AFFIDAVIT

CITY OF CINCINNATI, OHIO, TO WIT:

BEFORE ME, a Notary Public in and for the State of Ohio, personally appeared WILLIAM D. WAGNER, who stated under due oath of law as follows:

I, William D. Wagner, am the Director of Technical Affairs for the Archives of the American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Building D-7, Cincinnati, Ohio 45211. The Archives of the American Conference of Governmental Industrial Hygienists contains a copy of the "Documentation of Threshold Limit Values", 1962 Edition.

The pages attached hereto are true and correct copies of the publication, "Documentation of Threshold Limit Values", 1962 Edition, which is maintained in the Archives of the American Conference of Governmental Industrial Hygienists.

This document is in such condition as to raise no questions concerning its authenticity. It was received by the American Conference of Governmental Industrial Hygienists, and is presently maintained in the Archives Section of the American Conference of Industrial Hygienists, 6500 Glenway Drive, Building D-7, Cincinnati, Ohio 45211.

PLAINTIFF'S EXHIBIT 34-216

DOCUMENTATION OF

THRESHOLD LIMIT VALUES

AMERICAN CONFERENCE OF
GOVERNMENTAL INDUSTRIAL HYGIENISTS

COMMITTEE ON THRESHOLD LIMIT VALUES

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§
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William D. Wagner, Affiant, being first duly sworn, deposes and says:

That the foregoing statements are true.

William D. Wagner

SUBSCRIBED AND SWORN TO BEFORE ME on this the 8th day of October, 1993.

August Anthony Rizzuto
NOTARY PUBLIC

AUGUST ANTHONY RIZZUTO
Notary Public, State of Ohio
My Commission Expires_____

NOTARIAL SEAL
STATE OF OHIO

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1962

PREFACE

The documented evidence appearing in this publication has been taken mainly from technical papers and texts of industrial hygiene and toxicology that have appeared over the years and from the experience and knowledge of committee members. All informational sources are referenced. Occasionally, written communications to the committee members have been used to supplement formally published material, when such information has been substantiated by valid observation. It is this material that has been used in deriving the values given in the table of threshold limits which is published annually by the American Conference of Governmental Industrial Hygienists.

The format is designed to supply in brief the best available technical evidence substantiating the choice of the limiting concentrations. Substances are listed in alphabetical order for ready reference. The evidence on individual substances in this compilation is not necessarily final. The format facilitates the supplementation or modification of existing data, or the addition of information on new substances as it becomes available.

The committee urges careful study and review of this publication and welcomes suggestions or new data that will maintain the usefulness of this publication. Supplements will be published and offered for sale as new information justifies their appearance.

Communications should be addressed to the Chairman of the committee, Dr. H.E. Stokinger, or to the Secretary-Treasurer of the ACGIH. 1014 Broadway, Cincinnati 2, Ohio.

ACETALDEHYDE

200 ppm (Approximately 360 mg/m^3)

Iwanoff (1) stated that cats inhaling 280 ppm, even after seven hours, show no noticeable effect; if the dose is increased fourfold, temporary irritation of the air passages is observed. On this basis, Cook (2) suggested a maximal allowable concentration of 200 ppm.

The unacclimated subjects of Silverman, Schulte, and First (3) experienced some eye irritation at 50 ppm, but were willing to work an eight hour day in 200 ppm of acetaldehyde.

Fairhall (4) describes the effects as irritation, narcosis, bronchitis, albuminuria, fatty liver and lung edema. He concludes that inhalation does not cause chronic poisoning, and that death is due to anesthesia when prompt, or to lung edema when delayed.

Smyth (5) found rats survive four hours inhalation of 8000 ppm, but die from 16,000 ppm. The liquid causes severe corneal injury, irritates the skin, and may sensitize some persons.

References
1. Iwanoff, N.: Arch. fur Hyg. 73, 338 (1911).
2. Cook, W.: Ind. Med. 14, 938 (1945).
3. Silverman, L., Schulte, H. F., & First, M.W.: J. Ind. Hyg. & Tox. 28, 265 (1946).
4. Fairhall, L.T.: Industrial Toxicology, Williams & Wilkins, Baltimore, Md. (1949) p. 198.
5. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 136 (1956).

ACETIC ACID

10 ppm (Approximately 25 mg/m^3)

Sterner (1) concludes that 10 ppm is relatively non-irritating on the basis of industrial experience.

Patty (2) reports that 800-1200 ppm cannot be tolerated for longer than 3 minutes.

Smyth (3) found inhalation of 16,000 ppm by rats killed one of six.

Vigliani & Zurlo (4) report workers exposed 7 to 12 years to concentrations of 60 ppm, with one hour daily at 100 to 260 ppm, had no injury except slight irritation of the respiratory tract, stomach and skin. They regard 20 to 30 ppm to be without danger.

References
1. Sterner, J. H.: Ind. Med. 12, 518 (1943).
2. Patty, F. A.: Industrial Hygiene & Toxicology, Interscience Publications, N.Y. (1949), Vol. II, p. 886.
3. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 143 (1956).
4. Vigliani, E. C. & Zurlo, N.: Arch. Gewerbepath Gewerbehyg 13, 528-535 (1955). Abstracted in Arch. Ind. Health 13, 403 (1956).

ACETIC ANHYDRIDE

5 ppm (Approximately 20 mg/m3)

Henderson & Haggard (1) mention eye, nose and throat irritation and suggest that bronchial and lung injury are likely to occur from inhalation to acetic anhydride vapors.

Fairhall (2) considers acetic anhydride a marked lacrimator and finds systemic effects unlikely.

McLaughlin (3) discusses serious corneal injury from the liquid in industry.

Smyth (4) found rats inhaling 1000 ppm for four hours survived, but 2000 ppm was fatal. The liquid causes skin burns.

The value of 5 ppm was recommended by analogy with acetic acid.

References
1. Henderson, Y. & Haggard, H.W.: Noxious Gases, Reinhold Publishing Co., N.Y. (1943) p. 129.
2. Fairhall, L.T.: Industrial Toxicology, Williams & Wilkins, Baltimore, Md. (1949) p. 203.
3. McLaughlin, R.S.: Am. J. Ophthal. 29, 1360 (1946).
4. Smyth, H. F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 143 (1956).

ACETONE

1000 ppm (Approximately 2400 mg/m3)

Nelson, et al. (1) state that acetone produced slight irritation at 300 parts per million, but 500 ppm was still tolerated by most subjects.

Henderson & Haggard (2) conclude death is anesthetic with no organic injury below a narcotic level.

Lehmann & Flury (3) report a fatal acetone poisoning in a 12-year old child who wore a damp acetone dressing; and Fairhall (4) states that absorption of acetone vapors by workers has been definitely demonstrated by finding the substance in the urine of individuals so exposed.

Haggard, et al. (5) presume that from industrial experience and from the occurrence of acetone as one of the products of bodily metabolism, that the substance is without chronic effects.

Vigliani & Zurlo (6) found chronic respiratory tract irritation and dizziness in workers inhaling 1000 ppm three hours a day.

References
1. Nelson, K.W., Ege, J.F., Jr., Norwick, R., Woodman, L.E. & Silverman, L.: J. Ind. Hyg. & Tox. 25, 284 (1943).
2. Henderson & Haggard, H.W.: Noxious Gases, Reinhold Publishing Co., N.Y. (1943), p. 196.
3. Lehmann, K.B. & Flury, F.: Toxicology & Hygiene of Industrial Solvents, Williams & Wilkins, Baltimore, Md., (1943), p. 245.
4. Fairhall, L.T.: Industrial Toxicology, Williams & Wilkins, Baltimore, Md., (1949), p. 205.

5. Haggard, H.W., Greenburg, L.A. & Turner, J.M.: J. Ind. Hyg. & Tox. 26, 150 (1944).
6. Vigliani, E.C. & Zurlo, N. - thru abst. Arch. Ind. Health 13, 403 (1956).
7. Oglesby, F.L.: Presented at Industrial Health Conference, Detroit (1949). Unpublished.

ACETYLENE TETRABROMIDE

1 ppm (Approximately 14 mg/m^3)

Groups of rats, guinea pigs, rabbits, mice and monkeys were given repeated exposures, 7 hours a day, 5 days a week to vapor concentrations of 5 and 1 ppm of acetylene tetrabromide for periods of 6 to 6½ months. As judged by growth, mortality and gross pathological examination, 5 ppm was without adverse effect on rats, rabbits, mice and female guinea pigs. The growth of the male guinea pigs was moderately depressed and there was questionably significant increase in average kidney weight. The average liver and kidney weight of the rats was increased slightly. Histopathological examination revealed slight fatty degeneration in the parenchymal cells of the liver and slight cloudy swelling of the convoluted tubules of the kidneys.

As judged by growth, mortality, gross appearance and behavior, final body and organ weight studies, and gross and microscopic examination of the tissues, repeated exposure to vapor concentrations of 1 ppm acetylene tetrabromide was without adverse effect on rats, rabbits, mice, monkeys and guinea pigs (1).

Reference

1. Unpublished data, Biochemical Research Lab., Dow Chemical Co., Midland, Michigan.

ACROLEIN

0.5 ppm (Approximately 1.2 mg/m^3)

Iwanoff (1), studying the effect of inhalation of formaldehyde, acetaldehyde, and acrolein on cats found the last named to be the most severe. Exposure to approximately 10 ppm for 3½ hours caused respiratory irritation, salivation, lacrimation and mild narcosis. Animals, however, returned to normal in a few hours.

Cook (2) reports that Yant, Schrenk, Patty and Sayers found that 1 ppm of acrolein produces marked irritation of eyes and nose in five minutes or less, so suggests a tentative value of half of this for prolonged exposure.

Patty (3) concludes that 0.25 ppm is moderately irritating and suggests Cook's value of 0.5 ppm as a practical working level.

Henderson & Haggard (4) conclude that the main attack is on the upper respiratory tract, but that a high concentration can cause lung edema. They tabulate the following:

Physiological Response

	PPM Acrolein
Immediately detectable	1.0
Intense irritation	5.5
Lethal in a short time	10.0 and over
Unbearable	24.0

Smyth (5) found 4 hours of inhalation of 8 ppm kills one of six rats and all died from 16 ppm. The liquid causes severe corneal injury and burns of the skin.

References
1. Iwanoff, N.: Arch. fur Hyg. 73, 339 (1911).
2. Cook, W.: Ind. Med. 14, 938 (1945).
3. Patty, F.A.: Industrial Hygiene & Toxicology, Interscience Publications, N.Y. (1949) Vol. II, p. 936.
4. Henderson, Y. & Haggard, H.W.: Noxious Gases, Reinhold Publishing Co., N.Y. (1943) p. 138.
5. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 144 (1956).

ACRYLONITRILE

20 ppm (Approximately 45 mg/m3)

Dudley, Sweeney and Miller (1) found repeated inhalation of 153 ppm injurious to animals but believed that the effect was not chronic intoxication. Dudley and Neal (2) concluded that injury is due to formation of cyanide in the body. The 10 ppm hydrogen cyanide threshold limit is equivalent to 20 ppm if conversion is complete.

Brieger, Rieders and Hodes (3) reported that single 7-hour exposures to 75 ppm resulted in some deaths in dogs and monkeys, but none in rats.

The most important effect of acrylonitrile inhalation is acute poisoning due to hydrolysis to cyanide in the body. The 20 ppm threshold limit was derived from repeated animal inhalation studies and its relation to the accepted 10 ppm limit for hydrogen cyanide.

References
1. Dudley, H.C., Sweeney, T.R., and Miller, J.W.: J. Ind. Hyg. and Tox. 24, 225 (1942).
2. Dudley, H.C. and Neal, P.A.: J. Ind. Hyg. and Tox. 24, 27 (1942).
3. Brieger, H., Rieders, F., and Hodes, W.A.: Arch. Ind. Hyg. & Occ. Med. 6, 128 (1952).

ALDRIN

(1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-dimethanonaphthalene)

0.25 mg/m3)

The inhalation toxicities of DDT and lindane have been well documented. Because the mode of action and effect of aldrin is similar to these chlorinated hydrocarbons, it is acceptable procedure to develop a threshold limit by analogy in the absence of specific information on the latter. McGee (1) states that aldrin and lindane have similar actions in man.

The acute oral LD_{50} of DDT is 250 mg/kg, that of lindane 125, and that of aldrin 60 mg/kg. The threshold limit value of the first two would seem to be reasonably set at 1 and 0.5 respectively. Aldrin on this basis would be 0.25.

Princi and Spurbeck (2) found no ill effects in workmen exposed to an average of 5 mg/m3 of aldrin and chlordane for three years.

References
1. McGee, L.C.: Ind. Med. & Surg. 24, 101 (1955).
2. Princi, F., Spurbeck, G.H.: Arch. Ind. Hyg. & Occup. Med. 3, 64 (1951).

ALLYL ALCOHOL (PROPENE-1-01-3)

2 ppm (Approximately 5 mg/m3)

Although allyl alcohol is moderately to highly toxic for animals by inhalation, 1-hour survival and lethal levels being 500 and 10000 ppm respectively (1), the most important effect relating to its threshold limit is irritation. Severe eye irritation results from exposure to 25 ppm according to Hine, et al. (2); according to McCord (3), 5 ppm is slightly irritating to some individuals. Corneal necrosis has been reported (4) to result in temporary blindness in a man exposed to levels irritating to the eyes and nose. Sensory threshold studies indicate recognition of allyl alcohol by most individuals at about 0.8 ppm (2). Occasional exposure of individuals to allyl alcohol for a number of years resulted in no adverse medical findings, indicating no chronic or cumulative toxicity from this substance. Skin penetration may lead to serious systemic injury (visceral congestion, periportal congestion of the liver, hematuria and nephritis) and skin contact causes burns when evaporation is prevented or reduced.

The lacrimatory effects of allyl alcohol are characteristic in that it produces syndrome of lacrimation, photophobia, blurred vision, and retrobulbar pain (2). Although these symptoms persist for some hours following exposure, neither increased sensitivity nor tolerance appear to develop. There is no evidence also of histamine release following allyl alcohol exposure (5).

Torkelson, Wolt, Oyen, and Rowe (6), have suggested an over-all time-weighted average for daily 7-to 8-hour exposures of 2 ppm, and that practically all fluctuations be maintained below 5 ppm. These observations were based on repeated allyl alcohol vapor exposures of dogs, rats, rabbits, and guinea pigs for 5 weeks to 6 months for 7 hours daily at levels of 2 and 7 ppm of the vapor.

The threshold limit of 2 ppm would appear to provide protection against systemic effects and injury to superficial areas of the body, and to provide a reasonable freedom for most individuals from irritation.

References
1. Smyth, H.F., Jr., Carpenter, C.P.: J. Ind. Hyg. & Tox. 30, 63 (1948).
2. Dunlap, M.K., Kodama, J.K., Wellington, J.E., Anderson, H.H., Hine, C.H.: Arch. Ind. Health 18, 303, (1958).
3. McCord, C.P.: J. Am. Med. Assn. 98, 2289 (1932).
4. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).
5. Kodama, J.K., Hine, C.H.: J. Pharm. Exptl. Therap. 124, 97 (1958).
6. Torkelson, T.R., Wolf, M.A., Oyen, F., Rowe, V.K.: Am. Ind. Hyg. Assn. Quart. 20, 224 (1959).

ALLYL CHLORIDE

5 ppm (Approximately 15 mg/m3)

Repeated daily vapor exposures of this compound to small laboratory animals in concentrations from 1-100 mg/l (322-32,200 ppm) by Adams, Spencer and Irish (1) resulted in the conclusion that allyl chloride was the most toxic of the halogenated aliphatic hydrocarbons yet tested. Irritation to the mucous membranes occurred after a few minutes exposure at 10 mg/l. The narcotic action was very weak.

Histologic lesions were observed at the higher levels in the lungs and kidneys, with only slight changes in the liver. Animals surviving exposures appeared to recover without sequelae. Silverman, et al. (2) similarly observed irritative effects of this compound and set the highest tolerated concentration at 0.5 mg/l (12,000 ppm) and the minimal fatal dose at 3 mg/l. Comparison in animals showed allyl chloride far less irritating, however, than acrolein (3), whose threshold limit is 0.5 ppm. Similarly allyl chloride was far less irritating by the oral cutaneous and percutaneous routes than acrolein. Elkins (4) has suggested a tentative threshold limit of 5 ppm for allyl chloride which would appear on present information to be a reasonable level.

References
1. Adams, E.M., Spencer, H.C., Irish, D.D.: J. Ind. Hyg. & Tox. 22, 79 (1940).
2. Silverman, M., Abreu, B.E.: Univ. Cal. Publ. Pharm. 1, 119 (1938).
3. Silverman, M., Abreu, B.E.: Unpublished data.
4. Elkins, H.B.: Chemistry of Industrial Toxicology, Wiley & Sons, N.Y. (1950).

ALLYL PROPYL DISULFIDE

2 ppm (Approximately 12 mg/m^3)

Concentrations of allyl propyl disulfide were measured in an onion dehydrating plant and results reported by Feiner, Burke and Baliff (1). Irritation to the eyes, nose and throat occurred at various operations evolving onion oil, but were most pronounced near the slicing machine where an average concentration of 3.4 parts per million was found. The authors suggest a tentative value of 2-3 parts per million.

Reference
1. Feiner, B., Burke, W.J. and Baliff, J.: Ind. Hyg. & Tox. 28, 278 (1946).

ALUMINUM OXIDE

50 mppcf

Aluminum oxide (Al_2O_3) or alumina, exists in a number of natural and synthetic forms. Examples include (a) naturally occurring α-alumina; (b) α-alumina produced by heating hydrated alumina or α-alumina above 1250°C; (c) α-alumina, which is of different crystalline structure, produced by heating hydrated aluminas such as Gibbsite (hydrargillite) to 900-1000°C. Alundum (R) is a trade name for fused alumina refractories and abrasives, which usually contain from 95 to 99% Al_2O_3 (α-alumina) with 1.0 to 1.5 percent SiO_2.

Animal injection studies by Miller and Sayers (1) showed that α-alumina well below 40μ in particle diameter and in the form of Alundum gave an inert reaction. Stacy, King, Harrison, Nagelschmidt, and Nelson (2) found α-alumina almost inert when injected into the lungs of rats, but α-alumina at a particle size of 2μ was highly fibrogenic.

There are no clinical studies implicating aluminum oxide as a cause of pneumoconiosis in man, and the threshold limit is at the level of an inert or nuisance dust. Smith and Perina (3) reported 7 radiographs suggesting nodular silicosis among 53 individuals engaged in the manufacture of abrasive wheels made of silicon carbide and aluminum oxide. Of fifteen dust counts, 14 were in the range 26 to 212 million particles per cubic foot. Meiklejohn and Posner (4) studied films and

records of 99 china workers exposed to alumina used as placing material in firing of pottery and found no evidence of pneumoconiosis in the 87 exposed exclusively to alumina. This had been substituted for flint by regulation in 1947, following preliminary observations on lack of hazard by Sutherland, et al. (5).

The precise relation of aluminum oxide inhaled concurrently with silica fumes, in the production of pulmonary disease, (e.g., Shaver's disease) is still incompletely understood (6,7).

References
1. Miller, J.W., Sayers, R.R.: Pub. Health Rept. 56, 264, (1941).
2. Stacy, B.D., King, E.J., Harrison C.V., Nagelschmidt, G., Nelson, S.: J. Path. & Bact. 77, 417, (1959); Abstr. Bull. Hyg. 34, 907 (1959).
3. Smith, Adelaide, R., Perina, A.E.: Occ. Med. 5, 396 (1948). Abstr. Pneumoconiosis Abstracts, Vol. II, 1939-50, p. 267.
4. Meiklejohn, A., Posner, E.: Brit. J. Ind. Med. 14, 229, (1957); Abstr. Bull. Hyg. 33, 136 (1958).
5. Sutherland, C.L., Meiklejohn, A.; Price, F. N. R.: J. Ind. Hyg. & Tox. 19, 312 (1937). Abstr. Pneumoconiosis Abstracts Vol. 1, 1926-1938, p. 172.
6. Shaver, C.G., Riddell, A.R.: J. Ind. Hyg. & Tox. 29, 145 (1947).
7. Hatch, T.F.: Shaver's Disease, Summary, Chapter 32, pp. 498-503 in Pneumoconiosis (Sixth Saranac Symposium), Paul B. Heober, Inc., N.Y. (1950).

AMMATE (AMMONIUM SULFAMATE)

15 mg/kg

Ammate has an acute oral LD_{50} of 3900 mg/kg for rats (1). It is thus improbable that acute or chronic poisoning can result from exposure to it under ordinary conditions of use.

The threshold limit value of 15 is assigned by analogy in the absence of inhalation toxicity data, and because several years of extensive use have apparently caused no illness.

Reference
1. Lehman, A.D.: Q. Bull. Assoc. F. & D. Off. 15, 122 (1951).

AMMONIA

100 ppm (Approximately 70 mg/m^3)

Cook (1) states that the authority for 100 ppm goes back to K.B. Lehmann in Arch.F. Hyg. 5, 68 (1886) and this value is currently accepted.

Henderson and Haggard (2) record temporary blindness and intolerable respiratory irritation from high concentrations. They record the following physiological response values:

Physiological Response

	PPM Ammonia
Least detectable odor	53
Least amount causing immediate irritation of the throat	408
Least amount causing irritation of the eyes	698
Least amount causing coughing	1,720

Physiological Response - Cont'd.

	PPM Ammonia
Maximum concentration allowable for prolonged exposure	85 to 100
Maximum concentration allowable for short exposure (½ to 1 hour)	50 to 100
	300 to 500
Dangerous for even short exposure (½ hour)	2,500 to 6,500
Rapidly fatal for short exposure	5,000 to 10,000

Smyth (3), however, found 1 ppm detected and identified by 10 subjects.

Fairhall (4) notes eye and upper respiratory tract irritation, salivation, bronchial irritation, and lung edema, but no chronic systemic effect.

Elkins (5) found concentrations of 125 ppm irritating but 55 ppm not objectionable.

Silverman, et al. (6) found 500 ppm stimulated human respiration, irritated eye and throat, caused lacrimation; hence concluded that this concentration was undesirable and that the present accepted limit of 100 ppm is probably safe, but needs reexamination.

Vigliani & Zurlo (7) in workers inhaling 100 ppm found irritation of the respiratory tract and conjunctivae. Even 20 ppm in those not accustomed, caused complaint of irritation and discomfort.

References

1. Cook, W.A.: Ind. Med. 14, 936 (1945).
2. Henderson, Y. & Haggard, H.W.: Noxious Gases, Reinhold Publishing Co., N.Y. (1943), p. 126.
3. Smyth, H.F., Jr.: Am. Ind. Hyg. Quart. 17, 145 (1956).
4. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins, Baltimore, Md. (1949), p. 20.
5. Elkins, H.B.: Chemistry of Industrial Toxicology, Wiley & Sons, N.Y. (1959), p. 86.
6. Silverman, L., Whittenburger, J.L. & Muller, J.: J. Ind. Hyg. & Tox. 31, 78 (1949).
7. Vigliani, E. C. & Zurlo, N. - thru abst. Arch. Ind. Health 13, 403 (1956).

AMYL ACETATE

200 ppm (Approximately 1050 mg/m^3)

Patty, et al. (1) found that 2000 ppm does not injure guinea pigs in several hours, while at room temperature it was not possible to attain a fatal concentration in 30 to 60 minutes. Symptoms consisted of eye and nose irritation and narcosis.

Nelson, et al. (2) record slight throat discomfort at 100 ppm, and mild eye and nose effects with severe throat irritation at 200 ppm, the objectionable concentration.

Smyth (3) with rats inhaling substantially saturated vapors, reported anesthesia in two hours and death in eight hours. Chronic toxicity is not to be expected.

References
1. Patty, F.A., Yant, W.P., and Schrenk, H.H.: Pub. Health Rept. 51, 815 (1936).
2. Nelson, K.W., Ege, J.F., Jr., Morwick, R., Woodman, L.E., and Silverman, L.: J. Ind. Hyg. & Tox. 25, 284 (1943).
3. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 145 (1956).

AMYL ALCOHOL (ISO AMYL ALCOHOL)

100 ppm (Approximately 360 mg/m^3)

Nelson, et al. (1) reported a light throat irritation in unacclimated subjects at 100 ppm and objectionable eye, nose and throat irritation at higher concentrations.

Haggard, Miller and Greenburg (2) found the toxicity to be twelve times that of ethyl alcohol for anesthetic death. No chronic toxicity is to be expected.

Smyth (3) states that "the most important effect of amyl alcohol inhalation is narcosis. The 100 ppm threshold limit can be interpreted from human sensory data and analogy with butyl alcohol. It is low enough to prevent significant narcosis, but not to prevent slight irritation."

References
1. Nelson, K.W., et al: J. Ind. Hyg. & Tox. 25, 282 (1943).
2. Haggard, H.W., Miller, D.P., and Greenburg, L.A.: J. Ind. Hyg. & Tox. 27, 1-14 (1945).
3. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 145 (1956).

ANILINE

5 ppm (Approximately 19 mg/m^3)

Henderson and Haggard (1) cite data suggesting that 7 to 53 ppm of aniline vapor cause slight symptoms after several hours exposure; 100 to 160 ppm was believed to be the maximal concentration that could be inhaled for 1 hour without serious disturbance. Aniline poisoning is characterized by formation of methemoglobin, probably caused by a metabolite such as p-aminophenol.

Oberst, Hackley, and Comstock (2) exposed experimental animals (dogs, rats, mice, and guinea pigs) to aniline vapor at 5 ppm for 6 months and found no effects of exposure other than a slight methemoglobinemia in rats.

References
1. Henderson, Y., and Haggard, H.W.: Noxious Gases, 2nd. Rev., Ed. (1943), Reinhold Publishing Co., N.Y., pp. 225-228.
2. Oberst, F.W., Hackley, E.B., Comstock, C.C.: Arch. Ind. Health, 13, 379 (1956).

ANTIMONY

0.5 mg/m^3

According to Fairhall (1) the hygienic significance of antimony in industry is related both to the solubility of antimony and its compounds and their rate of elimination from the body. The relative order of toxicity intraperitoneally of antimony compounds of industrial interest, beginning with the most toxic, is metallic antimony, antimony trisulfide, antimony pentasulfide, antimony trioxide and antimony pentoxide. Toxicity by inhalation is greater than that by other routes. The most important effects of inhalation are chronic poisoning.

