DU PONT

Better Things for Better Living ... through Chemistry

FREON® PROPELLENTS

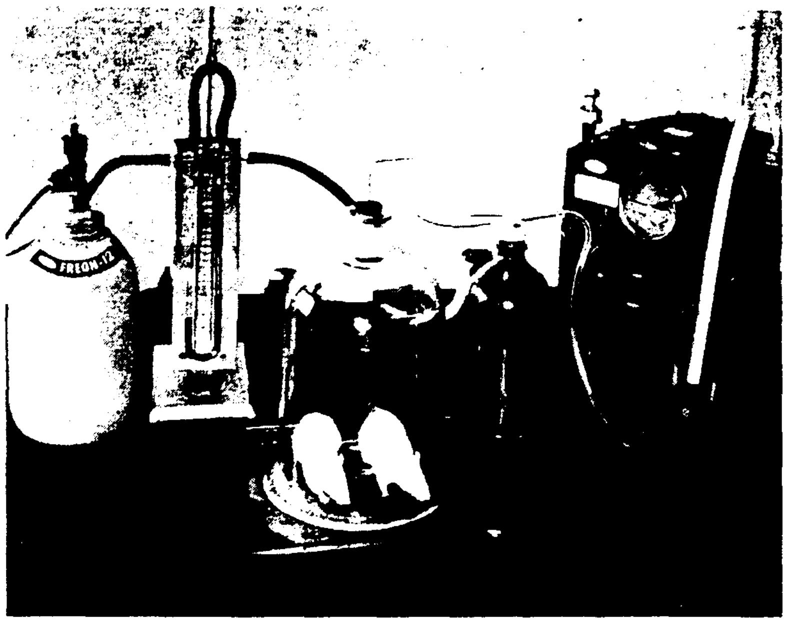
"FREON" Aerosol Report

A-54

TOXICITY OF PROPELLENTS

By: Fred T. Reed
"Freon" Products Laboratory
E. I. du Pont de Nemours & Company

REPRINTED BY PERMISSION
FROM THE OCTOBER 1960
ISSUE OF
AMERICAN PERFUMER



Test animals being exposed to propellent gas. The propellent is lead through a flowmeter into a mixing chamber. Here, 20% by volume is mixed with a measured amount of air, and the whole run through a test chamber with the animals.

Toxicity of Propellents

By Fred T. Reed
E. I. du Pont de Nemours & Co.

Of the many property requirements which an aerosol propellent must meet, certainly low toxicity heads the list. Vapor pressure, boiling point, solvent power and flammability are critically important properties, but even if these properties were ideal, a propellent material would be completely unacceptable if it did not have a low order of toxicity. In the discussion which follows only those propellents are considered which meet this rather broad requirement of low-order toxicity.

The primary concern in considering toxicity of aerosol propellents is inhalation. In addition, certain other areas are of interest, such as ingestion toxicity, skin sensitization and toxicity of decomposition products. In the last case, this usually is important only as thermal decomposition, as would occur when an aerosol product is sprayed into an open flame. When chemical decomposition of the propellent occurs in the container, the product is normally unacceptable for its intended application and thus would not be marketed. Of the various types of toxicity mentioned, only inhalation toxicity has been extensively studied for the many compounds which are used as propellents. The most detailed information available covers the fluorinated hydrocarbon propellents (Ref. 1).

The Underwriters' Laboratories have investigated several of the fluorinated hydrocarbons. Their findings are reported as group classifications. Tables II and III give these group classifications for all the common propellents and some of the less common propellents. Table II is intended as a reference table to give some idea of the types of compounds which would fall into the very low (more toxic) Underwriters' Laboratories classifications. Common materials with which the reader would normally be familiar were selected and, as is obvious, these materials listed in Table II would be completely unacceptable as propellents. In the case of methyl chloride, CH_3Cl, special handling conditions would be necessary because of its toxicity if it were used as a propellent.

The definition of the Underwriters' Laboratories classes are given in Table I. It is well to remind the reader at this point that this classification is based on inhalation toxicity only. Further details on this classification can be found in Ref. 1 and the references contained therein. Where no information is available a blank space is indicated.

Probably the most interesting point to note in Table III is the fact that Propellents 12, 114, 114a, 152 and C318 are grouped in the highest classification and indeed are less toxic than carbon dioxide. The latter normally constitutes a substantial percentage of the gases in the lungs which makes it quite apparent that those materials classified in Group 6 would be completely free of any inhalation hazards in their normal use as propellents. It is also worth noting that most of the compounds listed in Table III fall in a classification as high as carbon dioxide. Those few which fall below carbon dioxide, such as methylene chloride, still present no hazard in the quantities which are normally used in an aerosol product and in the manner in which the consumer uses the product.

