

September 21, 1983

AN-2518

TO: M. M. O'Mara

FROM: R. K. Hinderer

SUBJECT: 1983 Gordon Research Conference on Chemistry and Toxicological
Aspects of Combustion Products

EXECUTIVE SUMMARY

The 1983 Gordon Conference on combustion toxicology and chemistry was well attended and included many of the well-known researchers in the field (see Appendix 1). Representatives from State agencies of New York and New Jersey and other interested groups such as the Navy, NFPA, the Air Force, CPSC, NBS, Boeing, and Citibank were also in attendance. The international flavor of the Conference was maintained through the participation of Scientists from Canada, W. Germany, Czechoslovakia, and the U.K. The absence of Japanese representation and Dr. David Wooley (due to his recent promotion and change of responsibilities at the Fire Research Station/UK) was of particular interest.

The organizational changes within FRS appear to reflect continued spending/staff reductions. While Wooley is not completely detached from his previous areas of involvement, his participation certainly will be diminished. His position is likely to be filled by the two or three remaining staff scientists. Because of the important past and potential future contributions by this group we should closely monitor developments here and should continue direct contacts with Wooley and staff. When appropriate, we should utilize their technical capabilities and experience which have been a stabilizing force in an area which has a frequent propensity for the irrational.

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Although a significant number of the presentations, either totally or in part, were reviews of old material, many of the presentations were worthy of note. On the first day, the significant contribution of CO to fire deaths was noted and the impact of other factors such as low O₂, alcohol, coronary disease, heat, age and other gases such as HCN, NO₂, CO₂, and irritants were discussed. CO was singled out as the big killer with HCN being a weak second. The involvement of irritants was presented more as a factor of unknown significance. In his review of the Maryland study, Dr. Radford stated that the data indicated that 81% of the people would have been saved if detector systems had been used and 99% would not have died if a suppression system had been in place. Dr. Gunnet (U. of Connecticut) reviewed data on victims of early versus recent fires and indicated that toxic hazards have not changed.

The presentation by Dr. Kirkham (Chief of Aviation Toxicology/FAA) was quite interesting because it raised the question of the overall importance of toxicity or toxic hazard versus the total picture. His basic theme which arose from the grim slides of aviation accident victims was that toxicity was a factor in only a small percent of aviation fatalities. Impact and fuel were the major factors in most deaths.

The first day really set the tone for the whole Conference. The fact that many chemicals and materials produce nonspecific effects and that toxicity is only one factor in the overall fire hazard equation was noted.

Furthermore, data presented here and subsequently during the Conference indicated that data on synergism between CO and HCN is still conflicting and that the importance of irritants is still not well understood.

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During the remainder of the Conference a great deal of attention was given to combustion toxicity testing and the A. D. Little report for the State of New York. After Dr. Anderson (ADL) presented her work, I raised the issue of the high variability in the data using the U. of Pitt test and asked her (and Dr. Alarie) if this was a problem with the ramping method used to burn the materials. At this point Dr. Alarie's demeanor became extremely heated and his statements were quite derogatory. His bellicose statements were met by a chorus from several individuals in the audience challenging him and questioning the validity of the data. Because of the turmoil, the session was adjourned.

At lunch I pursued the subject with Dr. Alarie, however, he was very angry. The fact that Dr. Gann (NBS) supported my comments on the variability of the ramping method used in U. of Pitt test only angered him further. He was so upset that he made personal threats, "I'll get you" to Dr. Gann. Later, in a private conversation, Dr. Birky stated that personal threats had also been directed toward me.

The most important point is that here and throughout the session Drs. Anderson and Alarie appeared to stand alone in their opinion that small scale tests were of any use to the regulator. At one point, Drs. Alarie and Anderson tried to justify the ADL conclusions on the basis of regulatory needs and differences in regulatory mandates, but they met strong opposition. As one individual quite candidly rebuffed Dr. Alarie, (expletive deleted), there was another alternative; no test is acceptable.

