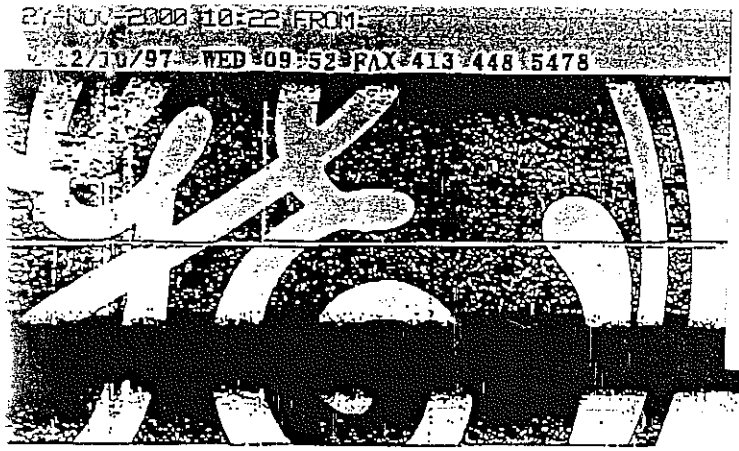


THE TRUTH ABOUT COMBUSTION TOXICITY

MYTHS:

- Some competitors' products are nontoxic
- Combustion toxicity is easily measured and accurately reported
- LEXAN* polycarbonate is nontoxic

FACTS:

- All materials can burn
- All materials release carbon monoxide when burned
- Carbon monoxide is toxic

NONTOXIC MATERIALS ARE NONEXISTENT

- There are numerous combustion toxicity tests
- RESULTS often CONFLICT from test to test
- Current industry trend is to quantify and standardize a combustion toxicity test

THERE ARE VARIOUS COMBUSTION TOXICITY TESTS WITH CONFLICTING RESULTS

- When LEXAN is forced to burn . . .
  - * Carbon monoxide IS released
  - * Toxic gases, typically associated with PVC burning, ARE NOT released (HCN, HCl, etc.)

THE STATEMENT "LEXAN IS NONTOXIC" IS MISLEADING . BECAUSE IT'S TECHNICALLY INCORRECT

TOXICITY IS A HIGHLY CONFUSING AND EMOTIONAL ISSUE! AVOID MISLEADING CUSTOMERS OR GIVING ERRONEOUS INFORMATION BY CONSULTING WITH TECHNICAL MARKETING.

* Registered trademark of General Electric Company

TM 89-6

TOXICITY

As with natural products, synthetic materials show variations in the number and type of toxic products produced during combustion. The variation depends upon the specific chemical composition of the individual materials and the conditions of combustion.

Both natural and synthetic materials produce carbon monoxide and carbon dioxide. The relative amounts are primarily dependent upon temperature and oxygen supply.

There are two laboratory techniques used to determine if there are toxic agents other than carbon monoxide in combustion products:

- Chemical - Analyze sample combustion products for known toxic compounds.
- Biological - Expose animals to sample combustion products and compare the results to animals exposed only to carbon monoxide.

The first technique directly determines if known toxic agents are present. However, because of the large number of different compounds produced, there may be unknown toxic agents or combinations of agents which are toxic.

By exposing live animals to combustion products, it is possible to judge if their mortality rate or "recovery" performance is different from animals exposed to carbon monoxide as a single toxic agent.

ANALYTICAL DETERMINATION OF TOXIC DECOMPOSITION PRODUCTS

The identification of the decomposition products of various materials permits them to be grouped according to the types of known toxic products produced under combustion conditions. The various groupings are obviously related to material composition as shown in the following table.

BASE MATERIALS*	COMPOSITION Carbon, Hydrogen, And...	SIGNIFICANT DECOMPOSITION PRODUCTS Carbon Dioxide, Carbon Monoxide and Others... ...Plus...	REFERENCES
Polyethylene	--	--	1
Polypropylene	--	--	
Polystyrene	--	--	1
Acrylic	Oxygen	--	
Polycarbonate	Oxygen	--	1, 3
Wool	Oxygen, Nitrogen	Hydrogen Cyanide	1
Urethane	Nitrogen	and various	1
ABS	Oxygen, Nitrogen	Nitrogen Oxides	3
Wood, etc. (cellulose)	Oxygen, Several	Several, including low molecular weight aldehydes such as Acrolein.	1, 2, 3
Polyvinyl Chloride	Chlorine	Hydrogen chloride, Vinyl Chloride, etc.	1

*NOTE: Polymer properties are often modified by the use of specific additives. These additives may also produce toxic products of combustion depending upon their composition.

The specific combustion products of polycarbonate produced in several different temperature ranges have been identified[1] and are shown in the table on the following page.