Brieger and Associates (2) found that rats and rabbits exposed to antimony trisulfide in a concentration of from 3.07 to 5.6 mg/m^3 for six weeks developed definite and consistent functional disorders of the heart, and parenchymatous degeneration of the myocardium. These results were taken to correspond with observations made on workers exposed at these concentrations over periods of from eight months to two years, in which abnormalities in blood pressure, electrocardiographic changes and deaths from chronic thrombosis occurred. On the basis of physical examinations of workers, atmospheric determination of antimony trisulfide concentrations and animal experimentation, it was concluded that the threshold limit value of 0.5 milligrams antimony/m^3 of air appeared reasonable.

Renes (3) reported 69 cases of illness developing among workers exposed to fumes of antimony, arsenic and caustic soda during 5 months operation of an antimony smelter in which antimony was the predominating contaminant. Antimony concentrations ranged from 4.69 to 11.81 mg/m^3.

No reports have appeared confirming the reasonableness of the choice of 0.5 mg/m^3 as a threshold limit for antimony.

References
1. Fairhall, L.T., Hyslop, F.: Pub. Health Rept. Suppl. No. 195, (1947).
2. Brieger, H., Semisch, C.W., Stasney, J., Pietnek, D.A.: Ind. Med. & Surg. 23, 521 (1954).
3. Renes, L.: Arch. Ind. Hyg. & Occup. Med. 7, 99 (1953).

ANTU (Alpha-Naphthyl-Thiourea)

0.3 mg/m^3

McClosky, et al. (1) report that the acute oral toxicity of ANTU varies greatly among different species, rats and dogs being the most susceptible (LD_{50}, 30-50 mg/kg) and rabbits the least (1000 mg/kg). Later studies showed an acute oral LD_{50} for monkeys of 4,250 mg/kg. The acute toxicity of ANTU for man is believed to lie somewhere between these extremes. Evaluation of the toxicity data for threshold limit recommendation is further complicated by the cumulative action of ANTU on the endocrine systems (thyroids and adrenals) leading to hypothyroidism upon repeated exposure, whereas a tolerance to certain of the acute effects of ANTU (pulmonary effusion) likewise occur. No information on either acute or chronic toxicity of ANTU has been reported.

The threshold limit of 0.3 mg/m^3 is believed to be sufficiently low to protect against adverse effects on health.

Reference
1. McClosky, W.T., Smith, M.I., Lillie, R.D.: Pub. Health Rept. 60, 1101 (1945).

ARSENIC

0.5 mg/m^3

The former threshold limit of 0.15 mgAs/m^3 air for metallic arsenic and arsenic trioxide was based on analogy with other metals, such as cadmium and lead in establishing the American War Standards by the American Standards Association (1). Subsequent industrial experience of one smelting and refining company (2) indicated that 0.5 mg/m^3 was a satisfactory operating limit. Operation under this limit appears not to have resulted in acute or chronic toxicity. Whether it is sufficiently low to prevent cancer during a working lifetime is unknown.

References
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2. Pinto, S.S.: Communication to Committee Member (1961).

ARSINE

0.05 ppm (Approximately 0.2 mg/m^3)

The extreme, acute toxicity of arsine is well known; 250 ppm for 30 minutes is fatal to man and 3-10 ppm can cause poisoning symptoms in a few hours (1). Nau (2) reported the conditions of an arsine exposure that indicated the previous limit of 1 ppm was too high. Elkins (3) reported a case of severe, but nonfatal, arsine poisoning that resulted from an exposure averaging 0.5 ppm. Elkins has concluded that 0.05 ppm arsine is not an unreasonable low limit on the basis of a study of chronic arsine exposures of Bulmer, et al. (4). Urinary As varied from 0.7 to 4 mg. in men showing toxic signs of exposure of jaundice and anemia. Assuming 75% of the As is excreted in the urine 1 mg. As/l corresponds to 1.33 mg. intake, or 0.133 mg. As/m^3 air if 10 m^3 air is taken as the average amount of tidal air inhaled during a working day. This corresponds to 0.033 ppm arsine, and supports the recommended limit of 0.05 ppm arsine.

References
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ASBESTOS

5 mppcf

Asbestos is a generic term applying to a number of mineral silicates that are incombustible in air and can be separated into filaments. The most widely used in industry is chrysotile, a magnesium silicate from serpentine. Other types include amosite (an iron magnesium silicate) crocidolite (a sodium iron silicate), tremolite (a calcium magnesium silicate) and anthophyllite (also an iron magnesium silicate).

Miller and Sayers (1) showed that intraperitoneal injection of amosite, chrysotile and crocidolite in guinea pigs produced the reaction of an inert dust. Vorwald et al. (2) confirmed this for short fibers (under 3μ) but observed that long fibers produced a fibrous reaction. Continuing unpublished work by Gardner, these workers demonstrated that long fibers (20 microns and above) produced peribronchiolar fibrosis in lower animals, and developed evidence that this resulted from mechanical rather than chemical action. Asbestos dust containing 0.6 per cent fibers longer than 10 microns, in concentrations of 138 mppcf (or 0.8 million "long" fibers per c.f.), was capable of producing experimental asbestosis in guinea pigs. When the concentration was 6.7 per cent fibers over 10 microns, 40 mppcf, (equivalent to 2.7 million "long" fibers per c.f.), the reaction developed in approximately half the time.

That exposure to asbestos is associated with development of a potentially disabling pneumoconiosis in man has been amply demonstrated by industrial experience (3,4,5,6,7,8,9,10,11). The present threshold limit relates to the prevention of asbestosis. It was recommended by Dreessen et al. (8), after study of 541 employees in three asbestos textile plants using chrysotile. Only three

doubtful cases of pneumoconiosis were found in those exposed to dust concentrations under 5 mppcf, whereas numerous well-marked cases were found above 5 mppcf. Counts were from impinger-collected samples in ethyl alcohol and distilled water. Both fibrous and non-fibrous particles were counted, but the latter greatly predominated. While chemical analyses of collected samples of airborne dust corresponded to those of settled dust samples, it is believed that dust counts of particulates by conventional methods can be expected to give only an indirect measure of the risk of asbestosis because of the great relative importance of long fibers.

References
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3. Merewether, E.R.A.: J. Ind. Hyg. 12, 198, 239 (1930). Pneumoconiosis Abstracts, 1926-1938, Vol. I, p. 128.
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5. Fulton, W.B., Dooley, A., Matthews, J. L., Houtz, R.L.: Penn. Dept. Labor and Ind. Bull. 42 (1935).
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BARIUM (and Compounds)

0.5 mg/m^3

The clinical entity "baritosis" has been reported in the industrial hygiene literature sporadically since 1934 when Leschke (1) described a case with almost fatal outcome in a baryta worker who had apparently inhaled ample quantities. Other reports of industrial exposure to barium compounds with or without exposure to lithopone have described pulmonary nodulation with or without decrease in lung function, such as dyspnea on exertion (2,3). More soluble forms of barium, as the carbonate, oxide and nitrate, tend to be more injurious, particularly acutely. Dusts of barium oxide are considered potential agents of dermal and nasal irritation (4).

The pharmacologic action of barium is well known (5); chief among the actions of barium is its effect on muscle, particularly cardiac, increasing its excitability. Skeletal, arterial, intestinal, and bronchial muscle are all affected by barium. In addition, effects on the hematopoietic system have been noted, as well as on the cerebral cortex.

Fazekas, et al. (6) have reported that subcutaneous injection of an aqueous solution of barium chloride at a dosage of 5 mg/kg caused acute toxicity with death after 2-2.5 hours. Chronic poisoning was achieved by the injection of solutions at 10, 5, and 2 mg/kg. Rabbits in this series were killed at 98 to 193 days. Effects on the central nervous system are described.

The present limit of 0.5 mg Ba/m^3 air was suggested by Hyatt (7), who employed this limit for a number of years at the Los Alamos Laboratories with satisfactory results for the control of exposure to barium nitrate. It is not known what degree of added safety this limit incorporates.

References
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3. Gombos, B.: Pracovni Lekarstvi 9, 399, (1957).
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BENZENE

25 ppm (Approximately 80 mg/m^3)

Winslow (1) first proposed a limit of 100 ppm based on extensive examination of exposed workmen and animal inhalation. After emphasizing marked loss in weight and damage to blood forming organs caused by a higher concentration (460 ppm) he recognized that chronic poisoning would develop even at the 100 ppm level but believed it would progress slowly enough to be detected by periodic medical examinations, and arrested by removal from exposure.

The effect of acute benzene poisoning is anesthesia, and chronic poisoning is characterized primarily by injury to the bone marrow. Benzene is particularly insidious because its effects can progress to a fatal outcome after all exposure ceases Smyth (2).

Patty (3) states that 100 ppm has only a faint odor.

Elkins (4) states that more than 140 fatal cases of benzene poisoning have been recorded, several from exposures around 100 ppm or even less, and attributes the decline since 1940 primarily to its replacement by safer solvents in many industries.

The threshold limit value for benzene is recorded as 100 ppm in the 1946 proceedings of the A.C.G.I.H. Since then the value has been successively reduced to 50 ppm, 35 ppm and is currently 25 ppm (5).

References
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2. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 145 (1956).
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4. Elkins, H.B.: Chemistry of Industrial Toxicology, Wiley, N.Y. (1959) p. 103.
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BENZYL CHLORIDE

1 ppm (Approximately 5 mg/m^3)

Flury & Zernik (1) conclude that 170 ppm is dangerous to cats in eight hours and 16 ppm intolerable to man in one minute.

Smyth (2) comments: "This is a potent lacrimator irritating to eye, nose and throat and capable of causing lung edema ..... It may be inferred that the liquid causes severe corneal injury ..... The 1 ppm threshold limit can be derived from older human sensory data. It is undoubtedly low enough to prevent lung injury".

References
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2. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 147 (1956).

BERYLLIUM

0.002 mg/m^3

The value of 2μg Be/m^3 air was adopted as an hygienic air standard by the Atomic Energy Commission following the suggestion of Eisenbud, et al. (1). It was a tentative limit that has been retained for more than a decade. Recent review of past industrial experience in Atomic Energy-operated plants has indicated that the limit may be exceeded by 2- or 3- fold without cases of either acute or chronic disease appearing at least within 10 to 12 years. At the present time, this cannot be interpreted to mean that 2μg Be/m^3 has an associated safety factor of 2- to 3-fold, because cases of chronic beryllium poisoning have developed extremely remote in time from the original exposure. The probability of cases arising under these conditions, however, is fast being reduced. Because beryllium and most of its compounds, except beryl ore ($Be_3Al_2Si_6O_{18}$) are capable of producing severe occupational disease with a high morbidity and mortality rate, and has been shown by Vorwald (2) to be capable of producing metastatic tumors in the rat, the present limit is retained.

References
1. Sterner, J.H., Eisenbud, M.: Arch. Ind. Hyg. & Occup. Med. 4, 123 (1951).
2. Vorwald, A.J.: (Unpublished) 7th Saranac Symposium (1952); Vorwald, A.J.: Acta Union Intl. contre le cancer 15, No. 3-4 (1959).

BORON TRIFLUORIDE

1 ppm (Approximately 3 mg/m^3)

Boron trifluoride (BF_3) is a severe pulmonary irritant leading to pneumonia in animals upon repeated exposure according to Stokinger and coworkers (1). Exposure to levels of 100 ppm resulted in a uniformly high mortality rate in 6 laboratory species and 15 ppm was occasionally fatal in 30-day studies. On the basis of these preliminary studies, a tentative limit of 1 ppm was set. Moreover, it had been assumed that boron trifluoride hydrolyzes rapidly and almost completely in air to hydrogen fluoride and the relatively nontoxic boric acid. Since 1 ppm of boron trifluoride would release 3 ppm (the threshold limit value) of hydrogen fluoride, the 1 ppm value seemed an appropriate standard for boron trifluoride.

Recent toxicologic studies of boron trifluoride by Torkelson, et al. (2) show that boron trifluoride does not hydrolyze so rapidly or completely as had been presumed, but is toxic per se. Rats, rabbits, and guinea pigs were exposed 5 days a week for months to boron trifluoride at concentrations of 12.8, 3-4 and 1.5 ppm. Chronic toxicity involved pneumonitis and dental fluorosis. At the lowest value, there was only marginal evidence of pneumonitis. Thus, while the original basis for the threshold limit value of 1 ppm appears not to be valid, the value nevertheless appears adequate, though possibly with little margin of safety. Torkelson, et al. have suggested a limit of 0.3 ppm or below.

References
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2. Torkelson, T.R., Sadek, S.E., Rowe, V.K.: Am. Ind. Hyg. Assn. J. 22, 263 (1961).

BROMINE

0.1 ppm (Approximately 0.7 mg/m^3)

Flury & Zernik (1) quote Lehmann that 0.75 ppm in a workroom caused no symptoms in six hours.

Henderson & Haggard (2) report the physiological response to various concentrations as follows:

Maximal concentration allowable for prolonged exposure	0.1 to 0.15	ppm
Maximal concentration allowable for short (½ - 1 hour) exposure.	4	ppm
Dangerous for short exposure.	40 to 60	ppm
Rapidly fatal " "	1000	ppm

and notes that is a respiratory irritant leading to lung edema.

Patty (3) discusses the safe concentrations of bromine vapor in air, states that Hess noted some effects from 0.15 ppm after several hours, and reports that a detectable odor occurs at about a 3.5 ppm value.

The ACGIH (4) in 1959, after a careful review of the data on this element, reduced the threshold limit value of bromine vapor from 1 ppm to 0.1 ppm.

References

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2. Henderson, Y. & Haggard, H.W.: Noxious Gases, Reinhold Publishing Co., N.Y. (1943), p. 133.
3. Patty, F.A.: Industrial Hygiene and Toxicology, Interscience Publications, N.Y. (1949), p. 554.
4. Transaction of the 21st Annual Meeting of the A.C.G.I.H., (April, 1959), p. 94.

BUTADIENE (1,3-BUTADIENE)

1000 ppm (Approximately 2200 mg/m^3)

Butadiene produces only very slight responses in man and animals; concentrations of 600, 2300 and 6700 ppm for an 8-month period of 6 days per week, 7.5 hrs. per day, caused no significant or progressive injury to small animals; 8000 ppm caused no greater effect (irritation) than did 200 ppm toluene in 2 individuals. The chief action of butadiene is narcosis produced only at very high concentrations; a 1% mixture (10,000 ppm) of butadiene in air breathed for 5 minutes produced only a more rapid pulse and a slight feeling of dryness and prickling in the mouth and nose (2). 140,000 mg/m^3 caused some irritation of the bronchi and lungs as well as some hyperplasia of bone marrow and irritation of the spleen.

In the light of the low degree of toxicity from butadiene even at relatively high concentrations and in view of the very mild irritant properties, the threshold limit of 1000 ppm would appear to offer a comfortable margin of safety from effects of exposure.

References
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2. von Oettingen, W.F.: Pub. Health Bull. 255, Washington, D.C. (1940).

2-BUTANONE (METHYL ETHYL KETONE)

200 ppm (Approximately 590 mg/m^3)

Patty, Schrenk and Yant (1) found guinea pigs tolerated 3000 ppm for several hours, whereas men found this concentration irritating to nose and eyes.

Nelson, et al. (2) reported slight nose and throat irritation at 100 ppm; mild eye irritation in some subjects at 200 ppm. They conclusively rejected 300 ppm and felt 200 ppm to be a practical limit.

Smith & Mayers (3) stated low grade intoxication occurred from exposures of 300-600 ppm.

A manufacturer's technical publication (4) on this compound summarizes its physiological properties and states, "The highest concentration of methyl ethyl ketone vapor which the majority of human subjects estimated satisfactory for eight hours was 200 ppm."

References
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2. Nelson, K.W., Ege, J.F., Jr., Morwich, R., Woodman, L.E., & Silverman, L.: J. Ind. Hyg. & Tox. 25, 284 (1943).
3. Smith, A.R., & Mayers, M.R.: N.Y. State Indust. Bull. 23, 176 (May 1944).
4. Methyl Ethyl Ketone, Tech. Pub. SC:50-2, 2nd edition (1950) Shell Chemical Corp., p. 97.

BUTYL ACETATE (n-Butyl Acetate)

200 ppm (Approximately 950 mg/m^3)

Sayers, et al. (1) found 3300 ppm to be the maximal amount tolerated for several hours exposure with but slight or no symptoms; however, immediate sacrificing and autopsy revealed congestion of brain, lungs, liver and kidneys.

Nelson, et al. (2) reported throat irritation in unacclimated subject at 200 ppm, becoming quite severe at 300 ppm.

Smyth (3) found rats inhaling substantially saturated vapors were not killed in four hours, but died within an eight-hour inhalation period.

Elkins (4) states that butyl acetate is much more strongly irritating than the lower esters; however, there is little evidence that it will cause chronic poisoning.

References
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3. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 148 (1956).

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BUTYL ALCOHOL (n-butanol)

100 ppm (Approximately 300 mg/m^3)

Tabershaw, et al. (1) reported eye irritation in workmen above 50 ppm, but no systemic effects below 100 ppm.

Sterner, et al. (2) followed workmen for 10 years with butyl alcohol concentrations held to 100 ppm, and for a briefer period to 200 ppm. Neither irritation nor systemic effects were found at the former value, but there was some eye irritation at 200 ppm.

Smyth (3), exposing rats, found that they were not killed in four hours at 8000 ppm. He concluded that no narcotic or irritative effects are to be anticipated at 100 ppm.

References

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3. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 148 (1956).

tert-BUTYL ALCOHOL

100 ppm (Approximately 300 mg/m^3)

The signs of intoxication in animals exposed to vapors of t-butyl alcohol are similar to those of other butyl alcohols. It has, however, a stronger narcotic action upon mice than has normal or isobutyl alcohol (1) (threshold limit, 100 ppm). t-butyl alcohol is more volatile than n-butyl alcohol. Eighteen repeated daily narcotic doses were not fatal to animals and no injurious effects resulted from a long-continued, easily tolerated, dosage. On the human skin, no reaction other than a slight erythema and hyperemia followed the contact with this substance (2). On the basis of the above information, it would appear that 100 ppm would prove a satisfactory threshold limit for t-butyl alcohol.

References

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2. Oettel, H.: Arch. exptl. Path. Pharmakol. 183, 641 (1936).

n-BUTYLAMINE

5 ppm (Approximately 15 mg/m^3)

Hanzlik (1) studied the toxicity and actions of the three straight-chain butylamines and reported increased reflex excitability, then depression and narcotic death with pulmonary edema.

Smyth (2) found rats to survive four hours at 2000 ppm but die at 4000 ppm. He stated further that unreported industrial experience suggests skin injury is the greatest practical hazard.

Additional unpublished industrial experience indicates that levels above

5 ppm may be irritating (3).

References
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2. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 148 (1956).
3. Fassett, D.W.: Unpublished observations, Lab. of Industrial Medicine, Eastman Kodak Co., Rochester 4, N.Y.

BUTYL CELLOSOLVE (2-Butoxyethanol)

50 ppm (Approximately 240 mg/m^3)

Werner and his associates (1,2,3,) compared the toxicity of butyl cellosolve with some other glycol ethers in experimental animals. The minimal lethal concentration of butyl cellosolve vapor on single 7-hour exposure of mice was 700 parts per million (1). Severe hemoglobinuria was common at concentrations near the lethal levels. Dyspnea was the most common sign of intoxication. Lung, kidney, and liver changes were seen. During repeated exposures of rats to 320 parts per million for 5 weeks (2), effects attributable to a mild hemolytic anemia were observed. Dogs exposed to 400 parts per million for 12 weeks developed only mild effects (3), from which it was concluded that dogs were more resistant to the hemolytic effects of butyl cellosolve than rodents.

Carpenter and his associates (4) exposed mice, rats, rabbits, guinea pigs, dogs, and monkeys to butyl cellosolve vapor, and observed the effects of hemolytic anemia and its sequelae. While rodents did not tolerate repeated exposure to 200 parts per million, this level was only slightly injurious to dogs. The authors suggested that humans were less susceptible than the experimental animals. In several single 8-hour exposures of humans to levels of 200 and 100 parts per million, no objective effects were seen except for urinary excretion of butoxyacetic acid. Subjectively, these concentrations were found to be uncomfortable, and mild irritation followed exposure.

From the above data (4), the threshold limit value was reduced to 50 parts per million in 1957; it is believed that this represents a safe level of exposure.

References
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p-TERTIARY BUTYLTOLUENE

10 ppm (Approximately 60 mg/m^3)

A recent, and apparently the only study (1), on the industrial hygiene aspects of p-TBT manufacture and handling, as well as a limited experimental study in rodents, has led to the conclusions that p-TBT is slightly toxic on ingestion following single exposures, moderately toxic on inhalation, and

practically nontoxic by skin exposures. p-TBT, however, was found to produce central depression and irritation of the respiratory tract as chief acute toxic effect in animals; repeated exposures produced changes in the liver and in the kidney. Microscopic degenerative hemorrhages in the spinal cord (2) and brain were seen in experimental animals at relatively low concentrations.

Human volunteers recognized concentrations as low as 5 ppm but found 80 ppm not especially unpleasant. A low-grade transient intoxication was observed in some workers during pilot scale production of p-TBT; signs and symptoms were chiefly referable to the cardiovascular, hematopoietic, and nervous systems.

The authors recommend a threshold limit of 10 ppm.

References
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2. Gerarde, H.W.: Toxicology and Biochemistry of Aromatic Hydrocarbons, Elsevier Pub. Co., New York (1960), p. 49.

CADMIUM OXIDE FUME

0.1 mg/m^3

Elkins (1) has documented a series of industrial experiences with cadmium oxide fume and dusts in which air concentrations of cadmium were correlated with health effects. No complaints occurred when exposures to fume from brazing operations ranged from 0.05-1.4 mg/m^3. Mild effects occurred from cadmium casting fume when the concentrations were between 0.17 and 0.46 mg/m^3. This was confirmed in another fume exposure from welding or copper-cadmium melting. Elkins believes, however, that the reported air concentrations of cadmium were lower than those causing the illness.

Fatal, acute poisoning has occurred from measured concentrations of cadmium fume of 3-100 mg/m^3. Reported illness occurred either at much higher (3-15 mg/m^3) dust concentrations in storage battery manufacture, or not at all from dusts of CdO and CdS when the concentrations ranged as high as 19-31 mg/m^3.

The above-noted experiences indicate a distinctly greater health hazard associated with inhalation of cadmium fume than of cadmium dusts, and that the limit of 0.1 mg/m^3 is probably sufficiently low to prevent serious pulmonary effects from exposure.

Recent environmental studies of the long-term effects of cadmium, however, place great emphasis on the cumulative effects of cadmium in the kidney and its possible relation to renal hypertension. Viewed from this aspect, any increment of cadmium is undesirable.

Reference
1. Elkins, H.B.: Chemistry of Industrial Toxicology, 2nd ed., pp. 34-38, Wiley & Sons, N.Y., 1959.

CALCIUM ARSENATE

0.1 mg/m^3

This long used insecticide was found to have an acute oral LD_{50} of about 100 mg/kg for rats by Ball and Sinclair (1) and chronically to lead to an abnormally high number of blind young when the parent rats were fed 5 mg/kg daily for 45 days. Other workers (2) have reported the acute oral LD_{50} to be 20

mg/kg for rats and 40 mg/kg for rabbits. Fairhall, et al. (3) in two-year feeding tests on rats established that calcium arsenate was even more toxic than lead arsenate. Based on their work, a threshold limit of 0.1 mg/m^3 was selected. Smyth (4) recommends that the value should be derived from the threshold limit for arsenic dusts which is 0.5 mg/m^3. As calcium arsenate is only 20% arsenic the calculated value would be 2.5 mg/m^3. Fairhall and Miller (5) found, however, that lead arsenate was less toxic than the calcium salt. This would indicate that a value calculated from one of the constituents of a compound may be erroneous. The 0.1 mg/m^3 value is, therefore, proposed.

References
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2. Compound No. 353, W.A.D.C. Technical Report 5516, Handbook of Toxicology, National Research Council, Vol. 1, p. 58, (1955).
3. Fairhall, L.T., Miller, J.W., Weaver, F.L.: Pub. Health Rept. Sept. 58, 955 (1943).
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CARBON DIOXIDE

5000 ppm (Approximately 9000 mg/m^3

The most outstanding effect of carbon dioxide is to stimulate the respiratory center. Stimulation is pronounced at 5% (50,000 ppm) concentration. The health of submarine personnel exposed continuously to 3% carbon dioxide was only slightly affected provided the oxygen content of the air was maintained at normal concentrations (1); when oxygen content was reduced to 15-17%, a variation in effects occurred according to duration of exposure. Impairment in general occurred at lower oxygen levels when exposure persisted over days and weeks. Deaths from carbon dioxide have been reported (2), but these were asphyxiating concentrations, probably several hundred thousand parts per million. The gas is weakly narcotic at 30,000 ppm (3) giving decreasing acuity of hearing and increasing blood pressure and pulse. Above this level subjective symptoms occur; at 50,000 a 30-min. exposure produces signs of intoxication, and 70,000 and 100,000 ppm, unconsciousness in a few minutes. Flury and Zernik (4) quote Lehman-Hess that 5500 ppm CO_2 for 6 hours causes no noticeable symptoms.

The threshold limit of 5000 ppm for carbon dioxide would appear to provide a reasonably good margin of safety for an 8-hr. daily exposure, provided ordinary amounts of oxygen are inhaled.

References
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CARBON DISULFIDE

20 ppm (Approximately 60 mg/m^3

Carbon disulfide vapor is largely absorbed through the lungs, though toxic

quantities can also be absorbed through the skin (1). Its effects are largely on the nervous system; single exposures are characterized by narcosis and its sequelae, symptoms of repeated exposure are nervousness, irritability, indigestion, bizarre dreams leading to insomnia, excessive fatigue, loss of appetite, and headache (1).