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Some new data presented at the Conference continued to erode confidence in small scale tests. Two studies were of particular importance. Studies of acrolein which were conducted at Southwest Research Institute for FAA suggests that primates (i.e., man) may be far less sensitive than rodents. Furthermore, this suggests that the same may be true for HCl. Other work reported by Dr. Purser (Huntingdon/UK) in conjunction with the Fire Research Station showed that irritants affect respiration differently in rodents than in primates. Using polypropylene (CO and acrolein are two important decomposition products) he showed that the RD_{50} in mice, which Dr. Alarie has always claimed is the amount which will incapacitate you in three minutes, does not produce impairment in primates. This data supported earlier work by Potts and Lederer which showed that the mouse RD_{50} for CO does not cause any effect in man.

These studies provide further support for studies which are being planned under the Vinyl Institute to better understand the relationship of rodents to primates (man). If the rodent is not a good model for man (i.e., is more sensitive) this could greatly affect combustion toxicity testing and, particularly, some of Dr. Alarie's methods.

Perhaps the most important aspect of this Conference was the presence of Ray Zielinski, project officer for the State of New York on the ADL study. Not only did he hear that toxicity is only one parameter in fire hazard assessment of material, but he got a strong message that small scale combustion toxicity tests are not capable of assessing real world toxic hazards and are therefore not acceptable for regulatory use. Reports at the end of the Conference indicated that Mr. Zielinski's perspectives were

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greatly changed by the Conference. More recently Debbie Neal reported that he called one of our lobbyists to say that what we have been telling him all along was correct. I have sent a letter to Mr. Zielinski to emphasize some of the comments I made at the Conference and to offer assistance in the future.

At the end of the week we were all asked to evaluate the Conference. Although there was a considerable amount of data which was not new, I rate it relatively high. I felt that this meeting was an extremely effective means of communicating and addressing controversial material. The next meeting on this subject will probably be held in 1985 and some of the Vinyl Institute supported research should be completed by then. The new Conference chairman will be Barbara Levin (NBS).



R. K. Hinderer

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GORDON RESEARCH CONFERENCE/CHEMISTRY AND
TOXICOLOGICAL ASPECTS OF COMBUSTION PRODUCTS

Monday, 8/15 - Epidemiology/Physiology/Pathology

Radford

(Data appears to be a review of the Maryland study)

- The lack of interest of the medical profession and representation of firefighters was noted.
- Toxic effect of the fire environment is due to many factors: low O_2 (O_2 decreases during flashover), CO_2 , HCN (via cytochrome reductase), irritants, and others (?).
- The reason so much is known about CO, CO_2 , and HCN is that you can measure them. (Impact of some agents such as HCl are difficult to assess because you can't measure them in the biological system.
- The decrease in fire deaths in the U.S. was noted and the possible role of fire detectors was discussed.
- The fact that the bulk of deaths occurred in homes was noted and the contribution of furnishings was discussed.
- NFPA published data shows that time to detection is > 40 minutes in 37% of fires (supports the use of detectors).