Conclusion

With LEXAN(R), the primary toxic product of combustion is carbon monoxide. No unusually toxic products have been identified.

1. E.A. Boettner, G.L. Ball, B. Weiss, Combustion Products from the Incineration of Plastics, Final Report of Research Grant No. EC00368 for the U.S. Environmental Protection Agency, Ann Arbor, University of Michigan (February 1973).
2. B.A. Zikria, D.C. Budd, H.F. Floch, and J.M. Ferrer, A Clinical View of Smoke Poisoning; National Research Council, National Academy of Sciences: Proceedings of the International Symposium on "Physiological and Toxicological Aspects of Combustion Products", (1974).
3. G. Kimmerly, Methodology for Toxicological Analysis of Combustion Products; National Research Council, National Academy of Science Proceedings of the International Symposium on "Physiological and Toxicological Aspects of Combustion Products", (1974).

BIOLOGICAL ASSESSMENTS OF THE TOXICITY OF COMBUSTION PRODUCTS

Analytical determination of toxic combustion products cannot, by itself, be used as the sole criteria for toxicity because the combustion products may contain both known and unknown toxic substances that can act both alone, and in combinations, to produce undesirable results.

Small animal testing is often used to help resolve this problem.

It is possible to identify the effect of various concentrations of a single toxic agent (carbon monoxide) on the behavior (mortality, symptoms, recovery patterns, etc.) of rodents (mice, rats, etc.).

If animals exposed to the combustion products of a specific material show similar behavior to that of animals exposed only to carbon monoxide, it is possible to conclude that the effects are no more accute than simple carbon monoxide poisoning.

However, if the behavior is significantly different (worse), it is possible to conclude that there are toxic compounds other than carbon monoxide present.

Tests performed on rats, using only CO as the toxic agent, show that a concentration of 70% carbon monoxide in the blood (i.e., 70% carboxyhemoglobin - 70% COHb) is fatal in 30 minutes.[14] A concentration of 55% COHb or less is considered sub-lethal.[15]

Consequently, if fatalities occur in rats whose COHb concentration is less than 55%, it can be concluded that toxic results other than carbon monoxide are contributory factors.

Using this information it is possible to draw the following conclusions about the toxicity of the combustion products of various materials shown in the tables on the next page.

- With ABS, Foamed ABS, and Cork (wood), factors other than CO were responsible for the deaths.
- With Polycarbonate and Spruce (wood), the data clearly shows that fatalities are due to carbon monoxide.

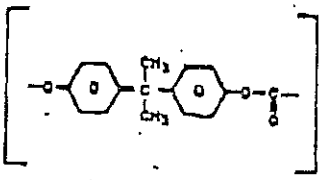
Conclusion: Carbon monoxide is the primary toxic product of combustion. No unusual toxic effects from combustion products have been identified.

[14] H. T. Hofmann and H. Oettel, Comparative Toxicity of Thermal Decomposition Products, Modern Plastics, 46, No. 10, p. 94, 98-100 (October 1969).

[15] M. M. Birky, Review of Smoke and Toxic Gas Hazards in Fire Environment, Proceedings of the International Symposium: Fire Safety of Combustible Materials, University of Edinburg (1975).

CHEMICAL ANALYSIS*

Bisphenol A - Polycarbonate consists of approximately 76% carbon, 19% hydrogen, and 5% oxygen.



Bisphenol A - polycarbonate

When heated in air, polycarbonate will begin to melt at about 370°C. At 475°C and 520°C, it will absorb energy and evolve a variety of decomposition products. Above 520°C, heat is liberated as more of the decomposition products are converted to carbon monoxide and carbon dioxide.

The following table identifies the gaseous products of combustion produced in several different temperature ranges. Depending upon the conditions, these compounds account for 40-60% of the polycarbonate consumed. The remainder is liquid residue primarily consisting of phenol and substituted phenols.

Polycarbonate Combustion Products Within Several Temperature Ranges*

Compound	475 C	475 - 500 C	500 - 550 C	550 - 1000 C	Total
Carbon Dioxide*	90	60	133	997	1280
Carbon Monoxide	10.3	14.6	60	248	333
Methane	2.25	2.48	5.69	3.75	14.2
Ethylene	0.09	0.31	0.39	0.33	1.12
Ethane	0.057	0.19	0.36	0.12	0.73
Propylene	0.095	0.17	0.085	0.026	0.37
Propane	0.022	0.067	0.03	----	0.12
Methanol	0.093	0.43	0.36	0.14	1.02
Acetaldehyde	0.092	0.10	0.06	0.085	0.34
1-Butene	0.062	0.038	0.008	0.042	0.15
Butane	0.001	0.004	0.001	0.004	0.01
Benzene	0.045	0.077	0.72	1.06	1.90
Toluene	0.066	0.19	0.46	0.18	0.90
Ethylbenzene	0.013	0.088	0.21	0.17	0.48
Styrene	0.006	0.008	0.14	0.036	0.06
% Plastic accounted for					59
% Residue (by difference)					41

*The quantity of each combustion product is reported in milligrams per gram of sample.