Wiley and associates (2) exposed animals repeatedly to carbon disulfide at 37 ppm and found significant toxic effects. They recommended that atmospheric concentrations be kept below 32 ppm. Patty's review (3) cites data to the effect that exposure of men to 160 to 230 ppm causes slight or no effects, 320 to 390 ppm causes slight symptoms after several hours, 420 to 510 ppm causes symptoms after ½ hour, 1150 ppm causes serious symptoms after ½ hour, 3210 to 3850 ppm is dangerous to life after ½ hour, and 4815 ppm is fatal in ½ hour. Elkins (4) reports that industrial poisoning has occurred at concentrations ranging from 50 to 100 ppm or more, but that no ill effects were found among workers exposed to concentrations averaging from 10 to 65 ppm. Barthelemy (5) reports that when carbon disulfide concentrations are kept below 30 ppm, no trouble was experienced. Rubin and Arieff (6) found equivocal evidence of toxic effects in persons exposed to an average concentration of from 2 to 26 ppm.

References
1. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins Co., Baltimore, Md., 2nd Ed. (1957), p. 181.
2. Wiley, F.H., Hueper, W.C., and von Oettingen, W.F.: J.Ind. Hyg. & Tox. 18, 733 (1936).
3. Patty, F.A.: Industrial Hygiene and Toxicology, Interscience Publications, N.Y. (1949), pp. 591-592.
4. Elkins, H.B.: Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., N.Y. (1950), p. 199.
5. Barthelemy, H.L.: J. Ind. Hyg. and Tox. 21, 141 (1939).
6. Rubin, H.H. and Arieff, A.J.: J. Ind. Hyg. & Tox. 27, 123 (1945).

CARBON MONOXIDE

100 ppm (Approximately 110 mg/m^3)

Carbon monoxide gas causes chemical asphyxiation by forming a stable compound with hemoglobin that reduces the oxygen-carrying capacity of the blood (1,2). Sequelae of poisoning include pathologic changes in the heart and brain (3,4). There is some controversy whether repeated exposure may cause chronic poisoning or repeated acute poisoning.

Sayers and associates (5) reported that exposure of men to 200 ppm caused slight symptoms. Sievers and associates (6) reported that men exposed to an average concentration of 70 ppm over a 13-year period did not suffer adverse effects. Henderson and Haggard (7) describe a time X concentration relationship such that exposure to 100 ppm for 3 hours produces no perceptible effect, exposure to the same concentration for 6 hours produces a just perceptible effect, exposure to that concentration for 9 hours causes headache and nausea, and exposure for 15 hours is dangerous. Vigliani and Zurlo (8) report their experience with carbon monoxide in gas works, involving 100 workers; they concluded that workers accustomed to concentrations of 100 ppm suffered no marked injury to health, but suggested 75 ppm in order to avoid all risk of poisoning.

The maximal concentration of carbon monoxide allowed in the tunnels of the New York Port Authority (9) is 250 ppm. In actual practice the average is 100 to 150 ppm. Untoward effects have not been observed during the past thirty years in the policemen who work in the tunnels. The eight-hour work shifts are arranged so that policemen work in and out of the tunnel for alternate 2-hour periods.

References
1. Drinker, C.K.: Carbon Monoxide Asphyxia, Oxford University Press, Oxford and New York, 1938.
2. von Oettingen, W.F.: Carbon Monoxide: Its Hazards and the Mechanism of its Action. Pub. Health Bull. No. 290, U.S. Govt. Print. Off. Washington, D.C., 1944.
3. Lewey, F.H., Drabkin, D.L.: Am. J. Med. Sci. 208, 502 (1944).
4. Schwedenberg, T.H.: J. Neuropath. Exper. Neur. 18, 597 (1959).
5. Sayers, R.R., Yant, W.P., Levy, E., Fulton, W.B.: Effects of Repeated Daily Exposure of Several Hours to Small Amounts of Automobile Exhaust Gas., Pub. Health Bull. No. 186, U. S. Govt. Print. Off. Washington, D.C., 1929.
6. Sievers, R.F., Edwards, T.I., Murray, A.L., Schrenk, H.H.: J. Am. Med. Assn. 118, 585 (1942).
7. Henderson, Y. and Haggard, H.W.: Noxious Gases and the Principles of Respiration Influencing Their Action, Reinhold Publishing Corp., New York, 2nd and Rev. Ed., 1943, pp. 167-168.
8. Vigliani, E.C., Zurlo, N.: Arch. Gewerbepath. u. Gewerbehyg. 13, 528 (1955). Abstracted in Arch. Ind. Health 13, 403 (1956).
9. The Port of New York Authority Medical Director - Personal Communication, 1956.

CARBON TETRACHLORIDE

25 ppm (Approximately 160 mg/m^3)

Carbon tetrachloride is toxic by several routes of entry. It is irritant to mucous membranes, depresses the central nervous system, causes effects on blood cells (perhaps mediated in part by hepatic injury), as well as metabolic changes and damage to the liver and kidney (1). Carbon tetrachloride is an important health hazard from either acute or chronic poisoning (2). Adams and Associates (3) conducted extensive quantitative studies on carbon tetrachloride toxicity, and found evidence of liver damage in laboratory animals on repeated daily exposure to the vapor down to levels of 10 ppm and some, possibly doubtful, evidence of liver damage to female guinea pigs at 5 ppm. von Oettingen (1) has reviewed a number of cases of human poisoning by the compound and levels above 100 ppm are stated to be unsafe. Several reports record illness from lower concentrations (4,5,6,7,8,9). Nevertheless the establishment of a threshold limit value is based to a great extent on carefully controlled experimental exposures of animals.

From these data, a threshold limit value of 25 ppm is considered low enough to prevent irreversible injury.

References
1. von Oettingen, W.F.: Pub. Health Serv. Pub. No. 414. U.S. Govt. Print. Off. Washington, D.C. (1955), pp. 75-112.
2. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins, Baltimore, Md., 2nd Ed. (1957), pp. 183-185.
3. Adams, E.N., Spencer, H.C., Rowe, V.K., McCollister, D.D., and Irish, D.D.: Arch. Ind. Hyg. & Occ. Med. 6, 50 (1952).

4. Heimann, H., and Ford C.B.: N.Y. Ind. Bull. 20 Nos. 7,8 - July, Aug. 1941.
5. Elkins, H.B.: J. Ind. Hyg. & Tox. 24, 233 (1942).
6. Ind. Hyg. Div., Ill. Dept. of Labor, Ill. Labor Bull., May 31, 1947, p. 10.
7. Avery, R.H. and Davis, L.: Natl. Safety News, Oct. 1945, p. 89.
8. Kazantzis, G., Bomford, R.R.: Lancet 1, 360 (1960).
9. Elkins, H.B.: Chemistry of Industrial Toxicology, Wiley, N.Y. (1959).

CELLOSOLVE (2-Ethyoxyethanol)

200 ppm (Approximately 740 mg/m^3)

Waite and associates (1) and Werner and associates (2,3,4) exposed animals to cellosolve vapor in a study of its acute and chronic toxicity. Single exposures occasionally produced changes in the lung, kidney, liver and spleen (2). Repeated exposures of rats to levels of 300 ppm and higher caused small but measurable effects on formed elements of the blood (3). Similar exposure of dogs at 800 ppm also caused hematologic effects (4).

Based on these experimental exposures of animals, a threshold limit value of 200 ppm is inferred to be low enough to prevent systemic injury. This value was established in 1946.

References

1. Waite, C.P., Patty, F.A., Yant, W.P.: Pub. Health Rept. 45, 1459 (1930).
2. Werner, H.W., Mitchell, J.L., Miller, J.W., von Oettingen, W.F.: J. Ind. Hyg. & Tox. 25, 157 (1943).
3. Werner, H.W., Mawrocki, C.Z., Mitchell, J.L., Miller, J.W., von Oettingen, W.F.: J. Ind. Hyg. & Tox. 25, 374 (1943).
4. Werner, H.W., Mitchell, J.L., Miller, J.W., von Oettingen, W.F.: J. Ind. Hyg. & Tox. 25, 409 (1943).

CELLOSOLVE ACETATE (2-ethoxyethyl acetate)

100 ppm (Approximately 540 mg/m^3)

Smyth (1) has summarized unpublished tests as showing that rats survive 1500 ppm for 4 hours, but 2 of 6 die after 8 hours. Dogs, after 120 seven-hour inhalations of 600 ppm, exhibited only a small increase in sulfobromphthalein retention, with eye and nose irritation. He concludes that "The most important effect of cellosolve acetate is chronic poisoning due to hydrolysis to cellosolve. The 100 ppm threshold limit can be interpreted from analogy with cellosolve."

Reference

1. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).

CHLORDANE

2 mg/m^3

(1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane)

A well authenticated oral LD_{50} of 590 mg/kg for rats (1) has been accepted for chlordane. Since its structure and action is similar to that of DDT and lindane with LD_{50} values of 250 and 125 mg/kg respectively, it would appear to be logical to assign a threshold limit value of 2 to chlordane (DDT

and lindane have been assigned 1 and 0.5 respectively). Moreover, Princi and Spurbeck (2) found no illness among workers as a result of exposure to chlordane and aldrin at 5 mg/m^3 for 3 years.

References
1. Ambrose, H.: Fed. Proc. 12, 298 (1953).
2. Princi, F., Spurbeck, G.H.: Arch. Ind. Hyg. & Occup. Med. 3, 64 (1951).

CHLORINATED CAMPHENE 60% (TOXAPHENE)

0.5 mg/m^3

Fitzhugh (1) presented data in 1950 showing that the acute, oral LD_{50} of toxaphene in oil was 25 mg/kg for dogs, 73 mg/kg for rats, and 210 mg/kg for guinea pigs.

The Hercules Powder Company released the following information in 1952 (2). Toxicologic investigations of toxaphene have shown that it is a poisonous substance with an irregular toxicity range. The LD_{50} for an oral dose of toxaphene shows a species variation from 288 mg/kg for the guinea pig to approximately 10 to 20 mg/kg for the dog. In solid form, it is not readily absorbed through the skin of animals; but in solution, it is readily absorbed through the skin. In chronic feeding tests over a six-month period, 800 ppm in the daily diet of guinea pigs and white rats caused no significant change in the weight curve, urine, blood, mortality, or tissue pathology. No indications of toxicity have been observed in monkeys when fed toxaphene at a rate corresponding to 10 ppm of their dietary intake. Approximately 60 ppm in terms of the daily diet was found to result in toxic symptoms after the second week of this feeding. The chronic ingestion of toxaphene may result in the accumulation of toxaphene or a chlorinated metabolite in the fatty tissues. Toxaphene is excreted, at least to some extent, in the urine in conjugation with sulfuric acid and glucuronic acid, and will disappear from the fat when the ingestion of toxaphene is terminated.

The acute toxicity of toxaphene is about 3 times that of DDT, but chronically toxaphene is less toxic. Its over-all toxicity is about that of lindane, and a threshold limit of 0.5 mg/m^3 is therefore suggested.

References
1. Fitzhugh, G.: Federal Security Agency Hearings, Washington, July 1950.
2. Alderson Reporting Co., 306 Ninth St., N.W., Washington 4, D.C.

CHLORINATED DIPHENYL OXIDE

0.5 mg/m^3

In a list of 14 chlorinated hydrocarbons (1), showing chlorine contents and permissible limits for air in workrooms, 0.5 mg/m^3 is suggested as the value for chlorinated diphenyl oxides containing 54 and 57 per cent chlorine.

Reference
1. Drinker, Cecil K.: J. Ind. Hyg. & Tox. 21, 1955 (1939).

CHLORINE

1 ppm (Approximately 3 mg/m^3)

Chlorine is a highly irritating gas. In Heyroth's review (1), data are cited indicating that men can work without interruption in air containing 1 to 2 ppm. Exposure to concentrations of 3 to 6 ppm causes irritation of the eyes, nose and throat, and sometimes headache from irritation of nasal sinuses. He reports that exposure for 1/2 to 1 hour at a concentration of 14 to 21 ppm is dangerous, and a concentration of 100 ppm cannot be borne for longer than one minute. In a review by Henderson and Haggard (2), it is suggested that a concentration of 0.35 to 1 ppm is the maximal concentration allowable for prolonged exposure, 3.5 ppm is the least detectable odor, 4 ppm is the maximal concentration allowable for 1/2 to 1 hour, 15 ppm is the least amount causing immediate irritation to the throat. 40 to 60 ppm is dangerous for even short exposures, and 1,000 ppm is rapidly fatal on short exposure.

References
1. Heyroth, F.F.: The Halogens, Patty, F.A., Industrial Hygiene and Toxicology, Interscience Publications, N.Y., 1949, Vol. II, pp. 547-549.
2. Henderson, Y., Haggard, H.W.: Noxious Gases, Reinhold Publishing Co., New York, 2nd and Rev. Ed., 1943, p. 132.

CHLORINE DIOXIDE

0.1 ppm (approximately 0.3 mg/m^3)

Elkins (1) has stated that a concentration of chlorine dioxide (ClO_2) of 5 ppm is definitely irritating and that 19 ppm of the gas inside the bleach tank was more than sufficient to cause the death of one worker (time of exposure not specified). On the basis of these findings Elkins suggested in 1950 a maximal acceptable concentration of 1 ppm. Petry (2) later reported bronchitis and pronounced emphysema in a chemist repeatedly exposed during several years to ClO_2; symptoms were increasing dyspnea and asthmatic bronchitis even without exposure (degree of exposure not stated). Gloemme and Lundgren (3) made a clinical investigation of workers exposed for 5 years to ClO_2 in a sulfite-cellulose plant. Chlorine in small amounts was also present, as was SO_2 on occasion. Except for leaks from faulty vacuum, concentrations of ClO_2 were below 0.1 ppm, Cl_2, about 0.1 ppm. Symptoms and signs of irritation of the eyes and respiratory tract leading to slight bronchitis were found in a majority (7 of 12) of the workers. Certain individuals showed irritation to the gastrointestinal tract, but no cerebral effects. All effects were attributed to short periods of exposure to concentrations considerably in excess of 0.1 ppm of ClO_2 and Cl_2. Sampling procedures were not sufficiently frequent to establish the magnitude of the ClO_2 exposure except that at 0.1 ppm apparently no untoward effects were experienced.

Dalhamn (4) further showed that concentrations approximating 0.1 ppm ClO_2 produced no abnormal reaction in rats exposed 5 hours daily for 10 weeks.

The recommended limit is accordingly based on the work of Dalhamn and of Gloemme and Lundgren, and by analogy with the limit for the triatomic oxidant gas, ozone.

References
1. Elkins, H.B.: The Chemistry of Industrial Toxicology, 2nd Ed., J. Wiley & Sons, Inc., N.Y., 1959.
2. Petry, H.: Chlordioxyd-ein Gefahrliches Reizgas, Arch. Gewerbepath. u. Gewerbehyg. 13, 363 (1954).
3. Gloemme, J., Lundgren, K.D.: Health Hazards from Chlorine Dioxide, Arch. Ind. Health 16, 169 (1957).
4. Dalhamn, T.: Chlorine Dioxide, Toxicity in Animal Experiments and Industrial Risks, Arch. Ind. Health 15, 101 (1957).

CHLORINE TRIFLUORIDE (ClF_3)

0.1 ppm (Approximately 0.4 mg/m^3)

The threshold limit of 0.1 ppm for chlorine trifluoride was set on the basis of acute, subacute and 6-month chronic toxicity studies (1,2).

Horn and Wier exposed two dogs and 20 rats to an average concentration of 1.17 parts per million of ClF_3 for a total period of six months on a six-hour-per-day, five-day-per-week basis. An additional two dogs and twenty rats served as controls. Early signs of toxicity in the dogs were coughing, sneezing, rhinorrhea, salivation, panting respiration and occasional expulsion of frothy fluid from the mouth and nose. After about 2 months both dogs had recurrent bouts of pneumonia. One dog died on the 115th day. Signs were not so pronounced in the rats, but after several weeks a bloodtinged discharge appeared about the nares and eyes. Six rats died during the course of the experiment. Pathologic findings were severe pulmonary irritation in both species among the survivors as well as among the animals that died compared with unremarkable pathology in the controls.

A threshold limit of 0.1 ppm recommended in 1955, is probably sufficiently low to prevent development of serious injury, but the suitability of the value requires further evaluation in controlled worker exposure.

References

1. Horn, H.H., and Wier, R.J.: Arch. Ind. Health 12, 515 (1955).
2. Ibid 13, 340 (1956).

CHLOROBENZENE (Monochlorobenzene)

75 ppm (Approximately 350 mg/m^3)

Some reviews of chlorobenzene toxicity (1,2) cite evidence that chlorobenzene is a central nervous system poison, causing narcosis. It appears to be less toxic than benzene, and without some of the effects of benzene on leukocytes. Some of the early reports of chlorobenzene poisoning may be misleading since apparently some accidental poisonings attributed to chlorobenzene exposure may have been caused by nitro or dichloro derivatives of benzene.

According to Cook (3) the U.S. Public Health Service suggests a standard of 75 parts per million as a guide.

References

1. Browning, E.: Toxicity of Industrial Organic Solvents, Chemical Publishing Co., Inc., New York, (1953), pp 187-189.
2. Lehmann, K.B. and Flury, F.: Toxicology and Hygiene of Industrial Solvents, Williams & Wilkins Co., Baltimore, Md. (1943), p. 188.
3. Cook, W.A.: Ind. Med. 14, 936 (1945).

CHLORODIPHENYL - 42% CHLORINE

1 mg/m^3

Acne, systemic poisoning and even death may result from exposure to chlorinated diphenyls (1,2). Acne is not an invariable warning sign of impending, more severe, systemic toxicity. Meigs (3) has reported 7 cases of mild to moderate chloracne among 14 workers exposed to a few parts per million of the vapors of Arochlor (chlorinated diphenyl). The material has

been shown to be absorbed through the skin causing fatty degeneration of the liver (4). Treon, et al. (5) found Arochlor "1242" to be without detectable effect on laboratory animals after 150, 7-hour exposures at 1.9 mg/m^3 (0.18 ppm) and that 24, 7-hour exposures at 8.6 mg/m^3 were probably without effect. Treon points out that the probability of industrial occurrence of the latter vapor concentrations is small, as they approach saturation; exposure to particulate matter as condensed droplets is possible, however.

The threshold limit of 1 mg/m^3 would seem to offer reasonably good protection against severe systemic toxicity but may not guarantee complete freedom from chloracne.

References
1. Schwartz, L.: Am. J. Pub. Health 26, 586 (1936).
2. Drinker, C.K., Warren, M.F., Bennett, G.A.: J. Ind. Hyg. & Tox. 19, 283 (1937).
3. Meigs, J.W., Albom, J.J., Kartin, B.L.: J. Am. Med. Assn. 154, 1417 (1954).
4. Paribok, V.P.: Farmakol. i. Toksikol. 17, 51 (1954).
5. Treon, J.F., Cleveland, F.P., Cappel, J., Atchley, R.W.: Am. Ind. Hyg. Assn. Quart. 17, 204 (1956).

CHLORODIPHENYL - 54% CHLORINE

0.5 mg/m^3

From an extensive study of the penta-and hexachloronaphthalenes, chlorinated diphenyls, and a mixture of these in animals by various routes of administration, including chronic exposure via the respiratory tract, plus a study of industrial exposures, Cecil Drinker, et al. (1,2) concluded that 0.5 mg/m^3 of chlorinated aromatic compounds containing more than 3 chlorine atoms per molecule should represent the limiting concentration for human exposure.

More recently Treon (3) studied the effects of two chlorinated diphenyl derivatives containing 42% and 54% chlorine respectively, in animals exposed 7 hours daily for 150 days during a period of 210 days. From the information derived from this carefully done and extended study, a tentative level of 0.5 mg/m^3 for chlorinated diphenyls containing 54% chlorine would appear reasonable for repeated daily exposures of industrial workers.

References
1. Drinker, C.K., Warren, M.F., Bennett, G.A.: J. Ind. Hyg. & Tox. 19, 283 (1937).
2. Drinker, C.K.: Ibid. 21, (1939)
3. Treon, J.F., Cleveland, F.P., Cappel, J., Atchley, R.W.: Am. Ind. Hyg. Assn. Quart. 17, 204 (1956).

CHLOROFORM (Trichloromethane)

50 ppm (Approximately 250 mg/m^3)

Cook (1) notes that 100 ppm is generally accepted on the basis of analogy with carbon tetrachloride. He believes that this value may be high and suggested exposures be kept below 50 ppm until more data are available.

Patty (2) suggests 300 to 400 ppm as a practical working level.

Challen (3) and associates reported severe symptoms (lassitude, digestive disturbances, mental dullness) in workers exposed to 80 to 240 ppm of chloroform and

less severe symptoms in a group exposed to 20 to 70 ppm.

References
1. Cook, W.A.: Ind. Med. 14, 936 (1945).
2. Patty, F.A., editor: Industrial Hygiene and Toxicology. Vol. II, Interscience Publishers, New York (1949).
3. Challen, P.J.R., Hickish, D.E. and Bedford, J.: Brit. J. Ind. Med. 15, 243 (1958).

1-CHLORO-1-NITROPROPANE

20 ppm (Approximately 100 mg/m^3)

Machle (1) and his associates reported that no fatalities resulted from exposures of 700 ppm for 2 hours. Higher concentrations and longer exposures resulted in fatalities. Although considerably less toxic by inhalation than 1,1-dichloro-1-nitroethane, the toxcity of 1-chloro-1-nitro-propane when administered orally is the greater by a factor of about 2. The limit of 20 ppm is derived by analogy with 1,1-dichloro-1-nitroethane.

Reference
1. Machle, W., Scott, E.W., Treon, J.F., Heyroth, F.F., Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 27, 95 (1945).

CHLOROPICRIN

0.1 ppm (Approximately 0.7 mg/m^3)

According to Flury & Zernik (1) chloropicrin in concentrations of from 0.3 to .37 ppm results in painful irritation to the eyes in 3 to 30 seconds; the response varied according to individual susceptibility. A concentration of 15 ppm could not be tolerated longer than a minute even by individuals accustomed to chloropicrin.

In addition to the skin and eye irritation from these lower concentrations, slightly higher levels cause lacrimation and vomiting, and finally bronchitis and death through pulmonary edema. A level of 4 ppm renders a man unfit for activity.

Whereas a threshold limit of 1 ppm might be reasonably free from injurious effects when inhaled for short periods, it does not appear to provide freedom from eye irritation in all individuals or insure against eventual pulmonary changes. Accordingly, a threshold limit of 0.1 ppm is recommended for repeated exposure to chloropicrin.

Reference
1. Flury, F. and Zernik, F., in Schadliche Gase, J. Springer, Berlin (1931), quoting Fries and West in Chem. Warfare (1921), p. 143 and Vedder, The Medical Aspects of Chemical Warfare (1925), p. 70.

CHLOROPRENE (2-Chloro-1,3-Butadiene)

25 ppm (Approximately 90 mg/m^3)

von Oettingen (1) and co-workers determined the minimal fatal concentration of chloroprene for eight hours exposure for various animals. Values of

160 to 5800 ppm were reported. Concentrations of 80 ppm were said to cause toxic symptoms in men.

Cook (2) on the basis of von Oettingen's work, suggested 25 ppm as the MAC.

References
1. von Oettingen, W.F., et al.: J. Ind. Hyg. & Tox. 18, 240 (1936).
2. Cook, W.A.: Ind. Med. 14, 936 (1945).

CHROMIC ACID AND CHROMATES (as CrO_3)

0.1 mg/m^3

Bloomfield and Blum (1) investigated chrome-plating operations in six plants, employing 27 workers as chrome platers, where the total number of persons exposed to the spray was about 100. Results of atmospheric determination of chromic acid concentrations, together with physical examinations of workers, showed that continuous daily exposure to concentration of chromic acid greater than 1 milligram in 10 cubic meters of air is likely to cause definite injury to the nasal tissues of operators.

Reference
1. Bloomfield, J.J., Blum, W.: Pub. Health Rept. 43, 2330 (1928).

CRAG HERBICIDE

Sodium 2 - (2,4-dichlorophenoxy) ethanol hydrogen sulfate

15 mg/m^3

This herbicide has an acute oral LD_{50} of 1500 mg/kg for rats. Smyth (1) reports that rats are unaffected by 0.02% in their diet for 2 years. Minor liver damage is caused by 0.06% (60 mg/100g diet).

It is thus in a low toxicity category with Ammate for which the threshold limit value was set at 15 mg/m^3.

Reference
1. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).

CRESOL (All isomers)

5 ppm (Approximately 22 mg/m^3)

Elkins (1) reports that cresol is not volatile enough to constitute a respiratory hazard under normal conditions but that it is a strong irritant and causes frequent dermatosis. Serious, or even fatal, poisoning may result if large areas of the skin are wet with pure or concentrated cresols.

Fairhall (2) considers the toxicity of the mixed cresols to be somewhat less than that of phenol. Meta-cresol is somewhat less poisonous and less irritant than phenol, while ortho-cresol is more toxic and para-cresol is the most toxic of all three. These differences are too small to be of any great practical importance.

Hamilton (3) and Hardy consider the action of cresol to be probably much the same as that of phenol.

References
1. Elkins, H.B.: Chemistry of Industrial Toxicology, 2nd Ed., Wiley & Sons, N.Y. (1958).
2. Fairhall, L.T.: Industrial Toxicology, 2nd Ed., Williams & Wilkins Co., Baltimore, Md. (1957).
3. Hamilton, A. and Hardy, H.L.: Industrial Toxicology, 2nd Ed., Paul B. Hoeber, Inc., New York, (1949).

CYANIDES

Alkali Cyanides: 5 mg/m^3

The lesser limit of 5 mg/m^3 for alkali cyanides compared with that of HCN, is based on the added irritation caused by the alkalinity, sufficient to result in epistaxis (nosebleed) and nasal ulceration (1). The air concentration of cyanide from the alkali cyanides producing this effect did not greatly exceed 5 ppm.

Reference
1. Elkins, H.B.: Chemistry of Industrial Toxicology, John Wiley & Sons, N.Y., (1950), pp. 91-92.

CYCLOHEXANE

400 ppm (Approximately 1400 mg/m^3)

Treon and his associates (1) found just demonstrable microscopic changes in liver and kidneys of rabbits exposed to 786 ppm cyclohexane for 50 periods of six hours each. No toxic changes were found in the tissues of rabbits after exposure for the same period to a concentration of 1.46 mg. per liter (434 ppm).