It would be advisable at this point to remind the reader that none of these compounds will support life. Thus, should any situation occur where the oxygen content of the atmosphere reaches such a low level as to fail to support life, then any of these compounds, if it is the only other gas present, becomes a serious hazard. This is a somewhat cumbersome way of saying that any of these propellents will cause suffocation if insufficient air is present. This becomes a problem only to the manufacturers of propellents and loaders of aerosol products. One might visualize the situation where a workman is asked to clean a tank which previously contained one of these propellent materials or possibly a solution of materials, including one of these propellents. The tank will certainly be filled with the vapors of the propellent and it is very likely that essentially no air will be in the tank. Unless the tank is well ventilated or the worker is wearing an air mask (not a gas mask), he will surely suffocate.

In addition to the Underwriters' Laboratories classifications a very useful tool in determining the inhalation toxicity of the vapors of a liquid is to refer to the "Maximum Allowable Concentration" (M.A.C.) published in various references on safety. An excellent source of listings of M.A.C. values are those given by the American Conference of Governmental Industrial Hygienists. These values are expressed as parts per million by volume of gas in air. It should further be explained that M.A.C. values are those levels of vapors which are harmless to humans under conditions of continued daily exposure year in and year out. Thus, they would be levels at which workers could be exposed to these gases throughout their working life time without injury. M.A.C. values are listed in Tables II and III for those compounds where the values have been published and a reasonable degree of accuracy indicated. Values listed in parentheses are extrapolated values. In the cases where this occurs in Table III the values are undoubtedly correct. The reader will note that none of the M.A.C. values listed exceed 1,000 ppm except carbon dioxide. It has been the practice in reporting M.A.C. values that no compound be listed with a value exceeding 1,000. Carbon dioxide is a special case since it is a component of exhaled breath. As might be expected, some discrepancies occur between the Underwriters' Laboratories classifications and the M.A.C. values. From a practical standpoint this is of no importance to the marketing of aerosol products. It is quite unlikely that anyone would consider using a propellent whose M.A.C. value is less than 100. Such a propellent would certainly place it in an Underwriters' Laboratories class of four or less.

In addition to inhalation toxicity, ingestion toxicity is becoming of greater interest to the aerosol field. Food products are already being marketed and many new ones contemplated. Included in Table III is a tabulation of approval by the Food and Drug Administration for the compounds listed. As yet, none of the halogenated compounds have been approved. The hydrocarbons, propane and butane, and the compressed gas propellents, carbon dioxide, nitrous oxide, nitrogen and air have all been approved. While the latter two compounds have not been specifically mentioned in any FDA listing, the writer assumes that there would be no question of their use since these gases normally occur in all food products.

To the writer's knowledge, the only halogenated compound for which FDA approval is being sought is "Freon-C318". The Du Pont Company has submitted data to the Food and Drug Administration covering ingestion toxicity studies with this compound and approval is expected by mid-1960.

The most difficult problem to overcome in obtaining acceptance of the commonly used propellent materials, namely the fluorinated hydrocarbons, is the generation of fluoride ion through hydrolysis on long term storage of aerosol food products with these propellents. While no acceptable tolerance level for fluoride ion has been stated by the Food and Drug Administration, it is almost certain that the generation of more than one or two ppm of fluoride ion per year would be unacceptable. This is an extremely difficult requirement to meet and it is very unlikely that any of the fluorinated hydrocarbons now being used by the aerosol industry could meet this requirement, even though some of them, such as Propellent 114, exhibit very low hydrolysis rates even in the presence of the acidic medium found in some food products.

Little data are available on skin sensitization of the commonly used propellent materials. However, the writer is aware of no cases of skin sensitization caused by propellents despite the tremendous exposure through the use of aerosol personal products. An obvious reason for this lack of data is the inability to conduct such tests because these materials are so volatile. Rabbit-eye tests by the Du Pont Company (Ref. 1a) have shown that the Propellents 12, 11 and 114 cause no reaction. These tests were conducted using a solution of the propellent in mineral oil at atmospheric pressure. Because of the low solubility of the propellents at atmospheric pressure, the concentration of propellent in the test solution was necessarily low. Nonetheless, this would represent realistic conditions.

All of the liquefied propellents are potential refrigerants and as the reader is aware, some of them are widely used as commercial refrigerants. This fact raises an important precaution which should be considered in handling and marketing aerosol products. If a workman or the consumer is sprayed by gross quantities of liquid propellent, freezing of the skin is a definite possibility. This is more often a problem with the workman than with the consumer since the consumer has considerable control of the aerosol as it is applied. Should he tend to spray an excessive quantity of the aerosol on his skin, he would be given adequate warning by the immediate chilling affect. It would certainly be wise, however, for the marketer of personal products to include on the label a warning against excessive spraying, with particular emphasis on spraying in the eyes.