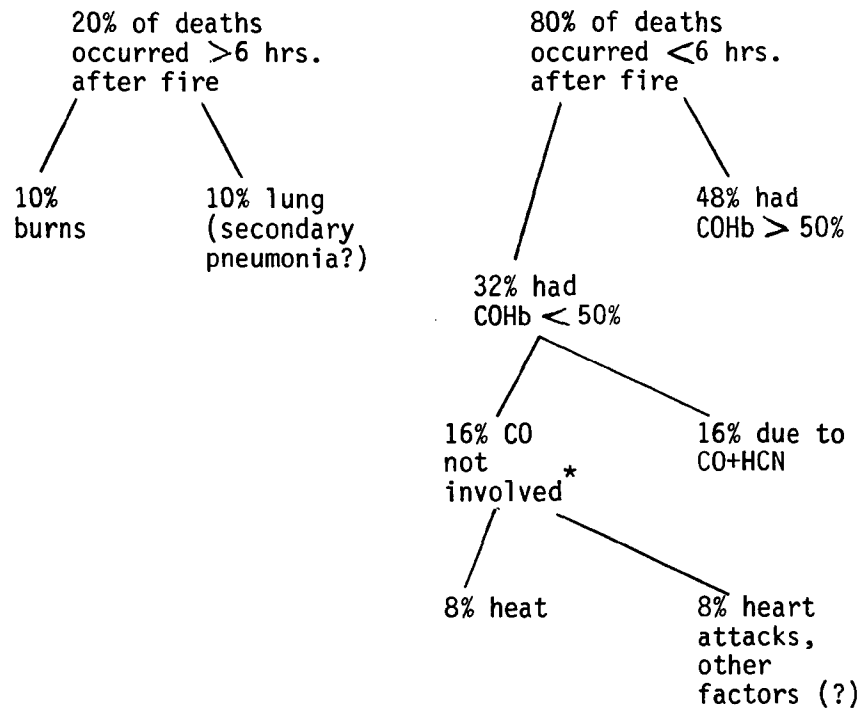
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- Smoking was found to be responsible for 50% of all fires and fire deaths.
- Approximately 25% (each) of fatalities occur in the living room and bedroom (50% combined).
- Fatalities are higher in the old and very young because of limited escape ability.
- Over 50% of fires occur between midnight and 6:00 A.M.
- In the real world, failure to escape is due to CO alone (30%), CO + alcohol (35%), young age/infants (12%), alcohol alone (3%), and coronary occlusion (3%).
- Heat is another important factor which is difficult to assess. A pig study has shown that the application of heat to the skin can release enough K^+ in the blood to be lethal. The analysis of K^+ in autopsies is needed.
- The combined effects of 1) low CO_2 and coronary stenosis and 2) CO plus HCN need to be considered.
- The Maryland data shows that smoke detectors would have saved 81% of all victims and a suppression system would have saved 99% (based on whether five minutes or more were available for escape and based on a small part of total population).

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- Detector systems could be an explanation for the decrease in fire deaths.
- Fire fatalities by medical cause



- Studies of COHb in non-smoking firefighters showed that CO is a significant factor. Respirators helped, but intermittent use of respirators was worse. (Masks tended to be taken off during overhaul, i.e., cleanup.)

* Some weakness due to difficulty in following medical certificate of death from one hospital to another.

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- Measurement of serum thiocyanate (metabolic product of CN^-) provides some evidence of excess HCN exposure in firefighters but needs repeating.
- Firefighter deaths are primarily due to stress (42%) and falls (29%).

Kirkham (FAA)

- Survival must be discussed on an acute and long-term basis. Incapacitation is the most important factor since it determines whether people can get out. Acute pulmonary injury is not well defined nor is treatment well understood. Long-term effects of exposure to smoke are typically bronchitis, emphysema, and sensitization.

(The following presentation was billed as political aspects of fires.)

- Air Canada: This plane had a bulkhead defect and was then refurbished. A fire occurred behind the bulkhead; circuit breakers went out. Wet towels were passed out by the crew. Only some were incapacitated since one man crawled over the body of another to get out.

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Such crashes present many problems. The coroner here is the mortician. Only five victims were autopsied by the Kentucky coroner and five by a consultant (Dr. Cleveland). Here the press also creates problems since they will take comments from anyone. (Previously he has shown a slide of fire victims and says, "Merritt (Birky), what could we have done with this type of victim and situation?")

- Spantax crash (Malaga, Spain):
There were 50 deaths with fuel involvement. One person reported transient loss of consciousness during exposure. This has also been noted by Crane in animals and is likely to be due to low O_2 .
- Mississippi Jail fire (27 deaths): Pulmonary edema was noted.
- MGM Grand (85 deaths): These were described as pure smoke deaths.

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- However, few deaths in aviation are due to fires. Toxicity was not a factor in the 727/Cessna collision in San Diego, the Chicago DC-10 crash, the Kennedy 727 (11 with severe burns and 114 shattered bodies), the KLM747/PAM747 runway disaster in the Canary Islands (fuel cell broke open spraying mist and fire), and the DC10 runway crash in Los Angeles (a pool of fuel burned the outside including the aluminum but the interior remained intact; only a fireman who went in for overhaul collapsed).
- In only two other cases was toxicity involved: the French air crash (122 deaths and incapacitation; virtually similar to Air Canada) and the Saudia Arabia plane fire where a 2-7 minute delay (so the Prince would not be inconvenienced) caused incapacitation and finally death.
- The "Cleveland fire test" and animal studies were described.
- Animal studies indicated that the toxicities of CO and HCN are additive. It was suggested that deaths in the 707 Pago Pago crash might have been due to HCN + CO and possibly other factors such as heat and low O₂.