Patty (2) (1949) summarized existing information on the toxicity of cyclohexane as follows:

"A concentration of 434 ppm is believed to be safe for rabbits. Whether human beings will observe any narcotic effects or be fatigued at this concentration remains to be established. However, it seems unlikely that serious or lasting consequences will result from exposure to 300 ppm and this should offer a satisfactory temporary bench mark until further studies are made."

References
1. Treon, J.F., Crutchfield, W.E., Jr., and Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 25, 323 (1943).
2. Patty, F.A.: Industrial Hygiene & Toxicology, p. 769, Interscience Publications, N.Y., (1949).

CYCLOHEXANOL

50 ppm (Approximately 200 mg/m^3)

Treon, Crutchfield and Kitzmiller (1) in their animal experimentation with cyclohexane and derivatives found that cyclohexanol at a concentration of 0.58 mg. per liter of air (145 parts per million) is very near the maximal safe level for rabbits. This concentration is not entirely harmless, since after 50 six-hour periods, there were scanty but definite evidences of toxic effects in the form of microscopic changes in the liver and kidneys of rabbits. Exposure to concentrations of 1.09 mg. per liter (272 parts per million) caused slight conjunctival irritation and slight ear-vein distention.

Nelson and his associates (2) found 100 parts of cyclohexanol to be objectionable to the ten persons subjected to this concentration in a study of sensory response to a number of solvent vapors. In this study the individuals classified the effect of the vapor on the eyes, nose and throat after 3 to 5 minutes' exposure.

References
1. Treon, J.F., Crutchfield, W.E., Jr., and Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 25, 323 (1943).
2. Nelson, K.W., Ege, J.F., Jr., Ross, Morwick, Woodman, L.E. and Silverman, Leslie: J. Ind. Hyg. & Tox. 25, 282-285 (1943).

CYCLOHEXANONE

50 ppm (Approximately 200 mg/m^3)

Treon and his co-workers (1) reported that the concentration of 0.75 mg cyclohexanone per liter of air (190 ppm) induced just demonstrable degenerative changes in the liver and kidneys of rabbits after 50 six-hour exposures. They conclude that this concentration is very little above the maximal safe concentration for these animals. Similar exposure at a concentration of 309 ppm cyclohexanone vapor caused very slight conjunctival congestion.

Nelson and associates (2) report that cyclohexanone was not tolerated by unacclimated subjects at 50 ppm, throat irritation being the most marked effect. Twenty-five p.m were not objectionable to most subjects during the 3-5 minute exposure.

References
1. Treon, J.F., Crutchfield, W.E., Jr., Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 25, 323 (1943).
2. Nelson, et al.: J. Ind. Hyg. & Tox. 25, 282 (1943).

CYCLOHEXENE

400 ppm (Approximately 1350 mg/m^3)

Lazarew (1) and Fairhall (2) found cyclohexene to be somewhat more toxic to animals than cyclohexane.

Cook (3) suggested 400 ppm as a MAC on the basis of analogy to cyclohexane.

References
1. Lazarew, N.V.: Arch. exp. Path. Pharmakol. 143, 223 (1929).
2. Fairhall, L.T.: Industrial Toxicology, Williams & Wilkins, Baltimore, Md. (1957) - 2nd Edition.
3. Cook, W.A.: Ind. Med. 14, 936 (1945).

DECABORANE

0.05 ppm (Approximately 0.3 mg/m^3)

Decaborane on repeated exposure by various routes of administration produced a toxicity intermediate between the more toxic pentaborane and the less toxic diborane (1,2,3). Significant health hazards were found from all practical routes of entry, especially the skin. By some routes of administrations

(percutaneous) and in some species (rats and rabbits) but not in all, toxicity to the central nervous system was intensified over that from single exposures. Also recovery from the effects of decaborane was less rapid than from diborane (several days, vs. a few hours). The central nervous system effects found in animals have been observed among plant personnel (4). On the other hand the inhalation hazard of decaborane, although comparable to that of pentaborane is definitely less. The threshold limit for decaborane of 0.05 ppm is derived by analogy with diborane and pentaborane.

References
1. Svirbely, J.L.: Arch. Ind. Hyg. 10, 298 (1954).
2. Svirbely, J.L.: Arch. Ind. Hyg. 10, 305 (1954).
3. Svirbely, J.L.: Arch. Ind. Health 11, 138 (1955).
4. Krackow, E.H.: Arch. Ind. Hyg. 8, 335 (1953).

DIACETONE ALCOHOL (4-hydroxy-4-methyl pentanone-2)

50 ppm (Approximately 240 mg/m^3)

Diacetone alcohol is used in lacquers and in the textile industry as a solvent for certain pigments. Silverman, Schulte and First (1) who investigated the sensory response to the vapor of this material found that eye irritation appeared in the majority of subjects at a concentration of 100 parts per million. Also at this level subjects complained of nose and throat irritation and of the objectionable odor and taste. Because of the number of complaints made by the exposed subjects at a concentration of 100 parts per million, 50 parts was decided upon as a more reliable limit. Most subjects, however, indicated that they could work for an 8-hour day at 100 parts per million.

von Oettingen (2) reports that in experimental work in which mice, rats, rabbits and cats were exposed to 2100 parts per million, restlessness, irritation of the mucous membranes, excitement and later, somnolence resulted. Kidney injury was observed in rabbits. Work, based largely on animal experimentation, would indicate that diacetone alcohol is about twice as toxic as acetone and that it may cause injury to the kidney, liver and blood.

In view of eye, nose and throat irritation occurring in persons exposed to 100 parts per million, a value of 50 parts per million is suggested for diacetone alcohol.

References
1. Silverman, L., Schulte, H.F. and First, W.W.: J. Ind. Hyg. & Tox. 28, 262 (1946).
2. von Oettingen, W.F.: Aliphatic Alcohols, Pub. Health Bull. 281, 138 (1943).

DIBORANE

0.1 ppm (Approximately 0.1 mg/m^3)

Comstock, et al. (1) studied the toxicity of diborane and found it to be a respiratory irritant, causing pulmonary edema. Repeated exposures of rats, guinea pigs, and dogs to the vapor for periods up to 6 months were performed; 17 of 18 rats and 2 of 2 dogs exposed at 5 ppm died, and 10 of 20 rats, 1 of 2 dogs and none of 10 guinea pigs died at 1 to 2 ppm exposures. Though there was no unequivocal evidence from necropsies of pulmonary changes,

there is reason to believe that repeated respiratory insult was the underlying cause of death; for example, dogs exposed at 5 ppm developed signs of respiratory infection, probably secondary to respiratory irritation. McAdams (2) has pointed out the difficulty in assessing pulmonary changes in rats from diborane exposure in the presence of changes from the intercurrent diseases widely prevalent in rats; this may account for the failure to detect morphological differences between rats repeatedly exposed to diborane and control rats.

Lawson and Jacobson (3) found the LC_{50} value of diborane on single 4-hour exposures of rats to be 40 or 80 ppm, depending on age or strain of rats used. They reported respiratory distress and and post-mortem pulmonary edema to be the only effects of exposure. Kunkel, et al. (4) described the effects of diborane exposure of animals in detail, and while some effects were noted that might be attributable to changes in the central nervous system, they concluded the primary effect to be production of pulmonary edema. Lowe and Freeman (5) report cases of human exposure to diborane resulting in nervous system intoxication. There is a report of a dog with anatomical lesions in the spinal cord following repeated exposure to diborane (6).

Thus, while the primary effect of diborane appears to be on the lungs, effects of neurological origin may occur. The threshold limit value of 0.1 ppm is interpreted from the study reported by Comstock and his co-workers.

References

1. Comstock, C.C., Feinsilver, L., Lawson, L.H., Oberst, F.W.: Chemical Corps Medical Laboratories Research Report No. 258, (1954).
2. McAdams, A.J., Jr.: Chemical Corps Medical Laboratories Research Report No. 362, (1955).
3. Lawson, L.H., Jacobson, K.H.: Chemical Warfare Laboratories Technical Report No. 2031, (1956).
4. Kunkel, A.M., Murtha, E.F., Oikemus, A.H., Stabile, D.E., Saunders, J.P. and Wills, J.H.: Arch. Ind. Health 13, 346 (1956).
5. Lowe, H.J., Freeman, G.: Arch. Ind. Health 16, 523 (1957).
6. Jacobson, K.H., Murtha, E.F., Weir, F.W., Yevich, P.P., Rothberg, S., Weeks, N.H.: Chemical Research and Development Laboratories Special Publication 2-34, (1960).

o-DICHLOROBENZENE

50 ppm (Approximately 300 mg/m^3)

Browning (1) states that 1000 ppm of o-dichlorobenzene was fatal to guinea pigs after 20 hours.

Cameron and Thomas (2) found liver damage in animals after exposure of a few hours at concentrations ranging from 50 to 800 ppm.

Elkins (3) reports concentrations approaching 100 ppm to be irritating but that no other toxic effects were noted.

Hollingsworth and co-workers (4) reported animals unaffected by repeated daily exposures at 90 ppm. They suggest 75 ppm as a maximal acceptable concentration, but recommend that all workroom concentrations should fluctuate below this level.

References

1. Browning, Ethel: Toxicity of Industrial Organic Solvents, Chemical

Publishing Co., New York (1953), p. 190.
2. Cameron, G.R., Thomas, J.C.: J. Path. Bact. 44, 281 (1937).
3. Elkins, Hervey B.: The Chemistry of Industrial Toxicology, John Wiley and Sons, Inc., N.Y., (1959) 2nd Ed., p. 150.
4. Hollingsworth, R.L., et al.: Arch. Ind. Health 17, 180 (1958).

p-DICHLOROBENZENE

75 ppm (Approximately 450 mg/m^3)

Cameron and Thomas (1) state that the injection of 0.005 gm in rats occasionally causes slight necrosis of the liver. Zupko and Edwards (2) gave the LD_{50} for rats by intraperitoneal injection as 2562 mg/kg. Domenjoz (3) reports the oral LD_{50} for mice as 2950 mg/kg. Rabbits exposed for 30 minutes daily to 100 mg/l showed irritation of eyes and nose, tremors and poor equilibrium. Rats given similar exposures showed signs of irritation and subsequently complete narcosis. Guinea pigs exposed to 100 mg/l showed the same symptoms as rats and mice but repeated exposure quickly caused death. Berliner (4) reported that feeding rabbits 5 gms of p-dichlorobenzene daily caused opacity of the lens in 3 weeks. Pike (5) repeated this work but failed to produce opacity. He believed that the effect was produced by naphthalene which may have contaminated the sample.

Claytor (6) reported the case of a patient who suffered swelling of the feet, ankles and hands after mothproofing garments all day with p-dichlorobenzene. Berliner (4) described two cases of cataract from exposure to the vapour of this chemical. Petit and Champaix (7) reported the case of a female worker who suffered tingling of the hands and, after 18 months, vertigo and loss of weight from working with a mixture of 90 parts of p-dichlorobenzene and 10 parts of hexachlorethane.

The evidence appears to indicate that p-dichlorobenzene is somewhat less toxic than the ortho isomer which has been assigned a threshold limit value of 50 (300 mg/m^3).

References

1. Cameron, G.R., Thomas, J.C.: J. Path. Bact. 44, 281 (1937).
2. Zupko, A.G., Edwards, L.D.: J. Am. Pharm. Assn. 38, 124 (1949).
3. Demenjoz, R.: Arch. int. pharmacol. 73, 128 (1946).
4. Berliner, M.L.: Arch. Ophthal. 22, 1023 (1939).
5. Pike, M.H.: J. Mich. Med. Soc. 43, 581 (1944).
6. Claytor, T.A.: J. Am. Med. Assn. 104, 1028 (1935).
7. Petit, G., Champaix, J.: Arch. mal prof. 9, 311 (1948).

DICHLORODIFLUOROMETHANE

1000 ppm (Approximately 4950 mg/m^3)

The first published work on the toxicity of this compound appears to be that of Sayers et al. (1) who found that animals repeatedly exposed at 200,000 ppm developed tremors and unsteady gait. There was no gross pathology.

Fairhall (2) states that it has little toxic action.

It is probable that asphyxia would result before concentrations become sufficiently high to be toxic.

References
1. Sayers, R.R., Yant, W.P., Chornyak, J., and Shoaf, H.W.: U.S. Bureau of Mines, Reports of Investigations 3015 (1930).
2. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins, Baltimore, Md. (1949), p. 347.

1,1-DICHLOROETHANE

100 ppm (Approximately 400 mg/m^3)

Henderson and Haggard (1) conclude that the toxicity of this compound is similar to that of carbon tetrachloride.

Smyth (2) found that rats survive 8 hours at 4000 ppm but are killed at 16,000 ppm, indicating an acute toxicity half that of carbon tetrachloride. In repeated inhalation by rats and dogs, chronic toxicity somewhat less than that of carbon tetrachloride was found.

The most important effect of 1,1-dichloroethane is chronic poisoning of the liver. The 100 ppm limit, considering the distinctive odor and irritating properties, may be low enough to prevent injury. In view of the serious nature of carbon tetrachloride poisoning, more data on 1,1-dichloroethane are needed.

References
1. Henderson, Y. and Haggard, H.W.: Noxious Gases, Reinhold Publishing Co., New York, 2nd Edition (1943), p. 201.
2. Smyth, H.F., Jr.: Unpublished work by Chemical Hygiene Fellowship, Mellon Institute, Pittsburgh, Pa.

1,2-DICHLOROETHANE (ETHYLENE DICHLORIDE)

100 ppm (Approximately 400 mg/m^3)

Spencer and associates (1) studied the toxicity of ethylene dichloride in experimental animals. Single exposures caused depression of the central nervous system, pulmonary irritation and damage to the liver, kidney, and adrenal gland. They reported the significant chronic effects to be hepatic and/or renal damage. Maximal vapor concentrations without adverse effects were 400 ppm for the rabbit, 200 ppm for the rat, and 100 ppm for the monkey and guinea pig.

From these data, a threshold limit value of 100 ppm is interpreted to be probably without effect on man upon repeated exposure.

Reference
1. Spencer, H.C., Rowe, V.K., Adams. E.M., McCollister, D.D., Irish, D.D.: Arch. Ind. Hyg. & Occ. Med. 4, 482 (1951).

1,2-DICHLOROETHYLENE

200 ppm (Approximately 790 mg/m^3)

The most important effects of dichloroethylene are narcosis and irritation of the central nervous system (1); it is, however, a less potent narcotic than chloroform (2). There are variations in the toxicity of the *cis* as compared to the *trans* form. Although there is not sufficient evidence from controlled or accidental exposures to the vapor on which to base a threshold

limit value likely to preclude injury, it appears from available published data that 200 ppm is low enough to prevent narcosis.

References
1. Fairhall, L.T.: Industrial Toxicology, The Williams and Wilkins Co., Baltimore, Md., 2nd ed., (1957), pp. 215-216.
2. Lehmann, K.B. and Flury, F.: Toxicology and Hygiene of Industrial Solvents, Translated by King, E., Smyth, H.F., Jr., The Williams and Wilkins Co., Baltimore, Md., (1943), pp. 172-177.

DICHLOROETHYL ETHER

15 ppm (Approximately 90 mg/m^3)

According to Schrenk, Patty and Yant (1), 35 ppm is the highest concentration without serious response in guinea pigs after several hours exposure.

Cook (2) states that the value of 15 ppm has been generally accepted for prolonged exposure.

References
1. Schrenk, H.H., Patty, F.A., Yant, W.P.: Pub. Health Rept. 48, 1389 (1933).
2. Cook, Warren A.: Ind. Med. 14, 936 (1945).

DICHLOROMONOFLUOROMETHANE

1000 ppm (Approximately 4200 mg/m^3)

When guinea pigs were exposed up to 2 hours to dichloromonofluoromethane at concentrations ranging from 1.2 to 10.2 per cent by volume (12,000 to 102,000 ppm) (1), concentrations of 5.2 per cent and lower produced signs of irritation, tremors, incoordination, and irregular breathing. All animals recovered after exposure, except those killed for pathologic examination; no lesions were found in those killed. Animals exposed to a contentration of 10.2 per cent died and, on autopsy, congested lungs, congested kidneys, congested liver, discolored spleen, and a highly contracted heart were found.

On the basis of the low toxicity of this compound and information on the low toxicity of compounds of similar structure, a threshold limit value of 1000 ppm is recommended as an attainable value rather than a hazard limit.

Reference
1. The Comparative Life, Fire, and Explosion Hazards of Dichloromonofluoromethane (21), Underwriters' Laboratories' Report, Miscellaneous Hazard No. 2630 (1935).

1,1-DICHLORO-1-NITROETHANE

10 ppm (Approximately 60 mg/m^3)

Machle and associates (1) found concentrations of 25 ppm to be without lethal effect in exposures totaling 204 hours. Concentrations of 50 ppm were lethal after a total exposure of 18 3/4 hours. Irritant effects observed on exposure to higher concentrations were not observed in animals exposed to 25 ppm 1,1-dichloro-1-nitroethane. A limit of 10 ppm is believed to be sufficiently low to prevent injury in man.

Reference
1. Machle, W., Scott, E.W., Treon, J.F., Heyroth, F.F., and Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 27, 95 (1945).

2,4-D (2,4-DICHLOROPHENOXYACETIC ACID)

10 mg/m^3

Rowe and Hymas (1) conclude that 2,4-D has a low chronic toxicity. The oral LD_{50} values for several animals range from 100 to 1000 mg/kg with the latter the most commonly recognized (2). The threshold limit value of 10 mg/m^3, although derived by interpretation from animal feeding studies, would appear to be justified on the evidence of use experience for over 10 years.

References
1. Rowe, V.K., Hymas, T.A.: Ann. J. Vetern. Res. 15, 622 (1954).
2. Hill, D.: J. Ind. Hyg. & Tox. 29, 85 (1947).

DDT (2,2-bis (p-chlorophenyl)-1,1,1-trichlorethane

1 mg/m^3

The U.S. Public Health Service (1) reported that human volunteers breathed 423 mg/m^3 of DDT for periods of one hour a day for six days. The only ill effect was eye irritation. Barnes (2) found no illness reported among workers using DDT throughout the world. In spite of these reassuring reports, the known accumulation of DDT and its detoxication product DDE in animals and man (3) and the possibility that delayed ill effects may occur after years of exposure to low levels makes it advisable to set a low limit. DDT is half as toxic as lindane in single oral doses. A threshold limit of 1.0 mg/m^3 is suggested largely by analogy with lindane.

References
1. Neal, P.A., von Oettingen, W.F., Smith, W.W., Malmo, R.B., Dunn, R.G., Moran, H.E., Sweeney, T.R., Armstrong, D.W., White, W.G.: Pub. Health Rept., Suppl. 177, (1944).
2. Barnes, J.M.: Toxic Hazards of Certain Pesticides to Men, World Health Organization, Geneva, Monograph 16, (1953).
3. Mattson, A.M., et al.: Anal. Chem. 25, 1065 (1953); Hayes, J.W., et al.: J. Am. Med. Assn. 162, 890 (1956).

DICHLOROTETRAFLUOROETHANE

1000 ppm (Approximately 7000 mg/m^3)

Yant and co-workers (1) and Nuckolls (2) found that animals withstood 25,000 ppm of this compound for 2 hours with little discomfort. The chemical is so inert that asphyxia would occur before toxic effects appear. The 1000 ppm limit represents an attainable value rather than a hazard limit.

References
1. Yant, W.P., Schrenk, H.H., Patty, F.A.: U.S. Bureau of Mines, Rpts. of Invest. 3185 (1932).
2. Nuckolls, A.H.: Underwriters' Lab. Report, Miscellaneous Hazards 2375 (1933).

DIELDRIN (1,2,3,4,10,10-HEXACHLORO-6,7, EPOXY-1,4,4a,5,6,7,8,8a-OCTAHYDRO-1,4,5,8-DIMETHANO-NAPHTHALENE)

0.25 mg/m^3

Treon and Cleveland (1) found that 25 ppm of dieldrin in the diet of rats for two years did not shorten their lives. Ball and Kay (2) found that 50 ppm of dieldrin fed to rats in their diet for 57 weeks caused significant repression of the estrus cycle and increase of nonspecific serum esterase activity.

The most generally accepted oral LD_{50} for dieldrin is 70 mg/kg. In the absence of inhalation data, the threshold limit value must be established on the basis of analogy with DDT and lindane as has been done in the case of aldrin.

References
1. Treon, J.F., Cleveland, F.P.: J. Agr. Food Chem. 3, 402 (1955).
2. Ball, W.L., Kay, K.: Arch. Ind. Hyg. & Occup. Med. 9, 306 (1954).

DIETHYLAMINE

25 ppm (Approximately 75 mg/m^3)

Brieger and Hodes (1) reported that rabbits exposed to 100 and 50 ppm of monoethylamine, diethylamine and triethylamine seven hours a day, 5 days per week, for six weeks, survived. Rabbits exposed to 50 ppm diethylamine for the six-week period showed marked irritation of the cornea and of the lung tissue. The limit of 25 ppm is believed on the basis of animal experimentation to be sufficiently low to prevent injury to man.

Reference
1. Brieger, H., Hodes, W.A.: Arch. Ind. Hyg. & Occ. Med. 3, 287 (1951).

DIFLUORODIBROMOMETHANE

100 ppm (Approximately 860 mg/m^3)

Comstock et al. (1) exposed rats and dogs daily for six weeks at a concentration of about 2,300 ppm CBr_2F_2. More than half the rats died; the dogs showed rapid and progressive signs of intoxication with weakness and loss of balance after a few days of exposure. Autopsy findings were diffuse passive pulmonary congestion, some liver damage, and evidence of damage to the central nervous system.

Daily concentrations of 350 ppm were tolerated by rats and dogs for as much as seven months without signs of intoxication.

A threshold limit of 100 ppm is believed to be sufficiently low to prevent serious effects in man upon repeated exposure.

Reference
1. Comstock, C.C., Kerschner, J., Oberst, F.W.: Chemical Corps Medical Laboratories Research Report No. 180 (1953).

DIISOBUTYL KETONE (2,6-DIMETHYLHEPTANONE-4)

50 ppm (Approximately 290 mg/m^3)

Carpenter (1) reports the results of exposure of rats to concentrations of the vapor ranging from 125 to 1650 ppm for seven hours per day for 30 days.

Exposure to 125 ppm caused no adverse physiologic effects in rats or guinea pigs, although guinea pigs exposed to 250 parts per million showed a decrease in liver weight.

Exposure of human subjects to 50 and 100 ppm for three hours indicated that daily exposure to 100 ppm would be uncomfortable, whereas it was felt that exposure to 50 ppm would be comfortable for an eight-hour exposure. On the basis of the above data, a threshold limit for diisobutyl ketone vapors of 50 ppm is recommended.

References

1. Carpenter, C.P., et al.: Arch. Ind. Hyg. & Occ. Med. 8, 377 (1953).

DIMETHYLANILINE (N-DIMETHYLANILINE)

5 ppm (Approximately 25 mg/m^3)

Authorities differ as to the toxicity of dimethylaniline for man. Hamblin (1) compares the toxicity of dimethylaniline to diethylaniline which he states is quantitatively less toxic than aniline, but which produces very similar effects - notably methemoglobinemia. Like aniline, it is readily absorbed through the skin thus increasing the body burden from inhalation. Henderson and Haggard (2) likewise conclude dimethylaniline is much less severe but von Oettingen (3) points out that the depressant effect of dimethylaniline on the nervous system appears to be greater than that of aniline. According to Mayer (4) the necrotizing effect of dimethylaniline is much less severe than aniline. Few reports of industrial experience are available from which to form an accurate appraisal of its health hazards. Hamilton (5) refers to two workers who, following an apparently severe exposure, collapsed immediately, were unconscious for 8 hours and complained of visual disturbances and intense abdominal pain. Watrous (6) refers to dimethylaniline as presenting an industrial hazard similar to that of aniline.

In view of the seriousness with which certain authorities regard the health hazards of dimethylaniline and despite the evaluation of a few who consider the dimethyl derivative less toxic than aniline, it would appear reasonable to limit the exposure to dimethylaniline to that of aniline, namely, 5 ppm.

References

1. Hamblin, D.O.: Industrial Hygiene and Toxicology, F.A. Patty, Ed. Interscience Publications, N.Y. (1949).
2. Henderson, Y. and Haggard, H.W.: Noxious Gases, Reinhold Publishing Corp., N.Y. (1943), p. 227.
3. von Oettingen, W.F.: Pub. Health Bull. No. 271, Washington, D.C. (1941).
4. Mayer, R.E.: Arch. Gewerbepath. Gewerbehyg. 1, 436 (1930).
5. Hamilton, A.: Monthly Labor Rev. 8, 199 (1919).
6. Watrous, R.M.: Brit. J. Ind. Med. 4, 111 (1947).

DIMETHYLFORMAMIDE

20 ppm (Approximately 60 mg/m^3)

Toxicologic studies conducted by Smyth and Carpenter (1) showed that toxic effects may result from oral administration, skin absorption or inhalation of dimethylformamide. Studies on dogs, conducted by Fleming (2), provided information which was used as a basis for the threshold limit value of 20 ppm. The recommendation resulting from this study was that concentrations of dimethylformamide in the atmosphere should be kept below 50 ppm, preferably not above 20 ppm for an eight-hour daily exposure (2). Exposure to excessive concentrations may result in liver and kidney damage.

References
1. Smyth, H.F., Jr., Carpenter, C.P.: J. Ind. Hyg. & Tox. 30, 63 (1948).
2. E.I. DuPont de Nemours & Co.: Dimethylformamide Product Information. Grasselli Chemicals Department, Wilmington, Delaware.

1,1-DIMETHYLHYDRAZINE

0.5 ppm (Approximately 1 mg/m3)

Hodge (1) described exposures of rats to 1,1-dimethylhydrazine vapor at a concentration of 18.4 volumes per cent; all of six rats died before 37 minutes of exposure. Difficult respiration was observed in these animals. Jacobson et al. (2) found the LC_{50} values for single four-hour exposures to be about 250 ppm for rats, 170 for mice, and 390 for hamsters. All of 3 dogs exposed for 4 hours to about 110 ppm died after convulsing. Similar exposure to about 25 or 50 ppm caused respiratory distress and convulsions in some of the dogs. Pulmonary edema and hemorrhage were the only significant pathologic findings in dogs, rats, and mice.

