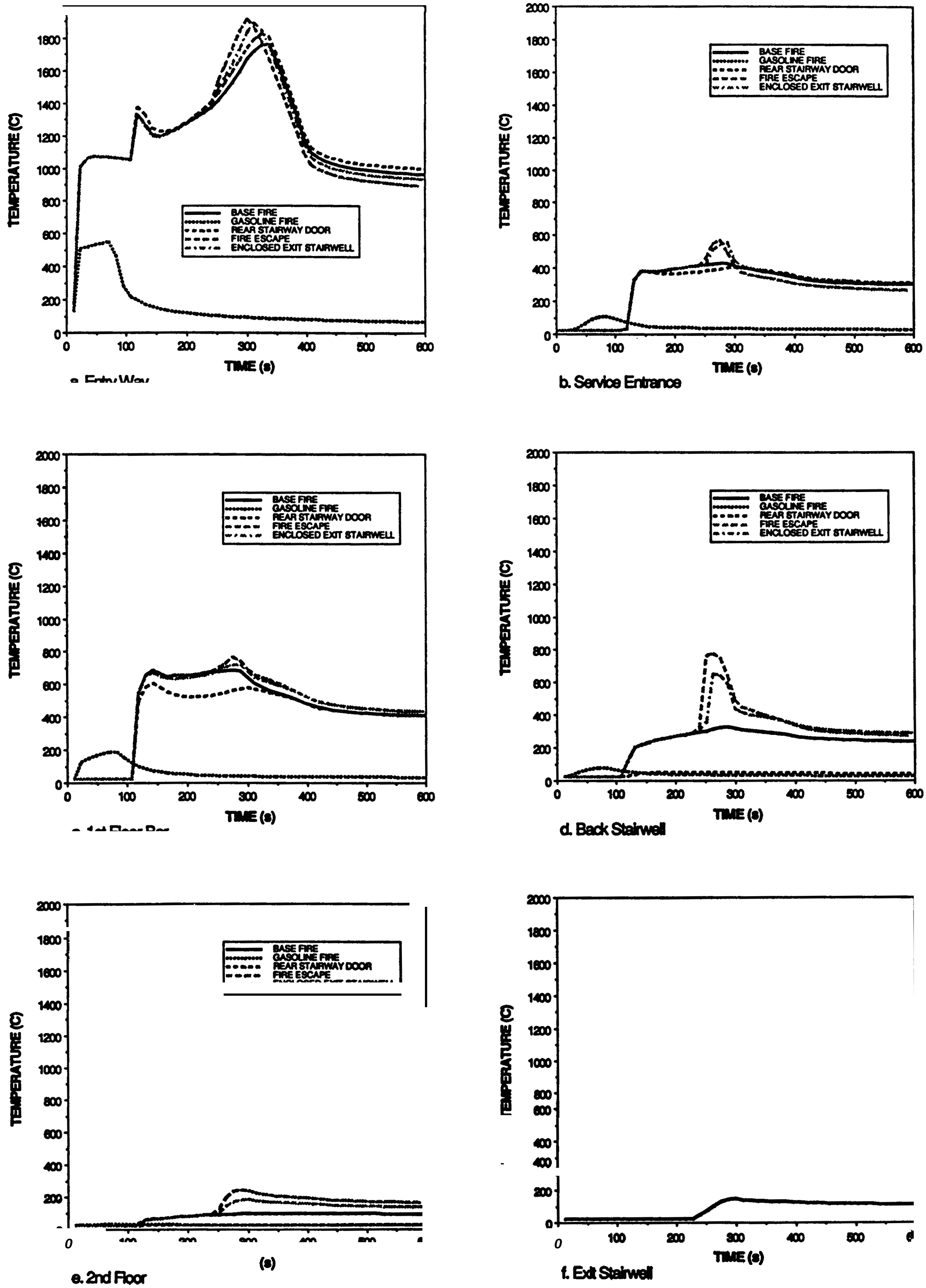

Figure 1 - Predicted Upper Layer Temperatures

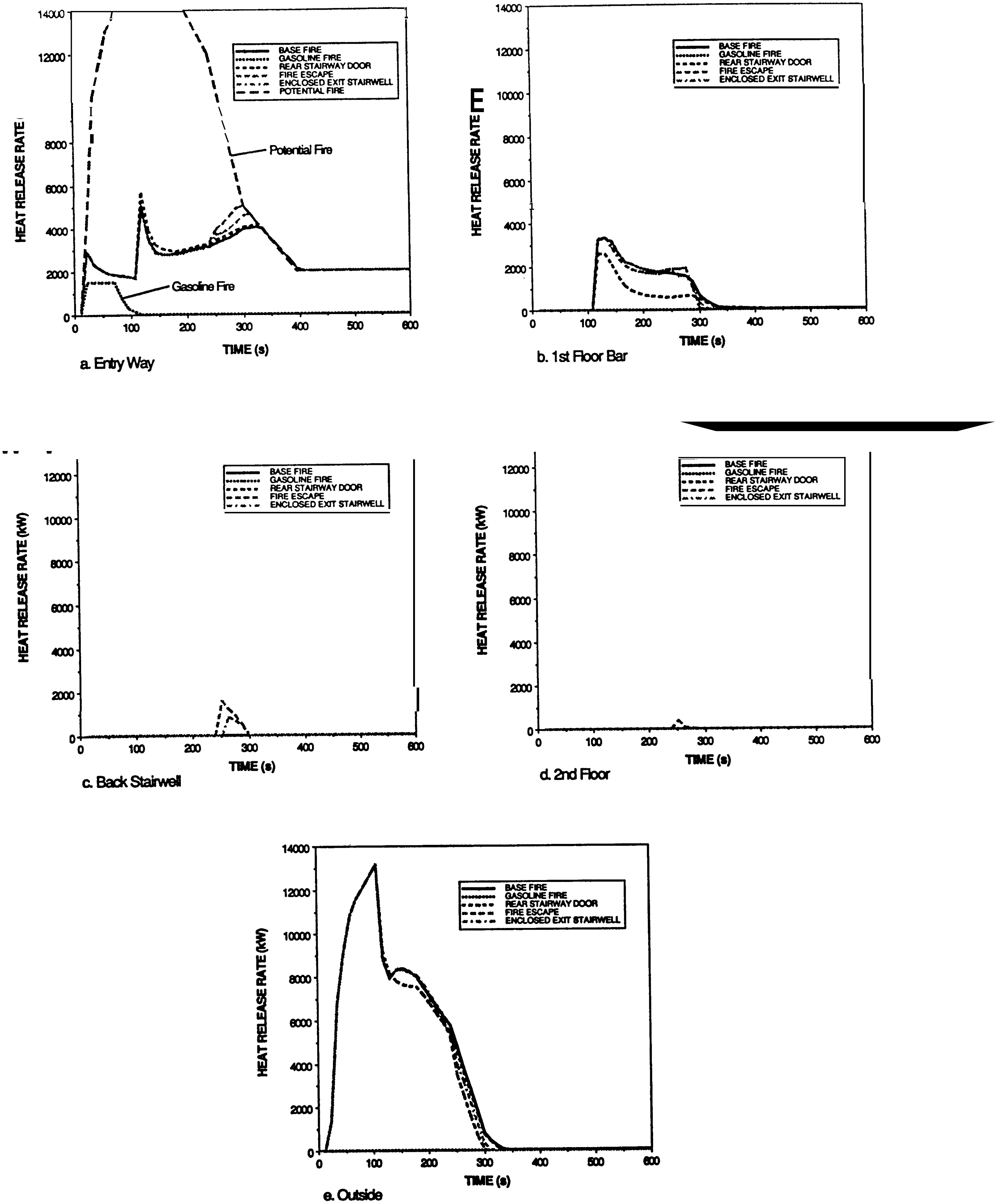

Figure 2 - Predicted Energy Release Rates

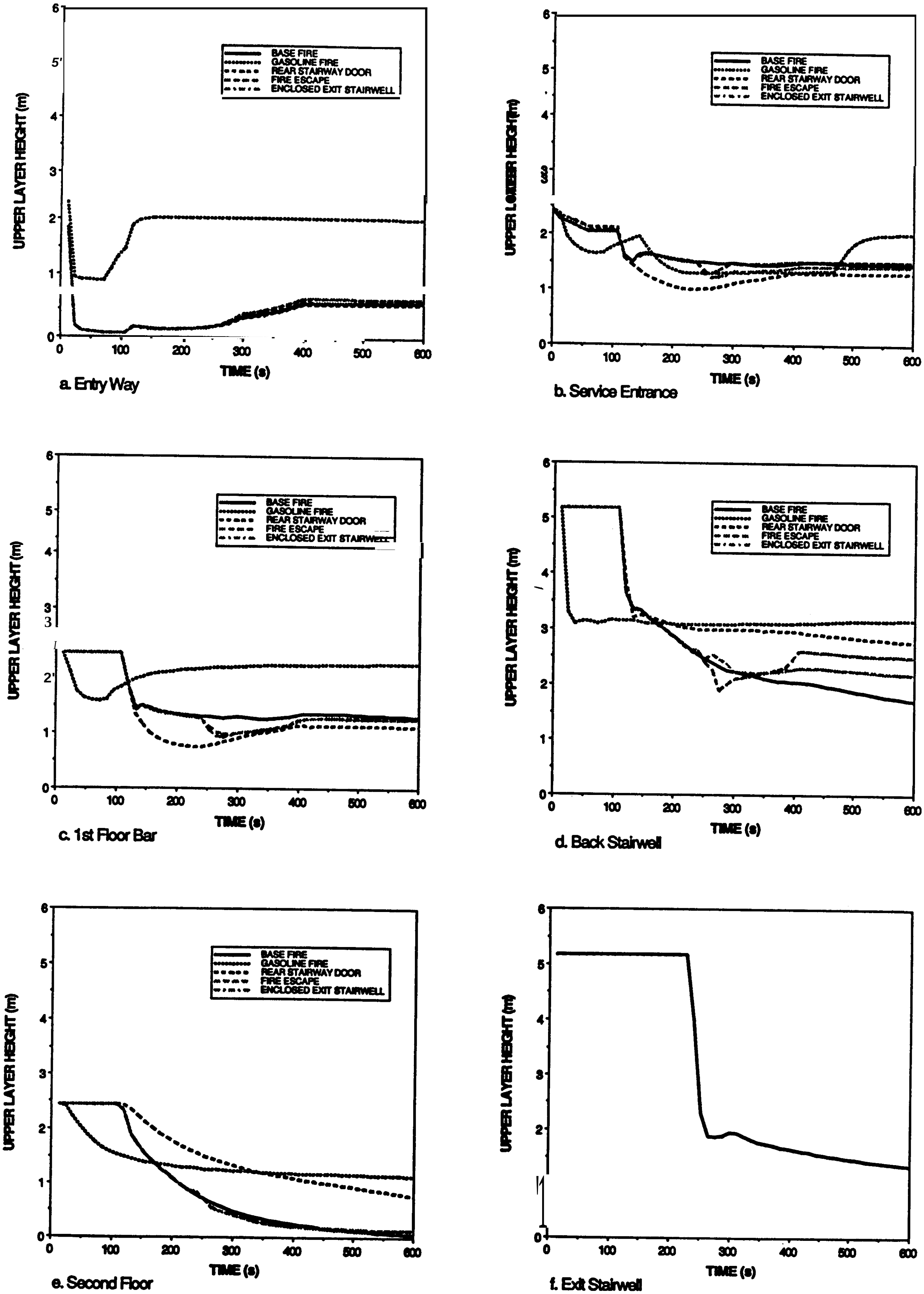

Figure 3 - Predicted Layer Height

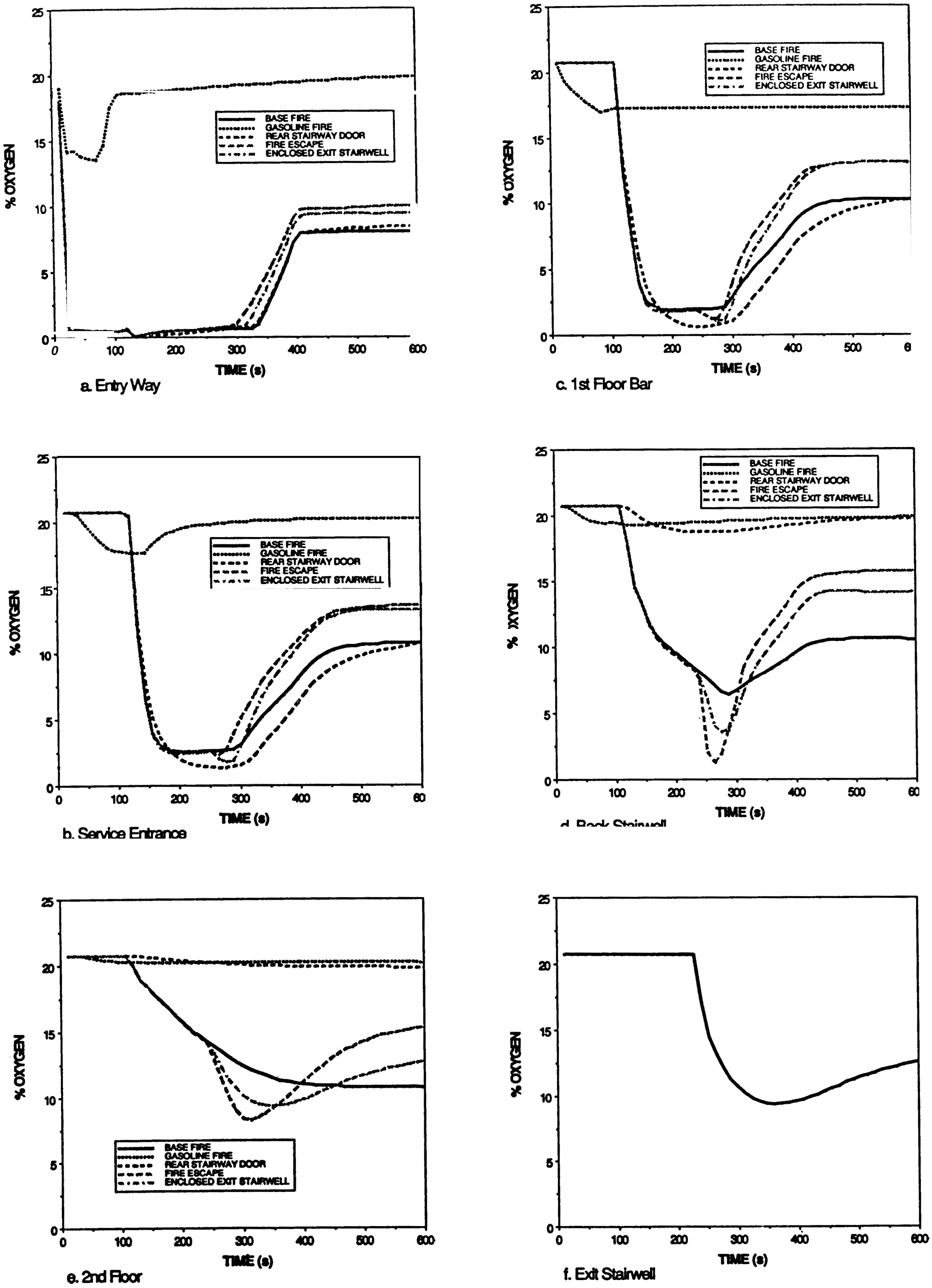

Figure 4 - Predicted Oxygen Concentrations

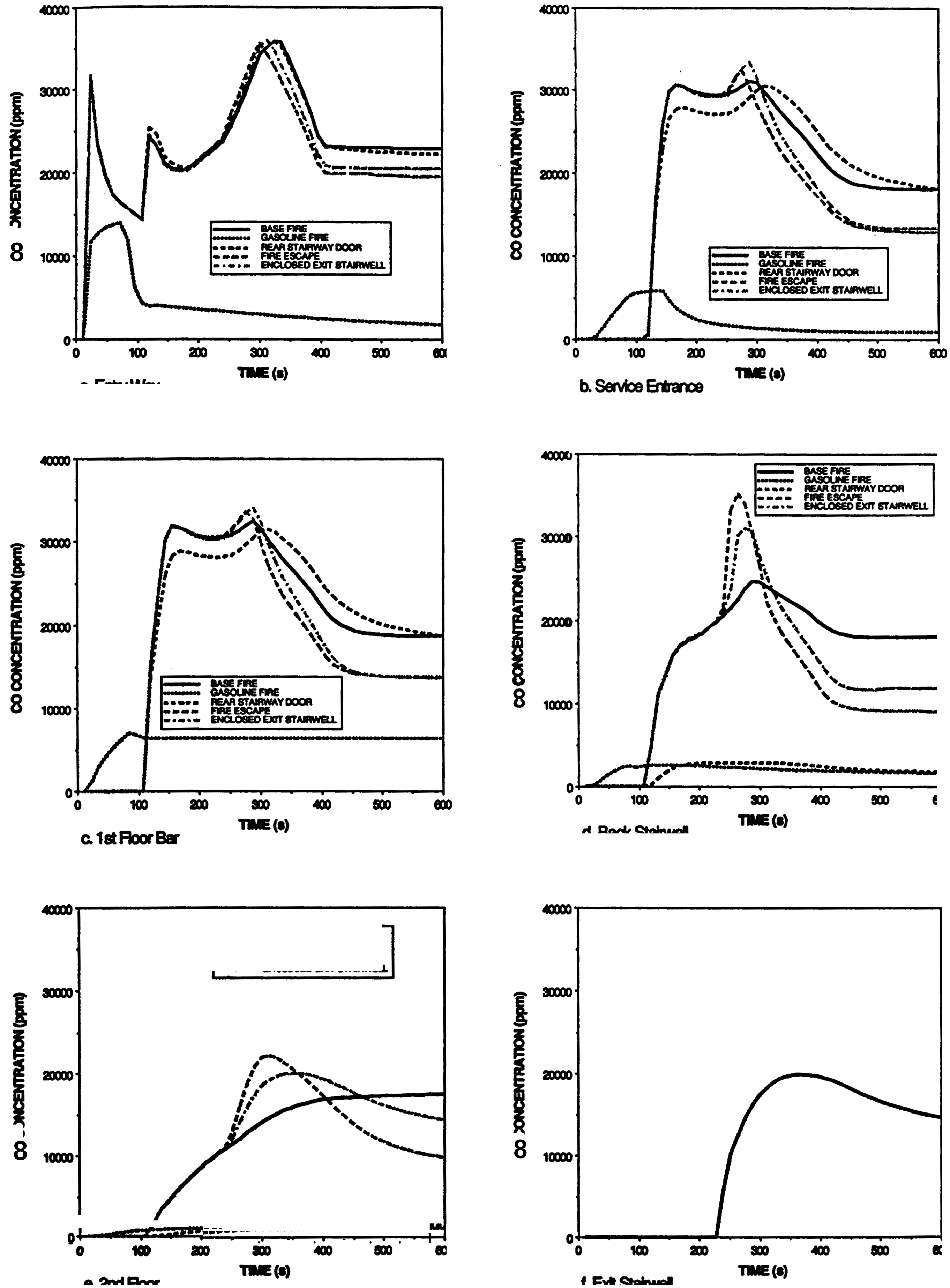

Figure 5 - Predicted Carbon Monoxide Concentrations

Table 1 - Assumed Fire Characteristics at Peak Burning

	Gasoline	Interior Finish*
Area	0.75 m^2	64.5 m^2
mass loss/unit area	0.045 kg/m^2-s	0.03 kg/m^2-s
Heat of Combustion	44 MJ/kg	12 MJ/kg
CO/CO_2 Ratio	.005 (.5)	.005 (.5)
C/CO_2 Ratio	1.0	1.0
Limiting Oxygen Index	1%	1%

Values which were modified after flashover are in shown in ().