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Grunnet

Margaret compared the pathological finding in victims from fires prior to and after the introduction and findings in animals exposed to wood and PVC. Pathological changes in both comparisons were similar. This is not surprising nor particularly new. The important thing was that someone outside the plastics industry, an academician, was pointing this out. We should keep Dr. Grunnet in mind for possible future projects.

Tuesday, 8/16 - Combustion Toxicity, Analytical, and Prediction Methods

Hartzell

- Gordon provided a brief review of DIN, FAA, NBS, U. of Pitt, and USF tests for combustion toxicity.
- He reviewed these large scale fire studies and noted temperature increases of approximately 800°F in less than two minutes.
- The ultimate point was that small scale tests don't model large scale fires.

Levin

- Barbara presented recent NBS work on the toxicity of combinations of gases.

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- Studies of CO and CO₂ (gradual increase and constant conc.) indicated some modifying effect of CO₂ on CO toxicity. This is not surprising, however, you would expect opposite effects at high versus low CO₂ concentrations. At high concentrations CO₂ would have a narcotic effect while at low concentrations, respiration would be stimulated. Blood acidosis is also expected.
- Another interesting observation was that COHb levels were not correlating well with CO levels for some materials. This suggests other factors could be involved or simply be due to the fact that COHb levels are not predictive of carbon monoxide intoxication.
- NBS has also looked at CO plus HCN. An additive effect appeared to be seen when comparing CO and HCN producing materials. Barbara noted that rate of gas generation must be considered when evaluating the data.
- NOTE: Basically NBS took 1/2 of the lethal CO concentration (1/2 of 5000 ppm) and 1/2 of the lethal HCN concentration (1/2 of 200 ppm). Lethality was observed at 2500 ppm CO in combination with 100 ppm HCN.

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- Barbara concluded that HCN may be reducing the respiratory rate. This does not make sense. There is probably some mechanism involving cytochrome oxidase. Probably what the animal is seeing is O_2 depletion via two different mechanisms, all adding up to the same effect.
- As a side note NBS found that PVC compares well with pure CO studies.
- There was quite a discussion regarding the mechanism of HCN evolution from PU. NBS appeared to get it from char while FRS gets it from yellow smoke. There was an unanswered question as to whether char and yellow oil was needed to produce HCN and a claim by NBS that no HCN is produced at 400° and $800^\circ C$. NBS speculated that char formation was needed. This was greeted with some degree of skepticism.

Alarie and Anderson

- These two presentations are covered in the executive summary. Alarie described his "pig in a box" method of evaluating pulmonary irritation and rate of recovery. He has been working on cotton dust and looking at sensitization.

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- He stated that PU is more irritating than PVC but could not identify the PU decomposition product. He also stated that Wooley's work with primates showed similar results using pulmonary irritation.

Voorhees

- This work was designed to develop a method that would allow one to identify the materials present in a fire by characterization of the aerosols from fires.
- The Potts furnace was used. The pyrolysis zone was characterized as containing polymer fragments and pyrolysates. In the flaming zone pyrolysates undergo oxidative decomposition to soot and "stable" product.
- The results indicate that this approach is very promising. Its favorable aspect is that it only requires a small amount of material. However, at present, it does have a problem identifying materials which represent <10%(w) of materials involved. Still, this could be useful to identify materials present in significant amounts.

Tewarson

- Archie discussed "fire hazard" and some of their research. His message was that one must consider overall fire hazards, not just toxic hazard.

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- PVC compared favorably with many of the materials tested. As an example, his data on "actual heat release rate" (mass loss rate X heat of combustion) indicated that PVC was better than wood (5.9 vs. 12.8, respectively).
- Emmons, in the last presentation of the Conference, indicated that the Factory Mutual combustion system did not model the real world.