Rinehart et al. (3) performed experiments on rats, mice and dogs involving repeated exposures for 6 hours a day, 5 days a week. All rodents dying from repeated exposure to 140 ppm had convulsions. Repeated exposure of dogs to 25 ppm caused ataxia and convulsive seizures in 2 of the 3 animals, and one of these died. No severe signs were seen in dogs exposed for 6 months to the vapor at 5 ppm, but at times some were lethargic and lost some weight. There was some anemia in the dogs exposed to 25 ppm, and a mild anemia in dogs exposed to 5 ppm. There was no evidence of liver dysfunction, but there was some deposition of hemosiderin in spleen, liver, lymph nodes and bone marrow at 25 ppm and in the spleen only at 5 ppm.

In the experimental studies cited, no significant evidence of liver damage, inferred to occur from analogy with hydrazine, was found. McKennis et al. (4) reported pharmacologic investigations on the action of the compound in experimental animals and concluded that 1,1-dimethylation of hydrazine results in a decreased ability of the hydrazine moiety to produce fatty livers. However, Shook and Cowart (5), describing some accidental exposures of man, found questionable evidence of liver dysfunction.

From these studies, a concentration of 0.5 ppm, or one tenth the concentration causing mild effects in dogs, is inferred as the threshold limit value.

References
1. Hodge, H.C.: Screening Toxicity Tests of Unsymmetrical Dimethylhydrazine, Division of Pharmacology and Toxicology, University of Rochester School of Medicine and Dentistry.
2. Jacobson, K.H., Clem, J.H., Wheelwright, H.J., Jr., Rinehart, W.E., Mayes, N.: Arch. Ind. Health 12, 609 (1955).
3. Rinehart, W.E., Donati, E., Greene, E.A.: Am. Ind. Hyg. Assn. J. 21, 207 (1960).

4. McKennis, H., Yard, A.S., Weatherby, J.H., Haag, H.B.: Chemical Corps Medical Laboratories Contract Report No. 64 (September, 1955), Army Chemical Center, Maryland.
5. Shook, B.S., Cowart, O.H.: Ind. Med. & Surg. 26, 333 (1957).

DIMETHYL SULFATE

1 ppm (Approximately 5 mg/m^3)

Smyth (1) found rats survive a four-hour inhalation at 15 ppm but die at 30 ppm in the same period.

Flury and Zernik (2) found that 13 ppm seriously poisoned rats in 20 minutes.

Browning (3) quotes work in which cats died in 1½ weeks at 195 ppm exposures. Monkeys, however, lived only 3 days at 26 ppm.

Smyth (1) concludes that whereas the limit of 1 ppm appears to be sufficiently low to protect against lung injury it may not be low enough to avoid bronchial irritation.

References

1. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).
2. Flury, F. and Zernik, F.: Schadliche Gase und Dampfe. J. Springer, Berlin (1931), p. 369.
3. Browning, Ethel: Toxicity of Industrial Organic Solvents, Her Majesty's Stationery Office, London (1952), p. 396.

DINITROBENZENE (All Isomers)

1 mg/m^3

A vast history of industrial experience with DNB poisoning has been reported by von Oettingen (1), and Hunter (2). This experience indicated DNB to be a highly toxic substance, exhibiting various signs and symptoms of involvement of the blood, although fatalities rarely occurred from exposure. Ready absorption of DNB through the skin is a well emphasized factor in the toxicity and hazard of this substance. Unfortunately no reference to the degree of exposure which produced these symptoms are to be found in these historical reviews. Moreover, currently there are no published reports, either in man or in animals, at measured levels of exposure. The basis for setting the limit for DNB must, therefore, be arrived at for the present on the basis of an estimate of the comparative toxicities of polynitro aromatic compounds relative to those of the mononitro derivatives.

Comparative acute LD_{50} values for the dinitro aromatic derivatives and the corresponding mononitro compounds by various routes in various animals show almost without exception that the dinitro compounds are more toxic by a factor of at least 5 (3). The LD values for the dinitro derivatives of benzene, toluene, phenol, o-cresol and alpha-naphthol range from 5-60 mg/kg, classifying these substances in the "Highly Toxic" category; the LD_{50} values available for the corresponding mononitro derivatives, benzene and phenol, all that are available, range from 20-1000 mg/kg or greater.

Accordingly, a tentative threshold limit for the dinitrobenzene isomers of 1 mg/m^3 would appear reasonable.

References
1. von Oettingen, W.F.: Pub. Health Bull. 271, Washington, D.C. (1941).
2. Hunter, Donald: The Diseases of Occupations, Little, Brown & Co., Boston (1955).
3. Handbook of Toxicology, Wm. S. Spector, Ed., Vol. I, WADC Tech. Rep. 55, 16 (1955).

DINITRO-o-CRESOL

0.2 mg/m^3

Harvey, Bidstrup and Bonnell (1) have found that when blood levels of dinitro-o-cresol exceed 15-20μg/g blood, symptoms of poisoning appear. The study was made on 5 human volunteers. These levels indicate considerable accumulation of the agent from repeated daily exposure, because the blood levels found were in excess of the amount attainable from a single daily dose. The 0.2 mg of dinitro-o-cresol per cubic meter of air can be shown to be based on calculations that take into account the recognized accumulation from long-repeated, daily dosage and in addition appear to offer an extraordinarily large factor of safety.

Reference
1. Harvey, D.G., Bidstrup, P.L., Bonnell, J.A.L.: Brit. J. Med. Pt. 2, 16 (1951).

DINITROTOLUENE

1.5 mg/m^3

The maximal safe concentration suggested by the Medical Branch of the Eighth Service Command, in its publication "The Toxicology and Prevention of Industrial Disease" is 1.5 milligrams per cubic meter of air.

Early symptoms resulting from exposure to this material include headache, fatigue, nausea, vomiting, marked chest pain and loss of weight. More advanced symptoms are jaundice and secondary anemia.

von Oettingen (1) concluded, in reviewing data from animal experiments conducted by others, that dinitrotoluene has some toxic effects and that these are of similar character as observed with other aromatic nitro compounds but become manifest only after the absorption of larger quantities.

Reference
1. von Oettingen, W.F.: The Aromatic Amino and Nitro Compounds, Their Toxicity and Potential Dangers, Pub. Health Bull. 271, Washington, D.C. (1941).

DI-PROPYLENE GLYCOL METHYL ETHER

100 ppm (Approximately 600 mg/m^3)

The first pharmacologic studies of di-propylene glycol methyl ether were made in dogs by the intravenous route by Shideman and Procita (1), who found the compound to be a moderate depressant for the central nervous system and heart; death occurred from respiratory arrest at doses of from 0.5 to 0.6 ml/kg.

A more extensive evaluation of the toxicity and hazards of the di-propylene derivative and the related mono and tri-propylene ethers was made by Rowe

et al. (2) who found the di-propylene ether to be on the border line between slightly and practically nontoxic by the oral route; a single acute oral LD_{50} was 5.4 ml/kg for rats. No single dose was found that would kill a rabbit by application to the skin, although some transient weight loss was observed and some narcosis. Skin absorption was evident, however, as 65 repeated doses during 90 days resulted in death in a significant number of the exposed rabbits at levels of 3 ml/kg and above. There was a possibility that the compound activated latent respiratory infection in the exposed animals. Repeated 7-hour daily inhalation exposures of 4 animal species, including the monkey, at levels of between 300 and 400 ppm produced mild ill effects in animals, consisting of narcosis and changes in the liver and lung. These levels, however, were very disagreeable to man; levels which might be voluntarily tolerated without complaint were considered to be safe with respect to organic injury.

The substance was found not to be an irritant to the skin and patch tests on 250 human subjects produced no sensitization.

References
1. Shideman, F.E., Procita, L.: J. Pharm. Exptl. Therap. 102, 79 (1951).
2. Rowe, V.K., McCollister, D.D., Spencer, H.C., Oyen, F., Hollingsworth, R.L., Drill, V.A.: Arch. Ind. Hyg. & Occ. Med. 9, 509 (1954).

DIOXANE (DIETHYLENE DIOXIDE)

100 ppm (Approximately 360 mg/m^3)

Smyth (1) found rabbits particularly susceptible, repeated inhalation at 800 ppm dioxane killing some with kidney injury within 30 days. The most important effect of dioxane inhalation is chronic poisoning centering in the liver and kidney. The 100 ppm threshold limit can be inferred from results of repeated animal exposure studies. It appears to be sufficiently low to prevent injury.

Browning (2), in referring to the work of Fairly, Linton and Ford-Moore, points out that lesions in the liver and kidney were produced in animals exposed at low concentrations of dioxane over long periods. The lesions were present after exposure at all concentrations, even the nonlethal 1 in 500 and 1 in 1000, (0.2 and 0.1 percent by volume, respectively).

Yant et al. (3) summarize the results of studies made by several investigators and describe work done by the Bureau of Mines on the toxicity of dioxane. Animal experiments described in the resume show that the toxicity of dioxane when inhaled, ingested or given by subcutaneous or intravenous administration is of a comparatively low order, but serious harm can be produced by large dosages. The primary pathologic changes are damage to the kidneys and liver. Injury to the kidneys and liver of animals has been produced by repeated exposure to 0.1 percent vapor by volume, and by absorption through the skin. Although the only serious trouble that had been reported was acute, poisoning attributed to several exposures to high concentrations of dioxane, the authors conclude that the possibility of chronic poisoning from carlessness in the use of this chemical exists.

References
1. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).
2. Browning, E.: Toxicity of Industrial Organic Solvents, Chem. Pub. Co., Inc., New York (1953), p. 269.
3. Schrenk, H.H., Yant, W.P.: J. Ind. Hyg. & Tox. 18, 448 (1936).

EPN (O-ETHYL-O-p-NITROPHENYL THIONOBENZENE PHOSPHATE)

0.5 mg/m^3

The oral LD_{50} of EPN for small animals was found to range from 7-33 mg/kg and 75 ppm were found to have no effect on rats by Hodge and co-workers (1). Because the principal effect of EPN is that of cholinesterase inhibition and it appears to be about 1/5 as toxic as the well-documented parathion, its threshold limit has been set at 0.5 mg/m^3.

Reference

1. Hodge, H.C., Maynard, E.A., Horwitz, L., DiStefano, V., Downs, W.V., Jones, C.K., Blanchet, H.J.: J. Pharm. Exptl. Therap. 112, 29 (1954).

ETHYL ACETATE

400 ppm (Approximately 1400 mg/m^3)

Smyth and Smyth (1) reported animals could withstand a concentration of ethyl acetate of 2000 ppm for 65, 4-hour exposures without apparent ill effects as measured by lack of change in body weight, and in red and white blood counts. Ethyl acetate is only mildly narcotic even at concentrations well in excess of 46 mg/l. Unacclimated subjects, however, found the odor objectionably strong at 200 ppm, and mild eye, nose, and throat irritation at 400 ppm (2).

The threshold limit of 400 ppm is believed to provide a level with a large safety factor from the standpoint of health, but may prove mildly irritating to some workers unaccustomed to the exposure.

References

1. Smyth, H.F., Smyth, H.F., Jr.: J. Ind. Hyg. 10, 261 (1928).
2. Nelson, K.W., Ege, J.F., Jr., Ross, M., Woodman, L.E., Silverman, L.: J. Ind. Hyg. & Tox. 25, 282 (1943).

ETHYL ACRYLATE

25 ppm (Approximately 100 mg/m^3)

The work of Treon and associates (1) has shown that the "no effect" inhalation concentration for monkeys and 3 rodent species was approximately 75 ppm for ethyl acrylate. The corresponding "no effect" level from inhalation by animals found by Smyth (2) for ethyl acrylate was approximately 50 ppm. Both investigators find that 25 ppm for ethyl acrylate justifiable as a threshold limit.

References

1. Treon, J.F., Sigmon, H., Wright, H., Kitzmiller, K.V.: J. Ind. Hyg. 31, 317 (1949).
2. Smyth, H.F., Jr.: Written communication to committee member, December 19, 1955.

ETHYL ALCOHOL

1000 ppm (Approximately 1900 mg/m^3)

Henderson and Haggard (1) consider concentrations of ethyl alcohol vapor

ranging from 250 to 1064 ppm safe for exposure during the working day. The vapors, even in low concentrations, are irritating to the eyes and upper respiratory tract. This feature of ethyl alcohol is more important in setting the standards for exposure than the secondary toxic effects from the absorbed alcohol.

Browning (2), in reporting on experiments on man, observes that the inhalation of 1.9 mg/liter (1000 ppm) causes slight symptoms of poisoning, 9.5 mg/liter (5000 ppm) causes strong stupor and morbid sleepiness. The inhalation of alcohol vapors causes local irritating effects on the eyes, headaches, sensation of heat, intraocular tension, stupor, fatigue, and a great need for sleep.

References
1. Henderson, Y. and Haggard, H.W.: Noxious Gases, Reinhold Publishing Corp., New York (1943), p. 219.
2. Browning, E.: Toxicity of Industrial Organic Solvents, Chemical Publishing Co., Inc., New York (1936), p. 220.

ETHYLAMINE

25 ppm (Approximately 45 mg/m^3)

Brieger and Hodes (1) showed that 100 and 50 ppm ethylamine produced irritation of the cornea and lung tissue in rabbits exposed for seven hours a day, five days a week for six weeks. Rabbits exposed to 50 ppm showed no corneal injury until after two weeks.

Reference
1. Brieger, H. and Hodes, W.A.: Arch. Ind. Hyg. & Occ. Med. 3, 287 (1951).

ETHYLBENZENE

200 ppm (Approximately 870 mg/m^3)

Yant and associates (1) reported that ethylbenzene vapors are irritating to the eyes and upper respiratory passages in concentrations below those causing serious response. Experimental exposure of six men showed that a concentration of 1000 ppm was very irritating to the eyes but gradually decreased on continued exposure until, after a minute or two, it was scarcely noticeable. At 2000 ppm, one observer stayed in the atmosphere five minutes and found that irritation to the eyes and throat gradually disappeared, but vertigo developed.

Browning (2) reports the observations of Oettel (3) that ethylbenzene is the most severe skin irritant of the benzene series. Its irritant effect on the eyes, occurring at concentrations of about 200 ppm, gives warning of dangerous concentrations.

References
1. Yant, W.P., Schrenk, H.H., Waite, C.P., Patty, F.A.: Pub. Health Rept. 45, 1241 (1930).
2. Browning, E.: Toxicity of Industrial Organic Solvents, Chem. Pub. Co., Inc., New York (1953), p. 64.
3. Oettel, H.: Arch. Exp. Path. Pharmak. 183, 641 (1936).

ETHYL BROMIDE

200 ppm (Approximately 890 mg/m^3)

According to Sayers and co-workers (2), 3200 ppm ethyl bromide for 9 hours was fatal to guinea pigs. Exposure to 1700 ppm for 13-1/2 hours caused no immediate symptoms but one of six animals died following exposure. von Oettingen (2), quoting the work of Bachem, states that 3500 ppm is the minimal lethal concentration for mice. Cook (3) suggests 400 ppm as a tentative value for the threshold limit. Patty (4) suggests 500 ppm as the maximal practical working level. The limit of 200 ppm is in line with other monohalogenated ethyl derivatives.

References
1. Sayers, R.R., Yant, W.P., Thomas, B.G.H., Berger, L.B.: Pub. Health Bull. No. 185, U.S.P.H.S. (1929).
2. von Oettingen, W.F.: The Halogenated Hydrocarbons--Toxicity and Potential Dangers, U.S. Dept. of Health, Education and Welfare, P.H.S. (1955).
3. Cook, W.A.: Ind. Med. 14, 936 (1945).
4. Patty, F.A., Ed.: Industrial Hygiene and Toxicology, Vol. II, Interscience Publishers, New York (1949), p. 800.

ETHYL CHLORIDE

1000 ppm (Approximately 2600 mg/m^3)

Lehmann and Flury (1) have reviewed ethyl chloride toxicity. The vapor produced narcosis and slight symptoms of irritation. Ethyl chloride is less toxic than methyl chloride and chloroform. It is easily absorbed through mucous membranes and the lungs and through the skin. It can produce narcosis in a very short period of time. Ethyl chloride is quickly eliminated from the body; most of this elimination occurs through the lungs. Because of its extensive use as an anesthetic, the concentrations causing narcotic effects in humans are known. Inhalation of 3.36 volumes per cent cause a quickly increasing toxic effect after 30 seconds; 2.5 per cent cause incoordination; 1.9 per cent cause a weak analgesia after 12 minutes; and 1.3 per cent cause slight symptoms of poisoning.

Based on these data, a threshold limit value of 1000 ppm or 0.1 volumes per cent, is recommended.

Reference
1. Lehmann, K.E. and Flury F.: Toxicology and Hygiene of Industrial Solvents, Translated by King, E. and Smyth, H.F., Jr., The Williams & Wilkins Co., Baltimore, Md. (1943), pp. 154-157.

ETHYL ETHER

400 ppm (Approximately 1200 mg/m^3)

Nelson et al. (1) reported that complaints of nasal irritation began at 200 ppm, and that a concentration of 300 ppm was objectionable as a working atmosphere.

Henderson and Haggard (2) estimate that, at a concentration of 400 ppm ether, a man of average weight would absorb a maximum of 1.25g and the concentration in the blood would be 0.018g/liter. This concentration in the blood is not associated with any signs of intoxication. These workers state further that the inhalation of 2000 ppm, if continued to equilibrium, would result in the absorption of some 6.25g ether, and a concentration of 0.09g/liter of blood, which would cause dizziness in some persons.

In view of data presented above and the fact that persons exposed experimentally did not have the opportunity to develop the tolerance which has been observed in workers, a threshold limit of 400 ppm is suggested. Regular exposure to this concentration should cause no demonstrable injury to health.

References
1. Nelson, K.W., Ege, J.F., Ross, M., Woodman, L.E., Silverman, L.: J. Ind. Hyg. & Tox. 25, 282 (1943).
2. Henderson, Y. and Haggard, H.W.: Noxious Gases (2nd Ed.), Reinhold Publishing Corp., New York (1943), p. 195.

ETHYL FORMATE

100 ppm (Approximately 300 mg/m^3)

Flury and Zernik (1) state that the narcotic dose is the same as the lethal dose - 10,000 ppm. These authors also state that in man a concentration of 330 ppm produces a slight irritation of the eyes and a rapidly increasing nasal irritation.

According to Browning (2), animals exposed to 16 mg/liter (5000 ppm) showed eye irritation and salivation. Exposure of cats to 32 mg/liter (10,000 ppm) for 80 minutes resulted in deep narcosis after 75 minutes and death after 90 minutes.

References
1. Flury, F. and Zernik, F.: Schadliche Gase, Springer, Berlin (1931), p 375.
2. Browning, E.: Toxicity of Industrial Organic Solvents, Chem. Pub. Co., Inc., New York (1953), p. 264.

ETHYL SILICATE (TETRAETHYL ORTHOSILICATE)

100 ppm (Approximately 850 mg/m^3)

Smyth and Seaton (1) found that exposure to approximately 2000 ppm is the maximal exposure for 60 minutes without the production of serious disturbances in guinea pigs, and rats. Five hundred ppm is the maximal exposure for several hours without causing serious disturbances. In man, 1,200 ppm is lacrimatory, and 250 ppm causes slight irritation of the eyes and nose. Eighty-five ppm may be detected by odor.

Pozzani and Carpenter (2) showed that exposure of rats to 400 ppm ethyl silicate for 7 hours a day for 30 days resulted in significant mortality and kidney, liver and lung damage in the survivors. Exposure of rats, guinea pigs and mice, however, at 88, 50 and 23 ppm for 7 hours a day, five days per week, for 90 days resulted only in a decrease in the kidney weights of mice exposed at the 88 ppm level.

Kasper, McCord and Fredrick (3) showed that animals exposed to 164 ppm ethyl silicate, eight hours per day for 17 days did not show weight increases equal to those of the controls.

References
1. Smyth, H.F., Jr., Seaton, J.: J. Ind. Hyg. & Tox. 22, 288 (1940).
2. Pozzani, U.C., Carpenter, C.P.: Arch. Ind. Hyg. & Occ. Med. 4, 465 (1951).
3. Kasper, J.A., McCord, C.P., Fredrick, W.G.: J. Ind. Med. 6, 660 (1937).

ETHYLENE CHLOROHYDRIN

5 ppm (Approximately 16 mg/m^3)

Koelsch (1) subjected animals to a few (2 to 8) repeated exposures of ethylene chlorohydrin in concentrations ranging from 700 to 800 ppm with fatal results in all cases.

Goldblatt (2) found that repeated exposure of 15 minutes a day at concentrations of 900 to 1000 ppm were fatal to rats within a few days.

Dierker and Brown (3) reported a fatal case of ethylene chlorohydrin poisoning resulting from a two hour exposure to a concentration estimated at 300 ppm.

Goldblatt and Chiesman (2) investigated two fatal and several non-fatal cases of intoxication by ethylene chlorohydrin. The average concentration in the non-fatal cases was 18 ppm. They suggest 2 ppm as a target concentration.

References
1. Koelsch, F.: Zentr. Gewerbehyg, Unfallverhut. 14, 312 (1927).
2. Goldblatt, M.W., Chiesman, W.E.: Brit. J. Ind. Med. 1, 207 (1944).
3. Dierker, H., Brown, P.G.: J. Ind. Hyg. & Tox. 26, 277 (1944).

ETHYLENEDIAMINE

10 ppm (Approximately 30 mg/m^3)

Carpenter et al. (1) have made a limited comparison of acute inhalation toxicities and found this substance to be from 1/40th to 1/100th as toxic as ethylene imine (q.v.) in a single 8-hour inhalation exposure. Later work from the same laboratories (2) showed that ethylenediamine produces no toxic effects at 132 ppm in rats other than a slight epilation. Human subjects found 100 ppm for a few seconds to be inoffensive but higher concentrations, 200 and 400 ppm, produced noticeable irritation to the nasal mucosa.

Dernehl (3) studied industrial exposures of a number of workmen over a 4-year period to a mixture of alkyl diamines which included ethylenediamine. Unfortunately for the present purpose, no record of the degree of exposure is given. The conclusions of this study were: (1) ethylene amines are an important cause of dermatitis, (2) the evidence suggested that these substances are both irritative and allergenic and that the allergenic effect may manifest itself in some susceptible individuals in the respiratory tract. Because of the hypersensitivity to these diamines, it becomes difficult, if not impossible, to establish a threshold limit that will insure prevention of these hypersensitive responses.

The limit of 10 ppm should reduce the incidence of such a response materially and should at the same time prevent other irritative and systemic effects in workers.

References
1. Carpenter, C.P., Smyth, H.F., Jr., Shaffer, C.B.: J. Ind. Hyg. & Tox. 30, 2 (1948).
2. Pozzani, U.C., Carpenter, C.P.: Arch. Ind. Hyg. & Occ. Med. 9, 223 (1954).
3. Dernehl, C.U.: Ind. Med. & Surg. 29, 541 (1951).

ETHYLENE DIBROMIDE (1,2-DIBROMOETHANE)

25 ppm (Approximately 190 mg/m^3)

Rowe and associates (1) studied the toxicity of ethylene dibromide in experimental animals, and found the vapor to cause depression of the central nervous system, pulmonary irritation, and hepatic and renal damage on single exposure, and pulmonary irritation and hepatic damage on repeated exposure. Animals exposed for 7 hours a day, 5 days a week, for about 6 months tolerated 25 ppm without adverse effects, but they did not tolerate well similar exposure to 50 ppm.

Based on these data, threshold limit value of 25 ppm is recommended.

Reference
1. Rowe, V.K., Spencer, H.C., McCollister, D.D., Hollingsworth, R.L., Adams, E.M.: Arch. Ind. Hyg. & Occ. Med. 6, 158 (1952).

ETHYLENE IMINE

5 ppm (Approximately 9 mg/m^3)

The effects of ethylene imine on man were reported by Denehy and Pflaum (1) but no data on atmospheric concentrations were presented.

Carpenter, Smyth and Shaffer (2) reported deaths to some animals following exposure to as little as 25 ppm for 4 to 8 hours. They found that the animals that survived had minimal symptoms.

According to Silver and McGrath (3) the modes of toxic action of ethylene imine and ammonia are quite different. They found the LC_{50} for a 10 minute exposure to ethylene imine to be about 2300 ppm. It is believed that 5 ppm is sufficiently low to prevent acute intoxication. Whether ethylene imine is radiominetic in man is not known.

References
1. Denehy, J.P. and Pflaum, J.: Ind. & Eng. Chem. 30, 778 (1938).
2. Carpenter, C.P., Smyth, H.F., Jr., Shaffer, C.B.: J. Ind. Hyg. & Tox. 30, 2 (1948).
3. Silver, S.D., McGrath, F.P.: J. Ind. Hyg. & Tox. 30, 7 (1948).

ETHYLENE OXIDE

50 ppm (Approximately 90 mg/m^3)

The main toxic problems from ethylene oxide encountered in industry result from cutaneous contact with aqueous solution of the compound. These solutions cause primary irritation and sensitization of the skin (1,2).

Chronic intoxication of men by ethylene oxide has not been reported. However, Hollingsworth and co-workers (3) and Jacobson and co-workers (4) have described the effects of repeated exposures of laboratory animals to ethylene oxide vapor. In the study reported by Hollingsworth, et al. (3), there was irritation of the respiratory passages, including the lungs, in animals repeatedly exposed at 204, 357, and 841 ppm; in addition, there were growth depressions, organ weight changes and organic injury to the livers, kidneys, adrenals, and testes of rats and guinea pigs. There were delayed but reversible paralysis and muscular weakness of the hind limbs of rats, rabbits, and monkeys.

Repeated exposures for 6 or 7 months at 113 ppm and 49 ppm were without effect other than a growth depression and a moderate increase in lung weight of rats exposed at 113 ppm.

In the investigations described by Jacobson, et al. (4) repeated exposures of rats at 400 ppm caused respiratory irritation, weight loss, weakness and death. Repeated exposures of dogs at 290 ppm caused muscular atrophy, weakness, and anemia. Repeated exposures of dogs, rats and mice at 100 ppm for 6 months caused no significant effects; however, there was a slight anemia in the dog.