Conclusion:

The primary toxic product of combustion is carbon monoxide. There are no unusual toxic products of combustion such as hydrogen chloride, phosgene, hydrogen cyanide, etc.

* E. A. Boettner, G. L. Ball, and B. Weiss, Combustion Products from the Incineration of Plastics, Final Report of Research Grant No. EC00368 for the U. S. Environmental Protection Agency. Ann Arbor, University of Michigan (February, 1973).

TOXICITY OF THE PYROLYSIS PRODUCTS OF THERMOPLASTIC MATERIALS ON RATS. TESTS WITH EQUAL VOLUME (300 BY 10 BY 5 MM) *

Sample	Temp. °C	Concentration in Air		COHb %	Number of Deaths out of 20
		CO ppm	HCN ppm		
ABS	350	150	100	5.8	0
	400	350	150	14.2	13
ABS Foam	350	100	20	6.2	0
	400	100	100	7.3	2
Polycar-bonate	500	3,500	0	44.0	0
	600	24,000	0	71.5	20

TOXICITY OF THE PYROLYSIS PRODUCTS OF SPRUCE WOOD AND CORK ON RATS. TESTS WITH EQUAL VOLUME (300 BY 10 BY 5 MM) *

Sample	Temp. °C	Concentration in Air		COHb %	Number of Deaths out of 20
		CO ppm	HCN ppm		
Spruce wood	300	1,000	0	27.6	0
	350	7,500	0	72.7	19
Cork	250	600	0	20.7	0
	300	1,000	10	21.5	2

* G. Kimmerly, Methodology for Toxicological Analysis of Combustion Products; National Research Council--National Academy of Science Proceedings of the International Symposium on "Physiological and Toxicological Aspects of Combustion Products", (1974) p. 143.

TOXICITY

BIOLOGICAL ASSESSMENTS

Recently, work has been published[1] on the toxicity of pyrolysis products from a number of natural and synthetic materials. The results separately rank materials by their incapacitating and lethal effects on test animals (Swiss albino mice).

- Four test animals are sealed in a transparent, 4.2 liter chamber. The pyrolysis products from one gram of sample material (heated from 200°C to 800°C at a rate of 40°C/min) enter the chamber via a connecting tube. The test period is 30 minutes.

  Time to Incapacitation (Ti) is recorded upon the first observation that any of the animals indicates loss of equilibrium by staggering, collapse or convulsions.

  Time to Death (Td) for each animal is recorded when cessation of movement and respiration occurs.

Under these conditions, the synthetic polymers were either comparable to or significantly less toxic than commercial cellulosic materials. Polycarbonate is ranked as the 3rd least toxic material tested when Time to Incapacitation is used as the criteria. Polycarbonate is listed as the least toxic material tested when Time to Death is used as the criterion.

[illegible]

Material	Ti min.
chlorinated polyvinyl chloride, 1	8.29 ± 0.40
hemlock, untreated	7.22 ± 2.03
flexible polyurethane foam	8.45 ± 0.40
hardboard, unfinished	8.56 ± 0.37
polyphenylene oxide, modified	8.85 ± 2.29
chlorinated polyvinyl chloride, 2	9.00
red oak	9.09 ± 1.00
cotton, surgical	9.11 ± 0.67
flexible polyurethane foam, FR	9.20 ± 0.57
particle board, untreated	9.32 ± 0.19
polybismaleimide	9.30 ± 0.14
polyphenylene sulfide, 3	9.39 ± 1.20
polyether sulfone, 300-P	9.63
Douglas fir	9.84 ± 0.12
polyaryl sulfone	10.01 ± 1.35
polyphenylene sulfide, 1	10.22 ± 1.50
polysulfone, modified	10.61 ± 1.33
polyether sulfone, 712-P	10.72 ± 1.74
polyphenylene sulfide, 2	10.84 ± 1.59
rigid polyurethane foam, FR	11.23 ± 0.30
acrylonitrile-butadiene-styrene	11.35 ± 1.32
polymethyl methacrylate	12.41 ± 0.26
polyether sulfone/glass fabric	12.76 ± 0.76
polycarbonate, FR	12.82 ± 1.76
polyether sulfone, 200-P	13.39 ± 2.28
flexible polychloroprene foam	14.03 ± 0.35
phenolphthalein polycarbonate/bisphenol A	14.15
polystyrene	15.18 ± 0.76
polycarbonate	16.02 ± 1.26
fluorene polycarbonate/dimethylsiloxane	16.77
polyvinyl fluoride	18.94 ± 2.35