Wednesday, 8/17 - Relevance of Small Scale Tests and Animal Models

Huggett

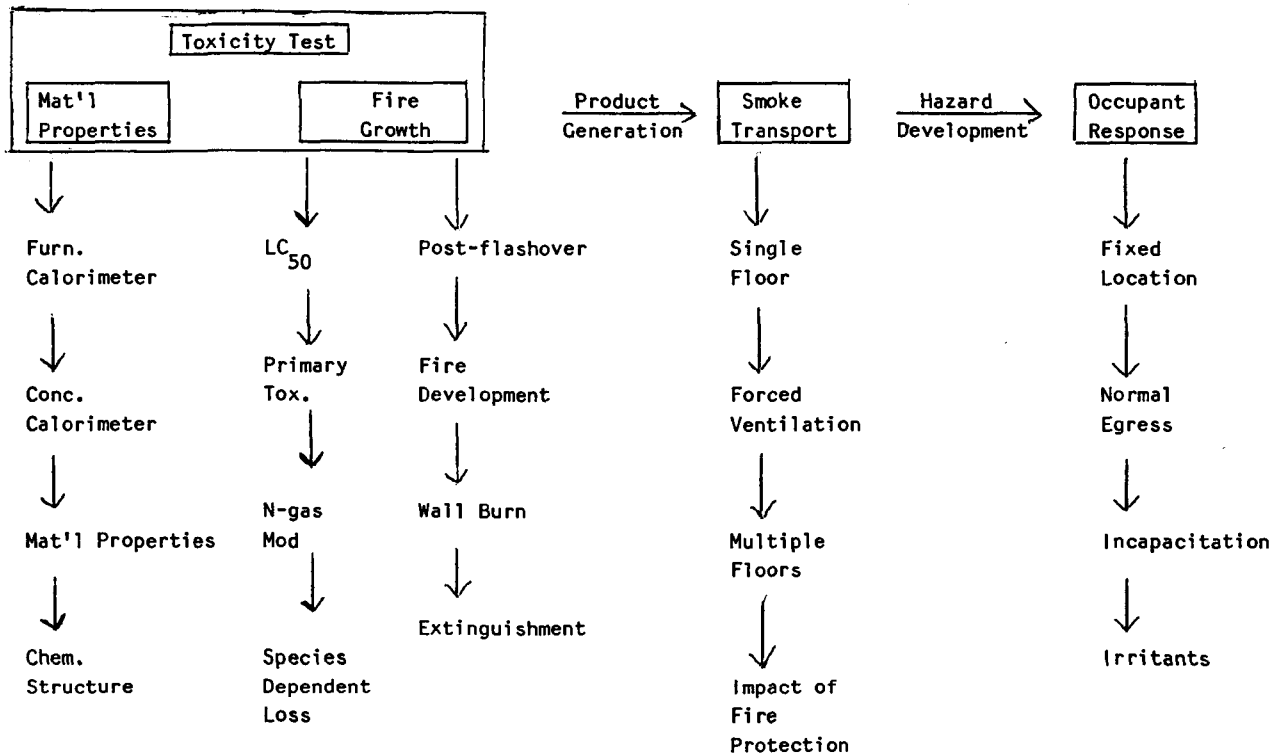
- Fire conditions are quite variable:
pyrolysis → smoldering → flaming → glowing.
- We don't know at what stage the deaths occur.
- There are many ways of burning, exposing, and measuring toxicity.
- Incapacitation models need validation.
- NBS criteria: 1) look at all conditions when appropriate (NBS is considering evaluation of smoldering conditions); 2) define what is happening in the furnace; 3) test materials under conditions of use; 4) define time-concentration relationship; 5) use lethality; 6) monitor for CO, use 14-day post-exposure period; 7) determine reproducibility, etc.

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NOTE: The suggestion that only lethality be used was challenged by a number of individuals. Incapacitation is important and must be included.

- NBS Toxic Hazard Assessment plans were outlined:



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Fardell

- 80% of fires occur in homes and 60% of deaths are due to toxic gases.
- Furnishings are of biggest concern (cigarettes and matches are biggest cause of fire in UK).
- More work needs to be done to understand the test system.
- Peter compared NBS vs. DIN furnace using CO_2/CO ratios vs. O_2 from large scale tests.
- The DIN method has problems with flatness of wire, foam burning, and size.
- The NBS/Potts furnace becomes opaque and high temperatures are needed in subsequent experiments; there is a need for statistical evaluation since some variability is noted.
- In compartment fires high and low ventilation is seen and O_2 drops to 4%. The NBS system does not mimic this pattern.
- Studies with polypropylene show that the rate of CO production ($\text{M}^3/\text{min.}$) varies depending on high vs. low ventilation.