The results from both of these investigations of the chronic toxicity of ethylene oxide indicate that a threshold limit value of 50 ppm offers an adequate margin of safety from ostensible systemic effects.

References
1. Sexton, R.J., Henson, E.V.: J. Ind. Hyg. & Tox. 31, 296 (1949).
2. Sexton, R.J., Henson, E.V.: Arch. Ind. Hyg. & Occ. Med. 2, 549 (1950).
3. Hollingsworth, R.L., Rowe, V.K., Oyen, F., McCollister, D.D., Spencer, H.C.: Arch. Ind. Health 13, 217 (1956).
4. Jacobson, K.H., Hackley, E.B., Feinsilver, L.: Arch. Ind. Health 13, 237 (1956).

FERBAM (FERRIC DIMETHYL DITHIO-CARBAMATE)

15 mg/m^3

Hodge, Maynard, Downs, Blanchet and Jones (1) reported the oral LD_{50} for rats to be more than 17 g/kg. Guinea pigs and rabbits were found to be somewhat less sensitive. Rats tolerated 0.01% in their diet for 30 days without effect, whereas 0.5% was required to kill them. Dogs were not injured by 25 mg/kg per day fed for six months. The inhalation effect of Ferbam in man appears to be the upper respiratory tract irritation of an inert dust.

The 15 mg/m^3 value is in line with these newer data.

Reference
1. Hodge, H.C., Maynard, E.A., Downs, W., Blanchet, H.J., Jr.: J. Amer. Pharm. Assn. Sci., Ed. 41, 662 (1952).

FERROVANADIUM

1 mg/m^3

The only published information on which a safe exposure limit may be based comes from Russian investigations of exposed workers and limited animal experiments. Roshchin (1) found that ferrovanadium dust gave rise in animals to serious pathologic changes only at very high concentrations and thus is less toxic than vanadium pentoxide. No acute intoxication occurred in animals exposed to concentrations as high as 10 mg/l in 1-hour exposures on alternate days for 2 months.

The limit of 1 mg ferrovanadium/m^3 of air would appear to provide freedom from injury from exposure, and to provide a considerable margin of safety in comparison with the limit of 0.5 mg/m^3 for vanadium pentoxide. The content of V_2O_5 associated with ferrovanadium dust during its manufacture is small.

Reference
1. Roshchin, I.V.: Gig. i. Sanit. 11, 49 (1952).

FLUORIDE

2.5 mg/m^3

Ronzani (1) in 1909 showed that exposure of animals to 3 ppm hydrogen fluoride for 30 days resulted in no intoxication. Roholm (2) in 1926 suggested that 15-25 mg/day as the probable toxic dose of cryolite. Later in 1937 Roholm (3) reported that fluorosis of the bones occurred among cryolite workers following prolonged exposure at 2 to 3 ppm. Subsequent industrial experience of Irwin (4) extending over a period of 2 to 3 decades, that included measurement of air and urinary fluoride levels, and x-ray examination for fluorosis, showed that no significant amount of bone changes occurred in workers provided the fluoride air levels were below 4-5 ppm (approximately 3-4 mg/m^3). Gaseous and particulate fluoride concentrations were approximately equal. A small incidence of slight bone changes occurred after 20 years of exposure when fluoride values exceeded 5 ppm and corresponding urinary fluoride averaged 6.3 mg F/day. These values are in line with distribution and excretion studies made by Largent (5).

References
1. Ronzani, E.: Arch. F. Hyg. 70, 217 (1909).
2. Roholm, K.: Klin. Woch. 15, 1425 (1926).
3. Roholm, K.: Fluorine Intoxication, Lewis & Co., London (1937).
4. Irwin, D.: Presentation at Symp. on Fluorides, Kettering Lab., Cincinnati, April 1954.
5. Largent, E.: Arch. Ind. Hyg. & Occ. Health 6, 37 (1952).

FLUORINE (F_2)

0.1 ppm (Approximately 0.2 mg/m^3)

The threshold limit of 0.1 ppm for elemental fluorine gas was set on the basis of a series of acute and subacute (30-day) exposure studies of animals by Stokinger et al. (1). The subacute toxicity of elemental F_2 gas was found to be distinct from that of hydrogen fluoride gas in 2 respects; 1. F_2 gas was approximately 10-fold more toxic than HF; 2. A variation in species susceptibility was noted; dogs were particularly susceptible to F_2, far less to HF; rats were less susceptible to F_2, especially so to HF.

In four, 30-day inhalation exposure studies at concentrations of fluorine of 25, 8, 3 and 0.8 mg/m^3 (16, 5, 2 and 0.5 ppm), fluorine was tolerated at 0.5 ppm. By comparison, hydrogen fluoride was tolerated at 7 ppm (6 mg/m^3). By "tolerated" is meant that few toxic effects were observed or that those effects that were observed were mild in degree. In dogs, the most susceptible species, no consistent, significant damage to pulmonary or renal tissue occurred; in rabbits, little or no pulmonary and no significant changes in blood NPN and calcium levels and no significant hematologic changes. On the basis of this evidence, the threshold limit of 0.1 ppm F_2 was set to provide a working environment of probable safety from the effects of F_2 and to incorporate a reasonably large factor of safety.

Reference
1. Stokinger, H.E. et al.: Pharmacology and Toxicology of Uranium Compounds, Voegtlin and Hodge, Eds., NNES, VI - 2 McGraw-Hill Co., (1949), Ch. 17, p. 1021.

FLUOROTRICHLOROMETHANE

1000 ppm (Approximately 5600 mg/m^3)

The only work on this compound appears to be that of Nuckolls (1), who found occasional tremors only in animals exposed at from 22,000 to 25,000 ppm. It is apparently almost inert physiologically. The 1000 ppm threshold limit probably allows a large margin of safety.

Reference

1. Nuckolls, A.H.: The Comparative Life, Fire and Explosion Hazards of Common Refrigerants, Underwriters Lab. Report, Miscellaneous Hazards 2375 (1933).

FORMALDEHYDE

5 ppm (Approximately 6 mg/m^3)

Formaldehyde irritates the eyes, respiratory tract and skin (1,2). Elkins (2,3) suggests that men develop tolerance to these irritant effects, but Henderson and Haggard (1) suggest that persons may become more susceptible on repeated exposure. These latter authors cite data indicating that a threshold limit value of 20 ppm is appropriate. However, Elkins (3) reports complaints from persons exposed to an atmosphere where the maximal concentration was from 5 to 6 ppm; eye irritation was noted in "unacclimated" persons exposed to much lower concentrations. He indicates that regular workers can tolerate without difficulty concentrations that are intolerable to outsiders, and suggests that the maximal acceptable concentration might be based on cutaneous, rather than on respiratory effects.

The threshold limit value of 5 ppm is inferred to be low enough to prevent respiratory injury, but not necessarily to prevent subjective evidence of irritation. Irritation in the form of itching eyes, dry and sore throats, disturbed sleep, and unusual thirst on awakening, has been reported in a few workers at levels of the order of 1 to 2 ppm formaldehyde (4,5). The threshold limit of 5 ppm obviously does not provide freedom from irritation to all exposed individuals.

References

1. Henderson, Y. and Haggard, H.W.: Noxious Gases, Reinhold Publishing Corp., New York, 2nd and Rev. Ed. (1943), p. 128.
2. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York (1950), pp. 116 and 231.
3. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York, 2nd Ed. (1959), p. 118.
4. Morrill, E.E., Jr.: Formaldehyde Exposure from Paper Process Solved by Air Sampling, Air Cond. Heat. Vent. 53, 94 (1961).
5. Bourne, H.G., Seferian, S.: Formaldehyde in Wrinkle-Proof Apparel, Ind. Med. & Surg. 28, 232 (1959).

FURFURAL

5 ppm (Approximately 20 mg/m^3)

Information is conflicting regarding the toxicity of furfural vapor. Gardner (1) concluded that the physiologic effects of the vapor were relatively mild and similar to that of butyl alcohol. A more recent report (2) describes

numbness of the tongue and mucous membranes of the mouth, absence of taste sense, and difficulties in breathing experienced in a furfural plant where there was inadequate ventilation. From the point of view of comfort, moreover, another report (3) showed that when the air contained from 0.007 to 0.053 mg furfural per liter of air, headaches, itching of the throat, and red and weeping eyes occurred. In addition, there has been a report (4) that furfural is damaging to the eyesight of some individuals.

On the other hand, Dunlop and Peters (5) state in their monograph "The Furans", 1953, that though many millions of pounds of furfural have been used in solvent and refining operations and in the synthetic resin industry during a 15-year period, furfural had not been considered hazardous to health under ordinary plant conditions (i.e. with adequate ventilation). Only occasional individual sensitivity was encountered.

From one report on furfural in which worker response is related to measured air concentrations (3) a level of 5 ppm is set on a comfort basis. It may not be sufficiently low to ensure freedom from respiratory sensitization.

References
1. Gardner, H.A.: Paint and Varnish Mfgrs. Assoc. of U.S., No. 250 (Oct., 1925).
2. Bugyi, B., Lepold, J.: Nepegeazsegugy 30, 229 (1949). (Hungarian); Ind. Hyg. Fndn. Abstr. 60 (1952).
3. Korenman, I.M., Resnik, I.B.: Arch. F. Hyg. 104, 344 (1930).
4. Kuhn, H.S.: Industrial Ophthalmology, C.V. Mosby, St. Louis (1944), p. 272.
5. Dunlop, A.P., Peters, F.N.: The Furans, ACS Monograph Number 119, Reinhold Publishing Corp. (1953).

FURFURYL ALCOHOL

50 ppm (Approximately 200 mg/m^3)

Mice have been exposed (1) for 10 minutes to 700 ppm of furfuryl alcohol with no toxic effects. Among rats exposed by Comstock and Oberst (2) for longer periods to the same concentration, 16% died after a 4-hour exposure and 25% after an 8-hour exposure. Rats and mice were exposed daily for six weeks to 19 ppm of furfuryl alcohol; only one rat and one mouse died. No important signs of toxicity were noted. Weight gain among the survivors was similar to that of controls. Deaths were not attributed to exposure.

References
1. NDRC, Unpublished report (February, 1942).
2. Comstock, C.C., Oberst, F.W.: Chemical Corps Medical Laboratories Research Report No. 139 (1952).

GASOLINE

500 ppm (Approximately 2000 mg/m^3)

Sayers and associates (1) reported dizziness in human test subjects at 700 ppm.

Drinker and associates (2) found slight respiratory tract irritation and headache in human subjects at 1000 ppm.

Elkins (3) found no sensory response, in industrial exposures, to 660 to 800 benzine.

References
1. Sayers, R.R., Fieldner, A.C., Yant, W.P., Thomas, B.G.H.: U.S. Bureau of Mines Monograph No. 2 (1927).
2. Drinker, P., Yaglou, C.P., Warren, M.F.: J. Ind. Hyg. & Tox. 25, 225 (1943).
3. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York (1950), p. 99.

HEPTANE (n-HEPTANE)

500 ppm (Approximately 2000 mg/m^3)

Patty and Yant (1) reported 1000 ppm to cause slight dizziness in man.

Reference
1. Patty, F.A., Yant, W.P.: U.S. Bureau of Mines Rep. of Invest. No. 2979 (1929).

HEXANE (n-HEXANE)

500 ppm (Approximately 1800 mg/m^3)

Drinker, Yaglou and Warren (1) found slight nausea, headache, eye and throat irritation at 1400 to 1500 ppm.

Nelson et al. (2) found no irritation at 500 ppm in unacclimated subjects.

References
1. Drinker, P., Yaglou, C.P., Warren, M.F.: J. Ind. Hyg. & Tox. 25, 225 (1943).
2. Nelson, K.W., Ege, J.F., Jr., Ross, M., Woodman, E.L., Silverman, L.: J. Ind. Hyg. & Tox. 25, 282 (1943).

HEXANONE (METHYL BUTYL KETONE)

100 ppm (Approximately 410 mg/m3)

Schrenk and co-workers (1), in their study of the acute response of guinea pigs to hexanone vapors at concentrations ranging from 1000 to 20,000 ppm, observed no definite reaction in guinea pigs on exposure to the lower concentration, even after 810 minutes exposure. At this concentration, however, human subjects reported a strong odor and moderate eye and nasal irritation.

Reference
1. Schrenk, H.H., Yant, W.P., Patty, F.A.: Pub. Health Rept. 51, 624 (1936).

HEXONE (METHYL ISOBUTYL KETONE)

100 ppm (Approximately 410 mg/m^3)

Specht (1) observed, in a study of acute response of guinea pigs to the inhalation of hexone vapors, that at the lowest concentration used, approximately 0.1 volume per cent (1000 ppm), the vapor was still exceedingly irritating to the eyes and nose of the operator. Guinea pigs showed little disturbance and only slight effect on the maintenance of usual stance, reflexes and temperatures.

Silverman and associates (2) reported that 100 ppm of hexone is the highest concentration of this vapor which the majority of subjects exposed estimated as satisfactory for an 8-hour exposure. Eye irritation was experienced at 200 ppm. In this study, an average of 12 persons were exposed at measured concentrations of solvent vapors for 15-minute periods.

References
1. Specht, H.: Pub. Health Rept. 53, 292 (1938).
2. Silverman, L., Schulte, H.F., First, M.W.: J. Ind. Hyg. & Tox. 28, 262 (1946).

HYDRAZINE

1 ppm (Approximately 1.3 mg/m^3)

Comstock et al. (1) exposed dogs and rats six hours daily, five days a week for six months at an average concentration of hydrazine of 5 ppm. The dogs lost appetite recurrently during exposure. There was some weight loss and fatigue. Recovery could be noted after weekends when exposures were suspended. The rats became sluggish and less active as the test progressed. No deaths were noted in either dogs or rats. At a concentration of 14 ppm, 2 of 4 dogs, 23 of 30 rats, 15 of 20 mice and 8 of 10 guinea pigs died during a 6-month test.

Reference
1. Comstock, C.C., Lawson, L.H., Greene, E.A., Oberst, F.W.: Arch. Ind. Hyg. & Occ. Med. 10, 476 (1954).

HYDROGEN BROMIDE

3 ppm (Approximately 10 mg/m^3)

Experimental work was done in a fume chamber of the Occupational Health Section, Connecticut State Department of Health, in which 6 persons were exposed to concentrations of hydrogen bromide ranging from 2 to 6 ppm (1). The following table shows the reaction of these individuals to exposures of several minutes duration. Subjective responses, as shown in the table, indicate that exposure at 5 ppm causes nose and throat irritation in some individuals, but it is unlikely that noticeable disturbances will occur if peak concentrations do not exceed this value.

Concentration Hydrogen Bromide	Nose Irritation	Throat Irritation	Eye Irritation	Detectable Odor
ppm				
2	6 Negative	6 Negative	6 Negative	6 Positive
3	1 Positive 5 Negative	1 Positive 5 Negative	6 Negative	6 Positive
4	3 Positive 3 Negative	1 Positive 5 Negative	6 Negative	6 Positive
5	6 Positive	1 Positive 5 Negative	6 Negative	6 Positive
6	6 Positive	1 Positive 5 Negative	6 Negative	6 Positive

Negative, means no subjective irritation.
Positive, means subjective response ranging from slight stinging sensation to a definite feeling of irritation.

Reference
1. Connecticut State Department of Health, Unpublished Data (1955).

HYDROGEN CHLORIDE

5 ppm (Approximately 7 mg/m^3)

Machle and associates (1) exposed animals to hydrogen chloride gas and described its strong irritant effect. Repeated exposures of animals at a concentration of about 34 ppm caused no immediate toxic effects and no morphological changes attributable to exposure. Henderson and Haggard (2) reported that exposure of men to 35 ppm causes irritation of the throat on short exposure, and 10 ppm is the maximal concentration allowable for prolonged exposure. Elkins (3) states, however, that hydrogen chloride is immediately irritating when inhaled in concentrations of 5 ppm or more. He believes that lower concentrations are not harmful.

Based on these reports, a threshold limit value of 5 ppm is interpreted to be sufficiently low to prevent toxic injury.

References
1. Machle, W., Kitzmiller, K.V., Scott, E.W. and Treon, J.F.: J. Ind. Hyg. & Tox. 24, 222 (1942).
2. Henderson, Y. and Haggard, H.W.: Noxious Gases, Reinhold Publishing Corp., New York, 2nd and Rev. Ed. (1943), p. 126.
3. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York, 2nd Ed. (1959), p. 79.

HYDROGEN CYANIDE

10 ppm (Approximately 11 mg/m^3)

According to Henderson and Haggard (1), slight symptoms follow exposure at 20 to 40 ppm. Dudley, Sweeney and Miller (2) found that dogs were seriously affected by exposure to 35 to 65 ppm, but could tolerate 30 ppm. Other animals were less susceptible. Valade (3) reported that repeated 30-minute exposures at 50 ppm were fatal to some dogs, whereas others were just perceptibly affected.

References
1. Henderson, Y. and Haggard, H.W.: Noxious Gases, Reinhold Publishing Corp., New York, 2nd and Rev. Ed. (1943), p. 174.
2. Dudley, H.C., Sweeney, T.R. and Miller J.W.: J. Ind. Hyg. & Tox. 24, 255 (1942).
3. Valade, P.: Bull. Acad. Nat. Med. 136, 280 (1952), Abstracted in Arch. Ind. Hyg. & Occ. Med. 7, 265 (1953).

HYDROGEN FLUORIDE

3 ppm (Approximately 2 mg/m^3)

Guidance in the selection of the threshold limit for hydrogen fluoride was

originally obtained from the experimental studies of Ronzani (1), who found no injurious action of fluoride in animals exposed for 30 days at 3 ppm HF despite the fact that fluorosis of the bone had been reported by Roholm (2) to occur among cryolite workers after prolonged exposure. Since these early reports (1909 and 1937 respectively) much evidence, both experimental and occupational, has accumulated to confirm the suitability of the 3 ppm limit. Stokinger et al. (3) found animals tolerated 7 ppm HF with only mild irritation of the respiratory tract in repeated daily exposures. Patty (4) found 22 ppm gradually irritating to the mucous membranes and 120 ppm irritating to the skin. An unpublished industrial medical study on hundreds of workers exposed to fluoride for periods of up to 30 years showed 20 of 265 workers with increased density of x-ray picture of pelvic ligaments when the average daily F excretion in the urine was 9.6 mg., but that only 2 of 402 workers with a daily urinary output of F of 6.3 mg. showed the pelvic changes. Reduction of the exposure to a urinary F output to 1.5 to 2 mg. F per day was not expected to result in any changes of health significance. The F concentrations in the environment resulting in the urinary F values (1.5 to 2 mg. F per day) ranged from 1 to 4 ppm F, of which about 50% was particulate, 50% gaseous (2). Thus it appears that the 3 ppm limit for fluoride is securely based on experience from industrial and animal exposures.

Evidence to the contrary is the statement of Elkins (5) that nosebleeds occur among workers exposed to 0.4 to 0.7 mg. F/m^3 and that sinus trouble was experienced in others exposed to 0.1 to 0.35 mg/m^3. The urinary excretion values quoted seem inconsistently high (2 to 6 mg. F per liter and up to 9.9 mg. per liter respectively) in relation to the air levels. Possibly dietary F is a factor.

References
1. Ronzani, E.: Arch. f. Hyg. 70, 217 (1909).
2. Roholm, K.: Fluorine Intoxication, Lewis & Co., London (1937).
3. Stokinger, H.E. et al.: Toxicity Following Inhalation of Fluorine and Hydrogen Fluoride, Chap. 17 in "Pharmacology and Toxicology of Uranium Compounds", Voegtlin & Hodge, Eds., NNES VI 2, McGraw-Hill Co., (1949).
4. Patty F.A.: Industrial Hygiene and Toxicology, Interscience Pub., Inc., New York (1949), p. 543.
5. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York, 2nd Ed. (1959), p. 72.

HYDROGEN PEROXIDE, 90%

1 ppm (Approximately 1.4 mg/m^3)

Comstock et al. (1) exposed dogs six hours per day, five days a week for six months to an average vapor concentration of 7 ppm of 90% H_2O_2. The dogs developed external body irritation, sneezing, lacrimation and bleaching of the hair. Autopsy disclosed greatly thickened skin but no hair follicle destruction. The lungs were found to be irritated. No significant changes in blood or urinary constituents were observed. Rabbits exposed daily for three months to 22 ppm showed no eye injury although the hair was bleached and irritation was noted around the nose.

A threshold limit of 1 ppm of H_2O_2 vapor is suggested.

Reference
1. Comstock, C.C., Hackley, E.B., Oberst, F.W.: Chemical Corps Medical Laboratories Research Report No. 243 (1954).

HYDROGEN SELENIDE

0.05 ppm (Approximately 0.2 mg/m^3)

Dudley and Miller (1) summarize their work on the toxicology of selenium by stating that "Inasmuch as 0.001 mg. H_2Se per liter produced death in 50% of the guinea pigs exposed for eight hours, the animals exhibiting symptoms of respiratory irritation and some changes in the liver, it is apparent that such a concentration would be dangerous for men, especially for periods of time in excess of four hours. In the light of our present knowledge and as a working basis for the control of workroom atmosphere where H_2Se is present, it can best be postulated that any concentration that can be detected by odor is potentially dangerous."

Buchan (2) reported five cases of industrial selenosis due to less than 0.2 ppm of hydrogen selenide. Predominating symptoms were nausea, vomiting, metallic taste in the mouth, alliaceous breath odor, and extreme lassitude and fatigue.

References
1. Dudley, H.C., Miller, J.W.: J. Ind. Hyg. & Tox. 23, 470 (1941).
2. Buchan, R.F.: J. Occ. Med. 3, 439 (1947).

HYDROGEN SULFIDE

20 ppm (Approximately 30 mg/m^3)

The original basis for the limit of 20 ppm H_2S was the report by Barthelmy (1) of 10-year industrial experience in connection with the manufacture of viscose rayon. It was set on the basis of elimination of eye irritation. The H_2S in the atmosphere was not pure, however, but was in association with carbon disulfide, ammonium sulfide and sulfuric acid, which were reported (1) "to promote hypersensitiveness of the conjunctiva and cornea to H_2S." Experiments indicate that the effects of H_2S and CS_2 are additive (2). Thus the suggested limit of 20 ppm may or may not be the most suitable level when H_2S is the sole air contaminant.

According to Elkins (3), 20 ppm is satisfactory for prevention of systemic effects, but may be productive of conjunctivitis. Elkins further states that the repeated exposure to 10 ppm may result in this condition (4).

Late effects of H_2S poisoning may result in inflammatory changes in the respiratory tract (5) in circulatory disturbances (bradycardia and temporary weakening of cardiac muscle) (6); peripheral neuritis, lymphocytosis and gastrointestinal disturbances have also been reported to follow H_2S exposure (7,8).

Thus it would appear that whereas levels of H_2S below 20 ppm on repeated daily exposure will not result in serious systemic injury, 20 ppm may not be sufficiently low to prevent effects on the eye.

References
1. Barthelmy, H.L.: J. Ind. Hyg. & Tox. 21, 141 (1939).
2. Fischer, R.: Biochem. J. 2, 141, 540 (1923).
3. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York, 2nd Ed. (1959), p. 97.

DOCUMENTATION OF

THRESHOLD LIMIT VALUES

AMERICAN CONFERENCE OF
GOVERNMENTAL INDUSTRIAL HYGIENISTS

COMMITTEE ON THRESHOLD LIMIT VALUES

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PREFACE

The documented evidence appearing in this publication has been taken mainly from technical papers and texts of industrial hygiene and toxicology that have appeared over the years and from the experience and knowledge of committee members. All informational sources are referenced. Occasionally, written communications to the committee members have been used to supplement formally published material, when such information has been substantiated by valid observation. It is this material that has been used in deriving the values given in the table of threshold limits which is published annually by the American Conference of Governmental Industrial Hygienists.

The format is designed to supply in brief the best available technical evidence substantiating the choice of the limiting concentrations. Substances are listed in alphabetical order for ready reference. The evidence on individual substances in this compilation is not necessarily final. The format facilitates the supplementation or modification of existing data, or the addition of information on new substances as it becomes available.

The committee urges careful study and review of this publication and welcomes suggestions or new data that will maintain the usefulness of this publication. Supplements will be published and offered for sale as new information justifies their appearance.

Communications should be addressed to the Chairman of the committee, Dr. H.E. Stokinger, or to the Secretary-Treasurer of the ACGIH. 1014 Broadway, Cincinnati 2, Ohio.

References
1. Sayers, R.R.; Am. Stds. Assn. Z37, No. 9, 1943; Cook, W.A.: Ind. Med. 14, 936, (1945).
2. Pinto, S.S.: Communication to Committee Member (1961).

ARSINE

0.05 ppm (Approximately 0.2 mg/m^3)

The extreme, acute toxicity of arsine is well known; 250 ppm for 30 minutes is fatal to man and 3-10 ppm can cause poisoning symptoms in a few hours (1). Nau (2) reported the conditions of an arsine exposure that indicated the previous limit of 1 ppm was too high. Elkins (3) reported a case of severe, but nonfatal, arsine poisoning that resulted from an exposure averaging 0.5 ppm. Elkins has concluded that 0.05 ppm arsine is not an unreasonable low limit on the basis of a study of chronic arsine exposures of Bulmer, et al. (4). Urinary As varied from 0.7 to 4 mg. in men showing toxic signs of exposure of jaundice and anemia. Assuming 75% of the As is excreted in the urine 1 mg. As/l corresponds to 1.33 mg. intake, or 0.133 mg. As/m^3 air if 10 m^3 air is taken as the average amount of tidal air inhaled during a working day. This corresponds to 0.033 ppm arsine, and supports the recommended limit of 0.05 ppm arsine.

References
1. Henderson, Y., Haggard, H.W.: Noxious Gases, Reinhold Publishing Co., N.Y. (1943).
2. Nau, C.A.: South. Med. J. 41, 341 (1948).
3. Elkins, H.B.: Chemistry of Industrial Toxicology, Wiley & Sons, N.Y. (1959).
4. Bulmer, F.M.R., et al.: J. Ind. Hyg. & Tox. 22, 111 (1940).