[illegible]

Increasing Toxicity ↑

Material	Td min.
flexible polyurethane foam	10.15 ± 0.68
polyether sulfone, 300-P	10.26 ± 0.32
polyphenylene sulfide, 3	10.27 ± 1.40
hemlock, untreated	10.30 ± 0.18
hardboard, unfinished	10.36 ± 0.54
polyphenylene sulfide, 1	11.07 ± 1.65
polybismaleimide	11.12 ± 0.11
flexible polyurethane foam, FR	11.18 ± 0.76
polyaryl sulfone	11.23 ± 1.68
red oak	11.30 ± 0.71
particle board, untreated	11.32 ± 0.04
polyether sulfone, 712-P	11.77 ± 1.57
polyphenylene sulfide, 2	12.40 ± 1.86
cotton, surgical	12.65 ± 1.01
Douglas fir	13.53 ± 0.61
rigid polyurethane foam, FR	14.05 ± 0.60
polyether sulfone, 200-P	14.47 ± 2.34
polyether sulfone/glass fabric	14.56 ± 0.23
polymethyl methacrylate	15.15 ± 0.23
polysulfone, modified	15.72 ± 1.60
polycarbonate, FR	16.26 ± 3.78
phenolphthalein polycarbonate/bisphenol A	16.92 ± 0.13
flexible polychloroprene foam	17.25 ± 0.56
acrylonitrile-butadiene-styrene	19.20 ± 4.35
polyphenylene oxide, modified	19.96 ± 3.61
polystyrene	20.03 ± 2.97
polyvinyl fluoride	20.50 ± 2.05
fluorene polycarbonate/dimethylsiloxane	20.57 ± 1.96
chlorinated polyvinyl chloride, 1	21.76 ± 4.27
chlorinated polyvinyl chloride, 2	22.76 ± 4.32
polycarbonate	23.56 ± 5.25

[1] C.J. Hilado, C.L. Slattengren, A. Frust, D.A. Kourtices and J.A. Parker, Relative Toxicity of Pyrolysis Products of Some Synthetic Polymers. J. Combustion Technology (August 1976).

IRRITATION

Not surprisingly, there are direct correlations between irritating products of combustion and toxic products of combustion. Many toxic compounds in sub-acute concentrations cause severe irritation to the respiratory tract and eyes.

In general, those materials which contain nitrogen, sulfur, chlorine, and other halogens such as fluorine, may produce decomposition products which are known irritants. Natural products such as wood, cotton, etc., produce low molecular weight aldehydes (acrolein, etc.) which are severely irritating.[1]

- In tests conducted by Lockheed Aircraft[2], human subjects were exposed to the combustion products from a variety of materials used in the passenger compartment of commercial aircraft. The results concluded that "the predominant factor affecting visibility is not the obscuration of vision by particles of smoke, but the irritating effects of combustion gasses, predominantly HCl and SO_2. These gases in combination with moisture in the eyes tend to cause great discomfort and irritation."

- Animal testing[3] was used to compare the irritability of combustion products from polycarbonate and polystyrene (film and foam). None of these products contain nitrogen, sulfur, chlorine, fluorine, etc. The amount of each material that had to be burned in order to generate sufficient amounts of combustion products to decrease the respiratory rate (a characteristic of sensory irritation) by 50% (RD_{50}) was determined. The results showed that polystyrene film was more irritating than polystyrene foam; and that polycarbonate was much less irritating than either material.

- In full scale testing conducted by General Electric, the decomposition products from LEXAN were quite low in irritation in comparison to a variety of synthetic and natural materials including plywood, hardboard, etc.

Conclusion

The decomposition products from LEXAN are relatively low in irritation and do not constitute an unusual hazard relative to wood.

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1. I. N. Einhorn, Physio-Chemical Study of Smoke Emission by Aircraft Interior Materials, Part I, Physiological and Toxicological Aspects of Smoke During Fire Exposure. Report No. FAA-RD-73-50, I, Department of Transportation, Federal Aviation Administration, Systems Research and Development Service, Washington, DC (July, 1973).
2. E. L. Lopez, Smoke Emission from Burning Cabin Materials and the Effect on Visibility in Wide-Bodied Jet Transports. Report No. FAA-RD-73-127, Department of Transportation, Federal Aviation Administration, Systems Research and Development Service, Washington, DC (March, 1974).
3. Y. Alarie, C. K. Lin, and D. L. Geary, Sensory Irritation Evoked by Plastic Decomposition Products. Amer. Ind. Hyg. Assoc. J. 35:654 (October, 1974)