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- With polypropylene, smoke production can be higher with high ventilation. (This goes against common thinking.)
- Based on CO_2/CO ratios vs. O_2 , the DIN method mimics the late stages of a fire and NBS the early stage.
- Because of the versatility of the DIN method, it can probably be modified to cover the whole range of a fire. Peter could not see how this could be done with the NBS test.

Williams

- This presentation covered DuPont's studies of the combustion toxicity of PTFE in an open gas flame versus the NBS furnace.
- Approximate lethal concentrations were:

0.07 mg/l	NBS historical
0.02 "	DuPont/NBS
>14.2 "	Methane flame
- The explanation of this difference is not clear but combustion with a gas flame in the presence of a secondary combustion source (Potts furnace) at the normal location also caused high mortality (i.e., 0.02-0.07 mg/l). Heat flux appears to be important in the formation of toxicants/toxicity.

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- Both Alarie and Wes Clayton tried to attack this work. It almost seemed as if they were trying to get revenge for our attack on the ADL work. This was a particular surprise in the case of Dr. Clayton. Although he does not appear to be particularly outgoing or friendly, the tone and manner of his questioning of Steve was one of the Prosecutor.

Stein

- This presentation was not very informative. Animal studies on cigarette smoke were discussed but no data was shown. He did state that smoke deposition studies have been conducted.

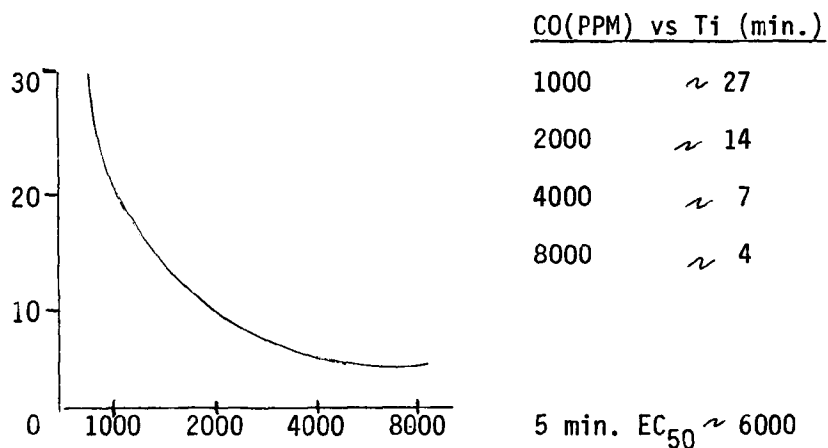
Purser

- This work involved toxicity studies with primates and rodents.
- Primates' exposure showed that with
 - 1) heavy work 20% COHb is incapacitating
 - 2) light work 30% " " "
 - 3) resting 40% " " "
- In primates irritants cause respiration to increase while in rodents respiration decreases.

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- Based on the observations in these studies there is some question whether upper respiratory effects might be concentration related and lower respiratory effects (delayed effects) might be dose-time related.
- The mouse RD_{50} did not cause irritation impairment in primates using polypropylene. This suggests the mouse may not be a good model for respiratory irritation in man.
- Time to incapacitation results with CO for primates are as follows:



- Dr. Purser stated that small scale tests are only useful for screening for super toxicants, not for hazard assessment.

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Kaplan

- Hal presented the results of recent studies sponsored by FAA.
- In their work the 5 min. EC_{50} for CO, in both rats and primates, was $\approx$ 6800 ppm. This is very close to the value reported by Purser.
- With acrolein, no lethality was observed in primates at 505 ppm; 1025 ppm was lethal. (Doses tested: 12, 25, 95, 100, 250, 505, 1025, and 2780 ppm.)