ASBESTOS

5 mppcf

Asbestos is a generic term applying to a number of mineral silicates that are incombustible in air and can be separated into filaments. The most widely used in industry is chrysotile, a magnesium silicate from serpentine. Other types include amosite (an iron magnesium silicate) crocidolite (a sodium iron silicate), tremolite (a calcium magnesium silicate) and anthophyllite (also an iron magnesium silicate).

Miller and Sayers (1) showed that intraperitoneal injection of amosite, chrysotile and crocidolite in guinea pigs produced the reaction of an inert dust. Vorwald et al. (2) confirmed this for short fibers (under 3μ) but observed that long fibers produced a fibrous reaction. Continuing unpublished work by Gardner, these workers demonstrated that long fibers (20 microns and above) produced peribronchiolar fibrosis in lower animals, and developed evidence that this resulted from mechanical rather than chemical action. Asbestos dust containing 0.6 per cent fibers longer than 10 microns, in concentrations of 138 mppcf (or 0.8 million "long" fibers per c.f.), was capable of producing experimental asbestosis in guinea pigs. When the concentration was 6.7 per cent fibers over 10 microns, 40 mppcf, (equivalent to 2.7 million "long" fibers per c.f.), the reaction developed in approximately half the time.

That exposure to asbestos is associated with development of a potentially disabling pneumoconiosis in man has been amply demonstrated by industrial experience (3,4,5,6,7,8,9,10,11). The present threshold limit relates to the prevention of asbestosis. It was recommended by Dreessen et al. (8), after study of 541 employees in three asbestos textile plants using chrysotile. Only three

doubtful cases of pneumoconiosis were found in those exposed to dust concentrations under 5 mppcf, whereas numerous well-marked cases were found above 5 mppcf. Counts were from impinger-collected samples in ethyl alcohol and distilled water. Both fibrous and non-fibrous particles were counted, but the latter greatly predominated. While chemical analyses of collected samples of airborne dust corresponded to those of settled dust samples, it is believed that dust counts of particulates by conventional methods can be expected to give only an indirect measure of the risk of asbestosis because of the great relative importance of long fibers.

References
1. Miller, J.W., Sayers, R.R.: Pub. Health Rept. 56, 264 (1941).
2. Vorwald, A. J., Durkan, T.M., Pratt, P.C.: Arch. Ind. Hyg. 3, 1 (1951).
3. Merewether, E.R.A.: J. Ind. Hyg. 12, 198, 239 (1930). Pneumoconiosis Abstracts, 1926-1938, Vol. I, p. 128.
4. Wood, W.B., Gloyne, S.R.: Lancet, Dec. 22, 1934, pp. 1383-1385.
5. Fulton, W.B., Dooley, A., Matthews, J. L., Houtz, R.L.: Penn. Dept. Labor and Ind. Bull. 42 (1935).
6. Lanza, A.J., McConnell, W.J., Fehnel, J.W.: Pub. Health Rept. 50, 1 (1935).
7. Donnelly, J.: J. Ind. Hyg. & Tox. 18, 222 (1936).
8. Dreessen, W.C., DallaValle, J.W., Edwards, T.I., Miller, J.W., Sayers, R.R.: Pub. Health Bull. No. 241. Wash., D.C., (1938).
9. Lynch, M.: Arch. Ind. Health. 11, 185 (1955).
10. Smith, K.W.: Arch. Ind. Health 12, 198 (1955).
11. Cartier, P.: Arch. Ind. Health 11, 204 (1955).

BARIUM (and Compounds)

0.5 mg/m^3

The clinical entity "baritosis" has been reported in the industrial hygiene literature sporadically since 1934 when Leschke (1) described a case with almost fatal outcome in a baryta worker who had apparently inhaled ample quantities. Other reports of industrial exposure to barium compounds with or without exposure to lithopone have described pulmonary nodulation with or without decrease in lung function, such as dyspnea on exertion (2,3). More soluble forms of barium, as the carbonate, oxide and nitrate, tend to be more injurious, particularly acutely. Dusts of barium oxide are considered potential agents of dermal and nasal irritation (4).

The pharmacologic action of barium is well known (5); chief among the actions of barium is its effect on muscle, particularly cardiac, increasing its excitability. Skeletal, arterial, intestinal, and bronchial muscle are all affected by barium. In addition, effects on the hematopoietic system have been noted, as well as on the cerebral cortex.

Fazekas, et al. (6) have reported that subcutaneous injection of an aqueous solution of barium chloride at a dosage of 5 mg/kg caused acute toxicity with death after 2-2.5 hours. Chronic poisoning was achieved by the injection of solutions at 10, 5, and 2 mg/kg. Rabbits in this series were killed at 98 to 193 days. Effects on the central nervous system are described.

The present limit of 0.5 mg Ba/m^3 air was suggested by Hyatt (7), who employed this limit for a number of years at the Los Alamos Laboratories with satisfactory results for the control of exposure to barium nitrate. It is not known what degree of added safety this limit incorporates.

4. Ibid, 1st Ed. (1950), p. 232.
5. Lange, R.: Samml. Vergift. 6, 233 (1935).
6. Hertz, A.: Samml. Vergift. 3, 277 (1932).
7. Telecky, L.: Deut. Med. Wochschr. 57, 1026 (1931).
8. Meyer, S.: Arch. Gewerbepath. 2, 526 (1931).

HYDROQUINONE

2 mg/m^3

Sterner, Oglesby and Anderson (1) have reported that vapors of quinone and dusts of hydroquinone arising in the manufacture of the latter produced characteristic eye injuries in workmen. The injuries developed gradually over a period of years, with no serious cases appearing from exposures of durations shorter than 5 years. No systemic effects were found associated with these injuries. Quinone was believed to be the chief causative agent, although hydroquinone dust was suspected as a contributory cause.

Since this study, a large number of clinical and environmental studies (2), made of workers in plants where these two substances were made, confirm the findings of the original report that no systemic effects arise at a level of 2 mg hydroquinone dust/m^3. Considerable animal experimentation performed at the Eastman Kodak Laboratory has confirmed the relative lack of systemic toxicity of hydroquinone, which has a widespread distribution in nature.

References

1. Sterner, J.A., Oglesby, F.L., and Anderson, B.: J. Ind. Hyg. & Tox. 29, 60 (1947).
2. Personal Communication - Dr. David Fassett, Eastman Kodak Co.

INERT DUSTS (Nuisance)

50 mppcf

Limits for nuisance dust are based not only on visibility and comfort, but also because of our lack of knowledge as to the ultimate effects of inhaling very high concentrations of such dusts upon the development of disease of the lungs other than pneumoconiosis. Lack of knowledge as to the effects of concurrent exposures to high concentrations of inert dusts and low concentrations of active dusts have likewise prompted prudence in recommending standards.

IODINE

0.1 ppm (Approximately 1 mg/m^3)

Iodine is irritant and corrosive, more so than bromine or chlorine, according to an observation attributed to Matt by Flury and Zernik (1). Pulmonary edema has been observed in dogs exposed to the vapor. The same source reports that man can work undisturbed at a concentration of 0.1 ppm; that work is possible but difficult at 0.15 to 0.2 ppm, and that work is impossible at 0.3 ppm.

The determinations made in a Massachusetts plant (2) showed concentrations ranging from 0.07 ppm at the nearest work area, to 1 ppm directly over the tank

containing the iodine solution.

Exposure to 0.07 ppm caused no complaints, but concentrations of 1 ppm over the tank was highly irritating.

References
1. Flury, F. and Zernik, F.: Schadliche Gase, Julius Springer, Berlin (1931).
2. Fahey, J.P.: Communications to Committee Member, 1960.

IRON OXIDE

15 mg/m^3

Drinker, et al. (1) suggest 10 mg/m^3 for control of exposure to iron oxide dust and fume. Drinker and Nelson (2) later recommended 30 mg/m^3 from limited trials. Similarly, the U.S. Department of Labor (3) from studies of welders, concluded that concentrations of iron oxide fume below 30 mg/m^3 was without effect.

H. F. Smyth, Jr. (4) feels that the 15 mg/m^3 by analogy with zinc oxide fume, is sufficiently low to prevent injury.

References
1. Drinker, P., Warren, H., Page, R.: J. Ind. Hyg. 17, 133 (1935).
2. Drinker, P., Nelson, K.W.: Ind. Med. 13, 673 (1944).
3. U.S. Dept. of Labor: Div. Labor Stds., Spec. Bull. No. 5 (1941).
4. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).

ISOPHORONE

25 ppm (Approximately 140 mg/m^3)

Smyth and associates (1) concluded from their work on experimental animal exposure that no effect whatever resulted from exposure to 25 ppm of isophorone vapors. Animals, 10 rats and 10 guinea pigs, were exposed for 30 8-hour days to concentrations ranging from 25 to 500 ppm. Isophorone, in higher concentrations, injured primarily as a kidney poison.

Smyth and Seaton (2) report that humans exposed at 40, 85, 200 and 400 ppm isophorone experienced eye, nose and throat irritation. A few complaints of nausea, headache, dizziness, faintness, inebriation and a feeling of suffocation resulted from 200 and 400 ppm. Symptoms of irritation and narcotic action decreased at concentrations of 40 and 85 ppm. Useful warning properties exist only at 200 and 400 ppm.

References
1. Smyth, H.F., Jr., Seaton, J., Fischer, L.: J. Ind. Hyg. & Tox. 24, 46 (1942).
2. Smyth, H.F., Jr., Seaton, J.: J. Ind. Hyg. & Tox. 22, 477 (1940).

ISOPROPYLAMINE

5 ppm (Approximately 12 mg/m^3)

Smyth et al. (1) reported that rats survive 4 hours inhalation of 4000 ppm, but die from 8000 ppm, indicating an acute toxicity half that of butylamine.

Smyth (2) cites unpublished industrial experience that levels above 5 ppm tend to be irritating, and suggests the most important effect from inhalation is respiratory tract irritation, with lung edema the maximal injury.

References
1. Smyth, H.F., Jr., Carpenter, C.P., Weil, C.S.: Arch. Ind. Hyg. & Occ. Med. 4, 110 (1951).
2. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).

LEAD

0.2 mg/m^3

Bloomfield, et al. (1) following a U.S. Public Health Service survey of the lead storage-battery industry, proposed a limit of 0.15 mg/m^3 for lead dust and fumes. Prior to this survey, a limit of 0.5 mg/m^3 had been used. Long industrial experience with the 0.15 mg/m^3 limit, however, showed that although atmospheric lead concentrations greater than 0.15 mg/m^3 occurred, lead absorption, as measured by urinalysis, were not indicative of harmful exposure. Elkins (2) has plotted a curve relating the lead content of urine and that in air, combined from a number of studies, and showed that urinary lead values of 0.2 mg/l corresponded with slightly more than 0.2 mg Pb/m^3 air. On the basis of this evidence and that from other sources, the Z-37 Committee of the American Standards Association proposed 0.2 mg Pb/m^3 for air for inorganic lead dusts and fume, except lead sulfide and chromate (3).

References
1. Russell, A.E., Jones, R.R., Bloomfield, J.J., Britten, R.H., Thompson, L.R.: Pub. Health Bull. No. 205, (1933).
2. Elkins, H.B.: Chemistry of Industrial Toxicology, J. Wiley & Sons, New York, 1959, pp. 51-57.
3. Unpublished Standard, A. S. A. Z-37 Comm. (1958).

LEAD ARSENATE

0.15 mg/m^3

Lead arsenate presents a double hazard in that it can produce either lead or arsenic intoxication. While the acute toxicity, due chiefly to arsenic, is less than that of calcium arsenate (1), the chronic effects are likely to be those of lead poisoning. In view of this a threshold limit slightly lower than that of other inorganic lead compounds is recommended.

Reference
1. Fairhall, L.T., Miller, J.W.: Pub. Health Rept. 56, 1610 (1941).

LINDANE (Hexachlorocyclohexane, gamma isomer)

0.5 mg/m^3

Comprehensive work on the vapor toxicity of lindane has presented a basis on which to establish the threshold limit for this insecticide in air. Treon and co-workers (1) found minimal pathology in several species of laboratory animals exposed 7 hours a day, 5 days weekly for about a year to an average of 0.7 mg/m^3 of lindane. On the other hand, Spear (2) exposed rats to 0.19 mg/m^3 for 24 hours daily, continuously for 655 days, and found no pathology. It would appear from this work that the dangerous level for rats lies somewhere between these 2 limits.

Treon has suggested 0.5 mg/m^3 as the threshold limit. Some authorities believe that man is more sensitive than the rat, hence this might be dangerously high. On the other hand, extensive use experience with lindane vaporizers suggests that no health hazard exists if the value of 0.5 mg/m^3 is not exceeded.

References
1. Treon, J.F., et al.: Rept. from Kettering Laboratory, (July 1951).
2. Spear, P.J.: Thesis, Univ. Mass. Lib., Amherst, Mass. (1952).

LITHIUM HYDRIDE

0.025 mg/m^3

Until recently, lithium and its inorganic salts were used to such a limited extent that they created no industrial health problems. The inherent toxicity of the lithium ion, however, is high, a few milli-equivalents in the plasma giving rise to serious signs and symptoms referable to the nervous system (1). These include anorexia, nausea, tremor, muscle twitches, apathy, mental confusion, blurring of vision, coma and death.

Recently, because of an industrial use for lithium hydride, an acute inhalation toxicity study of this substance was made in animals (2). At the atmospheric levels tested, between 5 and 55 mg/m^3, lithium hydride proved to be an intensely irritating and corrosive material. Levels in excess of 10 mg/m^3 eroded the body fur and skin on the legs of the animals and produced severe inflammation and ulceration of the eyes on occasion, as well as destruction of the external nasal septum. All levels, however, proved so irritating as to occasion repeated and persistent coughing and sneezing that resulted in emphysematous changes in the lungs. The trachea showed superficial sloughing of the muscosal epithelium. No chronic effects or sequelae were observed during an extended post-exposure period.

Industrial experience has shown that a reduction in atmospheric concentration of lithium hydride to 25μg/m^3 is required to attain just a sneezing level; a certain degree of tolerance, however, is acquired by those repeatedly exposed to lithium hydride at this level.

A level of 25μg/m^3 was suggested as a tolerable atmospheric level.

References
1. Goodman & Gilman: The Pharm. Basis of Therap., 2nd Ed., McMillan, N.Y. (1955).
2. Spiegl, C.J., Scott, J.K., Steinhardt, H., Leach, L.J., and Hodge, H.C.: Arch. Ind. Health 14, 468 (1956).

MAGNESIUM OXIDE FUME

15 mg/m^3

Drinker (1) and associates, reported results of experiments in 1927 in which four human subjects were exposed to measured concentrations of freshly generated magnesium oxide fumes. Although slight reactions were observed after several minutes exposure to concentrations of 4.1 to 5.8 mg/m^3, it was believed that severer exposures would lead to severer reactions.

Later, Drinker (2) showed, by animal experiments, and further experiments on man, that magnesium causes less marked results than does zinc, but that the inhalation of magnesium oxide produces in man a febrile reaction and a leukocytosis analagous to that caused by zinc oxide.

The limit of 15 mg/m^3 is recommended on the basis that this value represents a maximal desirable limit for dusts of relatively minor hazard.

References
1. Drinker, P., Thomson, R.N., Finn, J.L.: J. Ind. Hyg. 9, 187 (1927).
2. Drinker, K.R., Drinker, P.: J. Ind. Hyg. 10, 56 (1928).

MALATHION (0,0-DIMETHYL DITHIOPHOSPHATE OF DIETHYL MERCAPTOSUCCINATE)

15 mg/m^3

Malathion has been found to have an LD_{50} of about 2100 mg/kg by mouth for the rat under certain conditions. Albino rats receiving 5000 ppm of 90% grade malathion in their diet gained weight less rapidly than controls. Johnson, et al. (1) from a review of toxicity data concluded that malathion was not more than one-hundredth as toxic as parathion. Tousey (2) confirms the opinion of these authors. Culver, Caplan and Batchelor (3) found that a group of entomologists with maximal exposure of 5 hours at a peak of 56 mg/m^3 and an average of 3.3 mg/m^3 had normal cholinesterase levels.

On the basis of this work and analogy with parathion a threshold limit value of 15 mg/m^3 has been assigned to malathion.

References
1. Johnson, G.A., Fletcher, J.H., Nolan, K.G., Cassaday, J.T.: J. Econ. Entomol. 45, 279 (1952).
2. Tousey, R.G.: Agr. Chem. 9, 49 (1954).
3. Culver, D., Caplan, P., Batchelor, G.S.: Arch. Ind. Health 13, 37 (1956).

MANGANESE

5 mg/m^3

Flinn, Neal and Fulton (1) in a study of the health effects of manganese in a manganese dioxide ore-crushing plant, found no symptoms in men exposed to 30 mg/m^3 or less. As a result of this study, the Z-37 Committee of the American Standards Association adopted an hygienic air standard of 6 mg/m^3 in 1942.

Kesic and Hausler (2) reported cases of manganese poisoning in a plant in Yugoslavia when air concentrations of manganese oxide dusts were between 7 and 63 mg/m^3, but that the incidence of poisoning was apparently low when concentrations ranged from 3-9 mg/m^3. Baader of Germany, an authority on manganese poisoning, is of the opinion that 5 mg/m^3 of manganese is a suitable threshold limit (3). It would appear not to provide a large factor of safety.

References
1. Flinn, R.H., Neal, P.A., Fulton, W.B.: J. Ind. Hyg. & Tox. 23, 374 (1941).
2. Kesic, B., Hausler, V.: Arch. Ind. Hyg. & Occup. Med. 10, 336 (1954).
3. Personal communication to Threshold Limits Committee Member, 1960.

MERCURY - Metallic Vapor and Inorganic Compounds

0.1 mg/m^3

Neal, Flinn, et al. (1), in a study of the felt hat industry, found the prevalence of mercurialism to be proportional to the atmospheric concentration of mercury. No cases of mercurialism were found when air concentrations of mercury were less than 0.1 mg Hg/m^3 air. There was little factor of safety, however, as mercury concentrations 2-3 times greater often resulted in symptoms of mercury poisoning. Considerable evidence indicates metallic mercury vapor is the most toxic of the inorganic forms of mercury.

Fahy (2) reports that on the basis of several years study in the electronics and lamp industries, the 0.1 mg/m^3 appears satisfactory.

References
1. Neal, P.A., Flinn, R.H., Edwards, T.L., Reinhart, W.H., Hough, J.W., Dalla Valle, J.M., Goldman, F.H., Armstrong, D.W., Gray, A.S., Coleman, A.L., Postman, B.L.: Pub. Health Bull. No. 263, (1941).
2. Fahy, J.P.: Communication to Committee Member.

MERCURY (ORGANIC COMPOUNDS)

0.01 mg/m^3

Ahlmark (1) on the basis of Swedish industrial experience, suggested in 1948 a limit of 0.01 mg/m^3. In 1949 Lundren and Swensson (2) stated that concentrations fluctuate so widely that only a continuous analysis which detected important peaks could be considered reliable. They, therefore, recommended that no MAC be given. Trakhtenberg (3) in 1950 reported that mice died within three to five hours at 10 to 30 mg/m^3 of organic mercury and inferred that even 0.00001 mg/m^3 could not be tolerated by humans on a continuing basis. A later study by Dinman, et al. (4) in which particular care was taken to obtain accurate air concentrations of mercury, failed to reveal any consistent symptoms of mercury poisoning at mercury concentrations in the air between 0.01 and below 0.1 mg Hg/m^3. On occasion, mercury levels exceeded by a considerable amount this range for brief periods. Despite this new evidence, the former threshold limit of 0.01 mg Hg/m^3 air is retained, because newer types of organic mercurials of possibly greater toxicity than those studied by Dinman are appearing.

References
1. Ahlmark, A.: Brit. J. Ind. Med. 8, 480 (1948).
2. Lundgren, K.D. and Swensson, A.: J. Ind. Hyg. & Tox. 31, 190 (1949).
3. Trakhtenberg, I.M.: (Published in Hygiene & Sanitation, Russia, 1950), Abstracted in C.A. 44, 10162g (1950).
4. Dinman, B.D., Evans, E.E., Lynch, A.L.: Arch. Ind. Health 18, 248 (1958).

MESITYL OXIDE

25 ppm (Approximately 100 mg/m^3)

Smyth and associates (1) concluded that experimental animals exposed to 50 ppm mesityl oxide showed no effect whatever. In this work, 10 rats and 10 guinea pigs were exposed at concentrations ranging from 25 to 500 ppm for thirty 8-hour periods. Mesityl oxide effects were primarily narcotic in higher concentrations.

Silverman and co-workers (2), in testing sensory response to exposure to various organic vapors, found that a majority of individuals experienced some eye irritation at 25 parts of mesityl oxide per million of air and nasal irritation at 50 ppm. On the basis of an unpleasant taste which remained in some cases for 3 to 6 hours after exposure and nasal irritation at 50 ppm, these workers suggest 25 ppm as the highest concentration which would be satisfactory for an 8-hour day.

The Shell Chemical Corporation confirms 25 ppm as the threshold limit for comfort.

References
1. Smyth, H.F., Jr., Seaton, J., Fischer, L.: J. Ind. Hyg. & Tox. 24, 46 (1942).
2. Silverman, L., Schulte, H.F., First, M.W.: J. Ind. Hyg. & Tox. 28, 262 (1946).
3. Shell Chemical Corp., Toxicity Data Sheet, Mesityl Oxide, 1957.

METHOXYCHLOR (2,2-bis-p-METHOXY PHENYL-1,1,1 TRICHLORETHANE)

15 mg/m^3

Methoxychlor is perhaps the least toxic insecticide now in use. Lehman (1) reported an LD_{50} of 6000 mg/kg orally for rats, and a safe level in diet of 25 ppm. The estimated fatal oral dose to man is 450g (1 lb.) On the basis of this low toxicity, a threshold limit value of 15 mg/m^3 is believed to be sufficiently low to avoid a health hazard to man.

Reference
1. Lehman, A.J.: Assn. Food & Drug Off., U.S. Quart. Bull. 18, 9 (1954).

METHYL ACETATE

200 ppm (Approximately 610 mg/m^3)

Fairhall (1) notes that methyl acetate causes some irritation of the mucous membranes of the eye and of the upper and lower respiratory passages and that it is more weakly narcotic than some of the higher homologues such as amyl acetate.

Duquenois and Revel (2) reported ocular and nervous disturbances in workers exposed to this vapor. Inflammation of the eyes, nervous irritation and tightness of the chest were among the effects observed. It was suggested that methyl acetate may resemble methyl alcohol in producing atrophy of the optic nerve.

Cook (3) suggests that, in view of the work of Nelson et al. (4) on ethyl, butyl and amyl acetate, and the possibility of poisoning from the hydrolysis of these esters within the body, workers exposed to concentrations exceeding 100 ppm methyl acetate should be under medical observation.

References
1. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins Co., Baltimore, 2nd Ed. (1957), p. 281.

2. Duquenois, P. and Revel, P.: J.Pharm. Chim. 19, 590 (1934).
3. Cook, W. A.: Ind. Med. 14, 943 (1945).
4. Nelson, K.W., Ege, J.F., Jr., Morwick, R., Woodman, L.E., Silverman, L.: J. Ind. Hyg. & Tox. 25, 282 (1943).

METHYL ACETYLENE (PROPINE)

1000 ppm (Approximately 1650 mg/m^3)

Horn (1) exposed two dogs and twenty rats to an average concentration of 28,700 ppm methyl acetylene for a total period of six months on a six-hour-per-day, five-day-per-week basis. An additional two dogs and twenty rats were controls. During the course of the experiment, eight rats and no dogs died. Signs of toxicity were excitement, ataxia, salivation, mydriasis and tremors. Both dogs had convulsions three times during the six months. Weight gain was retarded in exposed animals of both species. Pathology indicated pulmonary irritation in exposed animals. Controls showed no pathology.

Reference

1. Horn, H.J., Weir, R.J., Reese, W.H.: Arch. Ind. Health 15, 20 (1956).

METHYL ACRYLATE

10 ppm (Approximately 35 mg/m^3)

The work of Treon and associates (1) has shown that the "no effect" inhalation concentration for monkeys and 3 rodent species was approximately 30 ppm for methyl acrylate.

Smyth (2) has found methyl acrylate to be approximately twice as toxic as ethyl acrylate in single inhalation exposures. Both investigators accordingly find 10 ppm for methyl acrylate justifiable as a threshold limit.

References

1. Treon, J.F., Sigmon, H., Wright, H., Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 31, 317 (1949).
2. Written communication to committee member: December 19, 1955.

METHYLAL (DIMETHOXYMETHANE)

1000 ppm (Approximately 3,100 mg/m^3)

Fairhall (1) notes that animals exposed at high concentrations of methylal often developed severe fatty changes in the liver, kidney and heart and inflammatory changes in the lungs. Lower concentrations generally produced no significant pathologic changes. In view of the LC_{50} value of about 18,000 ppm on 7-hour exposure for male laboratory animals (white mice and guinea pigs) and a threshold which appeared to be about 11,300 ppm, it was concluded that 1000 ppm methylal vapor would appear to be a reasonable, safe concentration for workers continuously exposed over an 8-hour working day.

Reference

1. Fairhall, L.T.: Industrial Toxicology, The Williams and Wilkins Co., Baltimore, 2nd Ed. (1957), p. 282.

METHYL ALCOHOL (METHANOL)

200 ppm (Approximately 260 mg/m^3)

According to Henderson and Haggard (1), methanol is eliminated slowly from the body, hence repeated exposures result in an increasing concentration in the blood and tissue.

Sayers and co-workers (2) observed no symptoms in dogs exposed 8 hours a day for 379 days at concentrations of methanol between 450 and 500 ppm. From these results Cook (3) concluded that 200 ppm can be accepted as a maximal acceptable concentration.

Fairly extensive industrial experience indicates 200 ppm is sufficiently low to prevent significant effects.

References
1. Henderson, Y. and Haggard, H.W.: Noxious Gases, Reinhold Publishing Corp., New York (1943), p. 218.
2. Sayers, R.R. et al.: U.S. Bureau of Mines, Report of Investigation No. 3617 (1942).
3. Cook, W.A.: J. Ind. Hyg. & Tox. 14, 936 (1945).

METHYL BROMIDE

20 ppm (Approximately 80 mg/m^3)

Elkins (1) suggests a maximal acceptable concentration value of 10 ppm in view of the insidious and serious nature of methyl bromide intoxication.