A final problem concerned with the toxicity of aerosol propellents is that arising from the decomposition of the halogenated propellents in an open flame or on exposure to very hot surfaces. Considerable information on this problem can be obtained in Ref. 1. The main products of thermal decomposition from the halogenated propellents are halogen acids, carbon dioxide and traces of phosgene. Phosgene is quickly hydrolyzed to carbon dioxide and hydrochloric acid. The literature indicates that the toxicity of phosgene and the halogen acids are essentially equivalent. Phosgene, probably because it was used as a war gas, has often been stated as the real danger of decomposing halogenated propellents. This is not true. The halogen acids are equally as dangerous and are present in considerably greater quantities. Fortunately, thermal decomposition is not a serious problem. The halogen acids are so irritating that, even at concentrations below any seriously toxic level, a person normally cannot remain in such an atmosphere. For example, should a housewife spray an aerosol insecticide directly into an open gas flame in her kitchen for a sufficient period of time to generate quantities of decomposition products, she would be driven from the room immediately by the irritating effects of the halogen acids. If the reader is interested in exploring this problem in greater detail, he is referred to Ref. 1 and the references contained therein.

In summary, it appears that the commonly used propellent materials present no hazard from inhalation. As a rough guide, those compounds falling in Underwriters' Laboratories classification of 5 and 6 or having M.A.C. values above 500 appear to be perfectly safe to use. Borderline conditions probably occur at Underwriters' Laboratories class 4 and M.A.C. values of 100-500. Any materials rated below these values would undoubtedly be unacceptable. For aerosol products which are to be ingested, it would appear that the formulator is limited to the compressed gases indicated in Table III. The remaining two general areas of toxicity, skin sensitization and thermal decomposition products, do not appear to be serious problems.

Table I

Underwriters' Laboratories Classification	Definition
1	0.5 to 1 vol. % serious injury in 5 minutes
2	0.5 to 1 vol. % serious injury in 30 minutes
3	2 to 2.5 vol. % serious injury in 1 hour
4	2 to 2.5 vol. % serious injury in 2 hours
4-5	Less toxic than 4 and more toxic than 5
5a	Much less toxic than 4 but more toxic than 6
5b	Data indicate classing as 5a or 6
6	20 vol. % no injury in 2 hours

Table II

Compound	Underwriters' Laboratories Classification	Maximum Allowable Concentration
SO_2	1	10 ppm
NH_3	2	100
CCl_4	3	25
CH_3Cl	4	100

Table III

Propellent	Underwriters' Laboratories Classification	Maximum Allowable Concentration	Food and Drug Administration Approval
11, CCl_3F	5a	1,000 ppm	No
12, CCl_2F_2	6	1,000	No
21, $CHCl_2F$	5	1,000	No
22, $CHClF_2$	5a	1,000	No
30, CH_2Cl_2	4-5	500	No
113, $CClF_2CCl_2F$	4-5	(1,000)	No
114, $CClF_2CClF_2$	6	1,000	No
114a, CCl_2FCF_3	6	(1,000)	No
142b, CH_3CClF_2	5a		No
152a, CH_3CHF_2	6		No
160, CH_3CH_2Cl	4-5	1,000	No
1140, $CH_2{=}CHCl$	(6)	500	No
C318, $CF_2CF_2CF_2CF_2$	6	(1,000)	No
CO_2	5a	5,000	Yes
N_2O			(Yes)
N_2	6		(Yes)
Air	6		Yes
Propane	5b	(1,000)	Yes
n-Butane	5b	(1,000)	Yes
i-Butane	5b	(1,000)	Yes

References

1. Fluorinated hydrocarbons: "Freon" Technical Bulletin S-16, E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware.

1a. "Aerosol News", Vol. 1, No. 2, p. 6, 1956, E. I. du Pont de Nemours & Co., Inc., Wilmington, Delaware.

2. Chlorinated hydrocarbons: Aerosol Age, p. 49, February, 1960.

3. Hydrocarbons: Goodhue and Franz, Proceedings, CSMA[3], p. 27, May, 1957.

4. "Freon-C318" Propellent: Blodgett and Webster, Aerosol Age, June, 1959.

5. Nitrous Oxide: ibid

6. Carbon Dioxide: Haase, Aerosol Age, p. 24, July, 1959.

7. Methylene Chloride: Reed, Aerosol Age, p. 27, June, 1956; Keubler, Aerosol Age, p. 49, February, 1960.

8. Vinyl chloride: Keubler, Aerosol Age, p. 49, February, 1960.