Thursday, 8/8 - Pathophysiology and New Perspectives in Combustion Toxicity

Sun

- These studies investigated the deposition of PAHs (Benzopyrene, Nitropyrene, etc.). One of the interesting aspects of this work was the development of a surrogate particle by coating GaO_3 . Size and morphology were similar to diesel particles.
- Three different furnace systems were used to study deposition in the Fisher 344 rat.

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- $B_{(a)}P$ alone and $B_{(a)}P$ plus coal tar were cleared rapidly from the lung. Diesel clearance was long while GaO_3 plus $B_{(a)}P$ was moderate. This suggests that the surrogate particle may still be somewhat different (biologically) from the diesel particle. This may be due to differences in surface energy, heat of absorption, etc.
- The particulate is largely excreted in the feces with a small amount of organic material found in the urine.
- Evidence of nasal, lung, liver and kidney metabolism was also found.

Christian

- This was a generic discussion of a material evaluation in a fire scenerio with discussion of model validation.

Birky

- Merritt gave a last minute presentation on the study he put together while he was at the Foundation for Fire Safety. I thought that it was quite amusing that he billed some of their development steps as the "1981 Cliffside Conference and the 1981 Reston Symposium". This all seemed a bit contrived. Scientifically his presentation was very weak. His protocol had many weaknesses, particularly because many of the parameters to be measured (i.e., benzene, corneal irritation, etc.) are general effects for many materials. Questions from the audience indicated they sensed this flaw.

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Panel Discussion

- Areas where new work is needed was identified as follows:
 - 1) effects on immune system
 - 2) better understanding of fire deaths
 - 3) better treatment methods
 - 4) better diagnostic methods
 - 5) more emphasis on evaluating materials in their intended use (large scale)
- There was also a comment by Alarie that irritants don't wake you up. Perhaps this is another area which should be followed up.

Klimisch

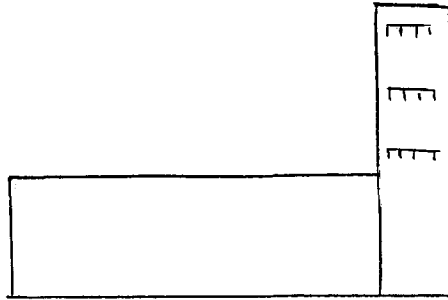
- Dr. Klimisch reviewed the DIN method for combustion toxicity evaluation. He stated that toxicity tests were not developed to regulate all materials and all applications. Furthermore, he stated that no supertoxic materials have been identified. The importance of overall fire hazard assessment was emphasized.

Michal

- Studies conducted by the Ore Research Institute in Czechoslovakia were described.
- In small scale studies they use a combustion furnace similar to DIN except that the furnace moves in the same direction as the air flow.

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- Their large scale work is particularly interesting because they have a 30 meter chimney connected to a corridor-type room. The chimney has platforms for



gas sampling.

- They have developed their own hazard formula for mines.

Bihr (ICBO)

- A historical review was given: 1) of contributions of code violations to fatalities; 2) of the development of flammability tests which were used for competitive advantage; 3) of the California political situation and Fire Marshal Favro's position (no tests are suitable); 4) that elimination of 50% of the building materials is a real turkey; and 5) that suppression and detection is the answer.

Orzel (CPSC)

- Rita provided an overview of CPSC research plans. They plan to look at PU foams in the NBS test and will screen upholstery materials containing flame retardants.

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- One of the Attendees asked if the FRS data had suggested to her that CPSC should rethink their use of the NBS furnace (Potts). Although her reply was not affirmative, the FRS comparison of the DIN and Potts furnaces did make an impact.

Emmons

- Dr. Emmons gave one of the best papers of the Conference. He started by comparing combustibility test data for 24 materials by an average of six standards from different countries. He compared these results to show the random nature of the data. Only two materials were consistently sorted out by all: cement and nitrocellulose.
- This was his way of leading into the fact that we don't know enough about what happens in real fires. He stated that a prediction scheme was needed to assess the use of materials in a given building setting.
- Slides of a large scale fire test in a bedroom were shown. At the full blown stage, only 1/2 gallon of water was needed to kill the fire in the bedroom.
- Dr. Emmons stated that more modeling and validation work is needed. He emphasized that materials are likely to be good under some conditions and not so good under others. Furthermore, we need to argue which tests are more universal.

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