* 3/16 inch thick plywood wall panels and low density fiberboard ceiling material.

Second Exit - $2000 (fire escape), $6000 (enclosed stair)

Non Combustible Interior Finish - $3000

SUMMARY OF OCCUPANT IMPACTS

Once all of the simulation runs were completed the TENAB model from HAZARD I was used to evaluate the time to incapacitation and lethality for each room in the building for each condition examined. These predicted results are presented in table 2. A complete explanation of the calculations on which these predictions is contained the HAZARD I documentation.[1]

These represent estimates of time to physical incapacitation (or death) for a normal adult within, and not moving from, the indicated room from the time of ignition of the fire in the entryway. The Purser models[12] are based on incapacitation experiments with monkeys and do not attempt to predict lethality. The NIST model is based on lethality experiments with rats, and estimate incapacitation. Persons who are physically incapacitated will remain stationary and will die unless rescued before lethal conditions are reached.

CONCLUSIONS

While we believe that the descriptions of the course of the fire provided by HAZARD I are representative of the actual conditions which occurred, it is important that they be verified to the maximum extent possible against all data obtained in the investigation, induding witness statements. In the course of this analysis the authors had no access to official reports or statements of witnesses, nor were any samples taken or physical tests run. The primary information source was articles in the press.

Based on the analysis reported herein, the following condusions have been reached.

1. HAZARD I predicted conditions quite similar to those reported for the actual incident, including times to and cause of death for the building occupants consistent with observations.
2. Calculations indicate that an automatic sprinkler head in the entryway would have promptly actuated and most likely prevented the spread of lethal conditions from the entryway into the rest of the dub.
3. A second means of egress might have reduced the toll, but probably would not have eliminated all of the fatalities. The degree of success would be a function of the speed of recognition of the danger and promptness of the start of evacuation; and is highly coupled to the width of the stairs.
4. Protecting the back stairs would have provided additional safe time for occupants of the second floor, but the structural integrity of the building would then become a crucial factor.
5. Noncombustible interior finish *appears* to be the least costly strategy for limiting the life loss in *this* incident. By limiting the fuel available to the gasoline spill, the impact of the fire on the building occupants would have been minimized. However even with noncombustible finish, if the fire had involved the contents of the first floor bar some life loss would have been likely.

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12. Purser, D. A., Toxicity Assessment of Combustion Products, Chapter 3 in the *SFPE* Handbook of Fire *Protection Engineering,* C. L. Beyler, ed. National Fire Protection Association, Quincy, MA (1988).