Ingram (2) reports that tests made in date-processing and packing houses, where a number of employees had been stricken, showed values ranging up to 100 ppm in the general workroom air, up to 500 ppm near the walls of ineffectively sealed chambers, and to over 1000 ppm at the breathing zone of workers entering the chamber to remove the fumigated fruit. In order to reduce concentrations to 20 ppm, it was determined experimentally that 60 air changes per hour were required. For the usual fumigation procedure 60 air changes have been found adequate for safety.

The action of methyl bromide was tested by Irish and associates (3) on rats, rabbits, guinea pigs and monkeys. Concentrations of 33 ppm caused no gross symptoms of histopathologic changes in rats, guinea pigs and monkeys. Rabbits, however, developed paralysis on repeated exposure. Rabbits survived repeated exposure for 6 months to concentrations of 17 ppm.

References
1. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York (1950), p. 233.
2. Ingram, F.R.: Arch. Ind. Hyg. & Occ. Med. 4, 193 (1951).
3. Irish, D.D., Adams, E.M., Spencer, H.C., Rowe, V.K.: J. Ind. Hyg. & Tox. 22, 218 (1940).

METHYL CELLOSOLVE (2-METHOXYETHANOL)

25 ppm (Approximately 80 mg/m^3)

Greenburg and associates (1) reported on 19 workers exposed to methyl cellosolve; there were neurologic and hematologic changes in all. The

concentration was not accurately known, but was afterwards estimated to be as low as 25 ppm. Young and Woolner (2) reported a death after ingestion of methyl cellosolve, with post-mortem findings of hemorrhagic gastritis and kidney and liver changes. Donley (3) reported a case of encephalopathy possibly due to methyl cellosolve exposure, and Parsons and Parsons (4) reported on 2 exposures to methyl cellosolve, resulting in encephalopathy and anemia.

Werner and associates (5,6) exposed animals to methyl cellosolve vapor. Repeated exposures of dogs at about 800 ppm caused hematologic changes; these workers observed no definite indications of central depression or stimulation.

Although the experimental exposures of dogs would indicate a threshold limit value somewhat higher than 25 ppm, the accidental exposures of men argue for the value of 25 ppm. The atmospheric concentrations in the latter instance, however, may be questioned.

References
1. Greenburg, L., Mayers, M.R., Goldwater, L.J., Burke, W.J., Moskowitz, S.: J. Ind. Hyg. & Tox. 20, 134 (1938).
2. Young, E.G., Woolner, L.B.: J. Ind. Hyg. & Tox. 28, 267 (1946).
3. Donley, D.E.: J. Ind. Hyg. & Tox. 18, 571 (1936).
4. Parsons, C.E. and Parsons, M.E.M.: J. Ind. Hyg. & Tox. 20, 124 (1938).
5. Werner, H.W., Mitchell, J.L., Miller, J.W., von Oettingen, W.F.: J. Ind. Hyg. & Tox. 25, 157 (1943).
6. Werner, H.W., Mitchell, J.L., Miller, J.W., von Oettingen, W.F.: J. Ind. Hyg. & Tox. 25, 409 (1943).

METHYL CELLOSOLVE ACETATE (ETHYLENE GLYCOL MONOMETHYL ETHER ACETATE)

25 ppm (Approximately 120 mg/m^3)

Smyth et al. (1) administered several glycol ethers and their esters, including methyl cellosolve acetate, to rats and guinea pigs by stomach tube; they concluded that the esters of glycol ethers are less toxic acutely than the glycol ethers. The LD_{50} dose of ethylene glycol monomethyl ether for rats was 2.46 g/kg of body weight and for guinea pigs 0.95 g/kg; the LD_{50} value for ethylene glycol monomethyl ether acetate for rats was 3.93 g/kg and for guinea pigs 1.25 g/kg. Lehmann and Flury (2) cite results of single and repeated exposures to the vapors of methyl cellosolve acetate. One-hour inhalation exposures at near saturated concentrations were tolerated by mice, guinea pigs and rabbits with only some irritation of accessible mucous membranes. Chronic poisoning resulted in kidney damage. Repeated exposures of rats, guinea pigs and rabbits at concentrations of 500, 800 and 1000 ppm resulted in deaths of cats at the 500 ppm level.

Because the ester hydrolyzes in the body to methyl cellosolve, the threshold limit value for methyl cellosolve acetate can be reasonably related to the value for methyl cellosolve which is 25 ppm.

References
1. Smyth, H.F., Jr., Seaton, J., Fischer, L.: J. Ind. Hyg. & Tox. 23, 259 (1941).
2. Lehmann, H.B. and Flury, F.: Toxicology and Hygiene of Industrial Solvents, Translated by King, E. and Smyth, H.F., Jr., The Williams and Wilkins Co., Baltimore (1943), p. 287.

METHYL CHLORIDE

100 ppm (Approximately 210 mg/m^3)

Fairhall (1) reports that though methyl chloride is metabolized in the body to methanol and hydrochloric acid, the toxic action of methyl chloride is chiefly attributable to the molecular entity. Some pulmonary irritation has been observed, however, in experimental animals (2). Severe poisoning results in central nervous system, hepatic, and renal effects and depression of bone marrow activity. Survivors may experience prolonged or permanent incapacitation. McNally (3) has reported 8 cases of poisoning by the compound. Smith and von Oettingen (4) exposed laboratory animals to methyl chloride, and found repeated exposure at concentrations of 500 ppm and greater to be dangerous. No effects were observed in animals repeatedly exposed at 300 ppm for 64 weeks. They suggested that man might be more susceptible to the toxic action of methyl chloride than laboratory animals.

The threshold limit value of 100 ppm is inferred from data on experimental intoxication of animals to be sufficiently low to prevent injury.

References
1. Fairhall, L.T.: Industrial Toxicology, The Williams & Wilkins Co., Baltimore, 2nd Ed. (1957), p. 284.
2. Sayers, R.R., Yant, W.P., Thomas, G.H., Berger, L.B.: Pub. Health Bull. 185 (1929).
3. McNally, W.D.: J. Ind. Hyg. & Tox. 28, 94 (1946).
4. Smith, W.H., von Oettingen, W.F.: J. Ind. Hyg. & Tox. 29, 47 (1947).

METHYL CHLOROFORM (1,1,1-TRICHLOROETHANE)

500 ppm (Approximately 2,700 mg/m^3)

Torkelson and associates (1) describe the toxicity of methyl chloroform from repeated exposures of animals and single exposures of men. Exposure of animals for 3 months at concentrations from 1000 to 10,000 ppm caused some pathologic changes in the livers and lungs of some species; the main effect of exposure appeared to be anesthesia. Exposure to the vapor at 500 ppm for 7 hours a day, 5 days a week for 6 months did not cause any toxic changes of significance in rats, guinea pigs, rabbits, or monkeys. Exposures of men to 920 ppm for 70 minutes resulted in mild indications of readily reversible toxicity; however, exposures at 1,900 ppm for 5 minutes caused a disturbed equilibrium in exposed men.

From these data, a threshold limit value of 500 ppm has been derived. Subsequent data derived from experimental human exposure to methyl chloroform support the 500 ppm limit (2). To prevent light headedness, however, the 500 ppm limit should not be exceeded for appreciable periods.

References
1. Torkelson, T.R., Oyen, F., McCollister, D.D., Rowe, V.K.: Am. Ind. Hyg. Assn. J. 19, 353 (1958).
2. Stewart, R.D., Gay, H.H., Erley, D.S., Hake, C.L., Schaffer, A.W.: Am. Ind. Hyg. Assn. J. 22, 252 (1961).

METHYCYCLOHEXANE

500 ppm (Approximately 2000 mg/m^3)

Lazarew (1) found that inhalation by white mice at a concentration of 7,500 to 10,000 ppm for 2 hours caused prostration and 10,000 to 12,500 ppm caused death.

Treon and associates (2) reported 1,200 ppm to be innocuous for rabbits. Prolonged exposure at 370 ppm appears to be harmless for monkeys.

References
1. Lazarew, N.W.: Arch. exp. Path. Pharmakol. 143, 223 (1929).
2. Treon, J.F., Crutchfield, W.E., Jr., Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 25, 199 (1943); ibid 25, 323 (1943).

METHYLCYCLOHEXANOL

100 ppm (Approximately 470 mg/m^3)

Treon and associates (1) found that rabbits and monkeys exhibited no evidence of discomfort or intoxication during exposure to methylcyclohexanol at concentrations of from 0.56 to 1.06 mg/l (121 ppm to 227 ppm). At 2.3 mg/l (493 ppm), it caused irritation to the eyes of rabbits. On the basis of observations made during experimental work with rabbits, it was concluded that the maximal safe concentration for prolonged exposure to methylcyclohexanol is very slightly below 0.56 mg/l (121 ppm).

Reference
1. Treon, J.F., Crutchfield, W.E., Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 25, 323 (1943).

METHYLCYCLOHEXANONE

100 ppm (Approximately 460 mg/m^3)

Treon and associates (1) found that rabbits and monkeys showed no evidence of discomfort or intoxication during exposure at a concentration of 0.82 mg of methylcyclohexanone per liter of air (180 ppm). At 2.31 mg/l (514 ppm), it caused irritation to the eyes of rabbits.

On the basis of their study of the effects of this material on rabbits, it was concluded that the maximal safe concentration for prolonged exposure lies between 0.82 and 2.31 mg/l (182 to 514 ppm).

Reference
1. Treon, J.F., Crutchfield, W.E., Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 25, 323 (1943).

METHYL FORMATE

100 ppm (Approximately 250 mg/m^3)

Schrenk and associates (1) found that guinea pigs exposed at concentrations of 1500 to 2000 ppm methyl formate for several hours showed no apparent effect. Symptoms occurring in the experimental animals during this study were, in the order of their occurrence, nose and eye irritation, retching movement, incoordination, narcosis accompanied by incoordinate movements of the extremities, and death.

Fairhall (2) attributed the physiologic effects resulting from inhalation of the esters of organic acids to the organic acid liberated by hydrolysis following absorption or contact with mucous surfaces and the skin. On these grounds, methyl formate would be expected to be more irritating than the acetate. Methyl formate has been found to have more irritating action than either methyl or ethyl acetate.

References
1. Schrenk, H.H., Yant, W.P., Chronyak, J., Patty, F.A.: Pub. Health Rept. 51, 1329 (1936).
2. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins Co., Baltimore, 2nd Ed. (1957), p. 386.

METHYL ISOBUTYL CARBINOL (Methyl Amyl Alcohol)

25 ppm (Approximately 100 mg/m^3)

Silverman (1) and associates reported that tests on human subjects for sensory response to various concentrations showed that eye irritation is produced at 50 ppm, though the odor is not objectionable at this level.

Reference
1. Silverman, L., Schulte, H.F., and First, M.W.: J. Ind. Hyg. & Tox. 28, 262 (1946).

α-METHYLSTYRENE

100 ppm (Approximately 480 mg/m^3)

The 100 ppm value is based on the following report of the Dow Chemical Company (1): "Groups of rats, guinea pigs, rabbits, mice, and monkeys were given repeated exposures 7 hours daily, 5 days per week at a concentration of 200 ppm of α-methylstyrene vapor for periods of about 6 months. As judged by growth, mortality, gross appearance and behavior, organ weight studies and gross and microscopic examination of the tissues, this vapor concentration had no adverse effect upon any of the species studied. On the other hand, four human subjects exposed to a concentration of 200 ppm of α-methylstyrene reported definite unpleasant odor and slight eye irritation after about two minutes. These experiments with human subjects indicated that concentrations of about 200 ppm are distinctly disagreeable. We suggest, therefore, an Industrial Hygiene Standard of 200 ppm based on toxicity. For engineering purposes, we suggest that the vapor concentration be controlled to 100 ppm α-methylstyrene in order to minimize complaints of exposed persons."

Reference
1. Dow Chemical Company, Private Communication to Committee Member (1955).

METHYLENE CHLORIDE (DICHLOROMETHANE)

500 ppm (Approximately 1750 mg/m^3)

Heppel and coworkers (1) found that repeated inhalation of 100,000 ppm caused some narcosis in animals, some deaths from lung damage and liver injury. Concentrations of 5,000 ppm breathed for 6 months reduced the activity of rats, but had no visible effect on three other species.

Fairhall (2) records human fatality after accidental anesthesia.

The most serious effect from inhaled methylene chloride in chronic poisoning leads to liver damage.

The 500 ppm value is considered to be low enough to prevent hazard to health.

References
1. Heppel, L.A., Neal, P.A., Highman, B., Porterfield, V.T.: J. Ind. Hyg & Tox. 26, 8 (1944).
2. Fairhall, L.T.: Industrial Toxicology, The Williams and Wilkins Co., Baltimore, (1949).

MICA

20 mppcf

Mica is a nonfibrous silicate occurring in plate form and includes nine different species. Muscovite and phlogopite are the major micas of commerce. The former is a hydrated aluminum potassium silicate, often called white mica. Phlogopite, and aluminum potassium magnesium silicate, is sometimes called amber mica. Other forms include biotite, lepidolite, zinnwaldite, moscoelite.

The threshold limit of mica from 1946 to 1951 was set at 50 mppcf, on the basis of its inert reaction when injected intraperitoneally in guinea pigs (1). It was reduced to the present figure of 20 mppcf after consideration of the studies by Dreessen, et al. (2) who found evidence of pneumoconiosis in 8 of 57 workers exposed for from 18 to 46 years to heavy concentrations of dust associated with mica-scrap grinding, largely muscovite. This was confirmed by Vestal, et al. (3). Heimann, et al. (4) concurred in the reasonableness of this limit, on the basis of studies in mica-processing plants in India (5,6,7).

References
1. Miller, J.W., Sayers, R.R.: Pub. Health Rept. 56, 264 (1941).
2. Dreessen, W.C., DallaValle, J.M., Edwards, T.I., Sayers, R.R., Eason, H.F., Trice, M.F.: Pub. Health Bull. No. 250 (1940).
3. Vestal, T.F., Winstead, J.A., Joiliet, P.V.: Ind. Med. 12, 11 (1943).
4. Heimann, H., Moskowitz, S., Harihara, Iyer, C.R., Gupta, M.N., Mankiker, N.S.: Arch. Ind. Hyg. & Occ. Med. 8, 531 (1953).
5. Govt. of India, Ministry of Labor: Health Hazards of Mica Processing, Report No. 4, New Delhi, Office of the Chief Adviser Factories, Ministry of Labor & Employment, 11 mim. pp. 1954. Abstr. Bull. of Hyg. 33, 1149 (1958).
6. India, Govt. of, Ministry of Labor: Silicosis amongst Hand Drillers In Mica Mining in Bihar (M. N. Gupa) 12 mimeographed pages, 1956, Report No. 12. New Delhi office of the Chief Adviser Factories, Ministry of Labor & Employment, Abstr. Bull. Hy. 32, 1168 (1957).
7. India, Govt. of, Ministry of Labor: Silicosis amongst Supervisory Staff in Mica Mining in Bihar (M.N. Gupa) 6 mimeographed pages, 1955 Report No. 8. New Delhi, office of the Chief Adviser Factories, Ministry of Labor & Employment, Abstr. Bull. Hy. 32, 1168, (1957).

MOLYBDENUM

SOLUBLE COMPOUNDS - 5 mg/m^3

INSOLUBLE COMPOUNDS -15 mg/m^3

Only two reports bearing on the industrial toxicology of molybdenum have

appeared (1,2). The two reports agree in their general conclusions that molybdenum compounds exhibit a low order of toxicity, but that some differences in toxicity may be ascribed to different compounds; the trioxide and ammonium molybdate were more toxic than the ore molybdenite, the metal or the dioxide. A possible reason for the low degree of toxicity is the recent finding that molybdenum is a necessary trace element in the body functioning in conjunction with the flavoprotein enzymes (3). Unfortunately, none of the work provides the type of data from which a threshold limit might be firmly set or from which one might be easily extrapolated; exposures in both reports were for one hour daily at relatively high concentrations.

Molybdenum trioxide, calcium molybdate, and ammonium molybdate, when fed to rats and guinea pigs in large doses of from 1,200 to 6,000 milligrams of molybdenum per kilogram invariably proved fatal. The fatalities were much less in animals fed 120 to 600 milligrams of molybdenum per kilogram. There were no fatalities when amounts as great as 6,000 milligrams of molybdenum as molybdenite per kilogram of body weight were ingested. The inhalation of the dust of molybdenum trioxide, calcium molybdate dust and molybdenum trioxide fume at an average concentration of approximately 5 milligrams of molybdenum per cubic foot of air proved injurious. No fatalities occurred in animals subjected to molybdic oxide fume for 24 one-hour exposures at an average concentration of 1.5 milligrams per cubic foot of air, and only one fatality in 24 one-hour exposures to molybdenite dust at an average concentration of 8.1 milligrams of molybdenum per cubic foot of air. Intraperitoneal injection experiments indicated a high mortality rate for guinea pigs injected with soluble molybdenum compounds in amounts of from 400 to 800 milligrams per kilogram. The effects were particularly noticeable with molybdic oxide and ammonium molybdate.

The conclusions from the Russian report (2) were that dust of molybdenum metal, the brown molybdenum dioxide, the trioxide and ammonium paramolybdate caused only a transitory irritation of mucosal surfaces in white mice after an intensive one-hour dusting. Repetition of the exposure over a period of 30 days caused some toxic symptoms from the trioxide and the paramolybdate, but just slight toxicity from the metal and the dioxide. As in the Fairhall report, suitable protection should be provided to insure against the inhalation of any considerable amount of the more soluble molybdenum compounds, with periodic medical examinations of the workers.

On this very tenuous basis, a limit of 5 mg Mo/m^3 is suggested for the more soluble and active molybdenum compounds, such as molybdenum trioxide and the soluble molybdates; 15 mg Mo/m^3 for the more insoluble compounds. As far as is known, these values include in them a relatively large factor of safety.

References

1. Fairhall, L.T., Dunn, R.C., Sharpless, N.E., Pritchard, E.A.: Pub. Health Bull. No. 293, U.S. Gov't Printing Off., Washington, D.C. (1945).
2. Mogilvskaya, O.Y.: Gigiena i. Sanit. 12, 18 (1950).
3. Mahler, H.R., Green, D.E.: Sci. 120, 7 (1954).

MONOMETHYLANILINE

2 ppm (Approximately 9 mg/m^3)

Treon and his associates (1) have described changes in the blood of animals inhaling MMA, with apparently concentrations for the most susceptible species falling between 2 to 8 ppm. Accordingly these authors tentatively suggest a threshold limit value of 2 ppm. Eckhardt (2) on the other hand, has suggested

a tentative level of 5 ppm, and Hammond (3), 25 ppm. The two latter suggestions have arisen from plant handling experience. Of these three values it would appear desirable to retain the lowest, that of Treon et al. It is to be noted that on the basis of animal experiments, even the level of 2 ppm offers very little margin of freedom from the blood response, and that this margin is less than that incorporated in the majority of threshold limit values. It may be justified, however, on the basis that the manifestation in the blood is early recognizable and consequently remediable, and for this reason it is a less serious hazard.

References
1. Treon, J.F., et al: J. Ind. Hyg. & Tox. 31, 1 (1949).
2. Eckardt, R.E.: Written communication to committee member.
3. Hammond, J.W.: Written communication to committee member.

NAPHTHA, COAL TAR

200 ppm (Approximately 800 mg/m^3)

(This is primarily a mixture of toluene and xylene;

see references on these chemicals).

NAPTHA, PETROLEUM

500 ppm (Approximately 2000 mg/m^3)

This is interpreted as a mixture of preponderantly paraffin hydrocarbons with somewhat lower molecular weight than gasoline; see references on gasoline.

NICKEL CARBONYL ($Ni(CO)_4$)

0.001 ppm (Approximately 0.007 mg/m^3)

The threshold limit for nickel carbonyl was based on the reported (1-4) association of cancer of the lung and nasal sinuses with the Mond process which involves production of nickel carbonyl, a volatile nickel compound. Since this time $Ni(CO)_4$ as the causative agent in these cancers has been questioned by Doll in England (5) on the basis of "no published evidence showing the size of the risks nor the extent to which they have been eliminated." Sunderman, et al. (6) in the U.S. maintain that $Ni(CO)_4$ is the etiologic agent in cancers observed in the Mond nickel workers and has reported production of carcinoma of lungs of rats with metastases to the kidney following exposure to $Ni(CO)_4$. The types of tumors produced, however, were not those generally associated with environmental agents suspected of causing lung cancer. The matter needs further investigation. In the present state of uncertainty and doubt, the limit of 0.001 ppm is retained; it is sufficiently low to prevent acute effects (pneumonitis) and to reduce materially the risk of carcinogenic effects.

References
1. Amor, A.J.: Bericht uben den VII Internationalen Kongress fur Unfall Medizin ung Berufskrankheiten, Frankfort, A.M. 1938, 2, 941 Thieme, Leipsig (1939).
2. Chief Inspector of Factories: Ann. Rep. Chief Inspector of Factories for 1950, 145 HMSO London (1952).
3. Loken, A.C.: T. Nordske Laegeforen 70, 376 (1950).
4. Hueper, W.C.: "Occupational Tumors and Allied Diseases" Springfield, Ill., Chas. Thomas (1942).
5. Doll, R.: Brit. J. Ind. Med. 15, 217 (1958).
6. Sunderman, R.W. et al: Arch. Ind. Health 20, 36 (1959).

NICOTINE

0.5 mg/m^3

Wilson and De Eds (1) fed diets containing nicotine to growing rats for a 60-day period. They were unaffected by 0.006%, but did not survive 0.05%. Ball (2) found nicotine sulfate to have an oral toxicity of 150 mg/kg for rats. Lehman (3) has estimated the fatal human dose of nicotine to be 60 mg; the threshold limit of 0.5 mg/m^3 corresponds to a human intake sufficiently to be below the danger level.

References
1. Wilson, R.H., DeEds, F.: J. Ind. Hyg. & Tox. 18, 553 (1936).
2. Ball, W.L.: Departmental Report, Dept. Natl. Health & Welfare (Can.), (1952).
3. Lehman, A.J.: Assn. Food Drug. Off. U.S. Quart. Bull. 13, 65 (1949).

NITRIC ACID

10 ppm (Approximately 25 mg/m^3)

Fairhall (1) reported that continued exposure to the vapor of nitric acid may bring about a chronic bronchitis and more severe exposure may cause a chemical pneumonitis.

Treiger (2) states that even though pulmonary edema, cardiac failure and bronchopneumonia are controlled, death results from pulmonary fibrosis. The prognosis depends directly upon the concentration of fumes and duration of exposure. Fairhall concluded from these and other data that the amount of nitric acid fume in workshops should not exceed 10 ppm.

References
1. Fairhall, L.T.: Industrial Toxicology (2nd Ed.), Williams and Wilkins, Baltimore (1957), p. 83.
2. Treiger, P.: Ind. Med. 16, 395 (1947).

p-NITROANILINE

1 ppm (Approximately 6 mg/m^3)

On the basis of the statements appearing in Fairhall (1) who quotes Hunter that paranitroaniline is more toxic than aniline and the fact that aniline is set at 5 ppm, it is suggested that a level no higher than 1 ppm be set for paranitroaniline. According to Hunter, referred to above, the meta derivative is still more poisonous than the para form and accordingly if this isomer is present with paranitroaniline, then the limiting value should be still further reduced.

Reference
1. Fairhall, L.T.: Industrial Toxicology, 2nd Ed., Williams and Wilkins, Baltimore, (1957), p. 304.

NITROBENZENE

1 ppm (Approximately 5 mg/m^3)

Henderson and Haggard (1) appear to have provided the only published, quantitative information on the levels of nitrobenzene associated with the acute

response; no similar information on the chronic response appears to be available on nitrobenzene vapor in this country. According to these authors 200 ppm is the highest concentration that can be inhaled for 1 hour without serious disturbance; 40 to 80 ppm produces slight symptoms after exposure of several hours; and 1 to 5 ppm are suggested as the highest concentration safe for daily exposure.

The effects of overexposure to nitrobenzene are grave, resulting in anemia, central nervous system involvement, and effects on the spleen and liver.

Reference

1. Henderson, Y., Haggard, H.W.: Noxious Gases, Reinhold Publ. Corp., N.Y., (1943), p. 228.

NITROETHANE

100 ppm (Approximately 310 mg/m^3)

Machle and associates (1) have reported 500 ppm nitroethane to be a safe and well-tolerated concentration for laboratory animals, including the monkey; a concentration of 1000 ppm is lethal, however, for some animals. Nitroethane, however, is irritating on continued inhalation, but there is no skin absorption.

The threshold limit of 100 ppm can be considered a level providing a reasonable degree of safety and comparative freedom from irritation.

Reference

1. Machle, W., Scott, E.W., Treon, J.: J. Ind. Hyg. & Tox. 22, 315 (1940).

NITROGEN DIOXIDE (NO_2)

5 ppm (Approximately 9 mg/m^3)

The threshold limit of 25 ppm formerly set for oxides of nitrogen was simultaneously redefined to apply only to nitrogen dioxide and revised downward to 5 ppm on the basis of animal studies reported by Gray et al. (1,2). Rats exposed to the vapors of red fuming nitric acid 4 hours daily, 5 days/week for 8 or more weeks showed lung injury at concentrations averaging in excess of 8 ppm. Similarly, rats exposed daily for 6 months at 4 ppm showed no lung changes attributable to the toxic effects of NO_2. The NO_2 concentrations varied considerably from the mean as indicated from the reported standard deviations.

On the basis of a Russian report (3) of workers that were exposed to oxides of nitrogen that did not vary much above 2.8 ppm during 3 to 5 years but in whom blood catalase values were reduced. Ripperton (4) performed a continuous exposure of young rats to 0.5 ppm NO_2 for 6 weeks. Although blood catalase values were felt to be significantly different from controls, the hygienic significance of these findings is in doubt. The Russian workers, however, reported "probable chronic bronchitis" and emphysema of the lungs from the chronic NO_2 exposure.

Adley (5) reported that short exposures of workmen to nitrogen oxide concentrations averaging 25 to 38 ppm resulted in no demonstrable physiologic res-

ponse, but that 80 ppm for from 3 to 5 minutes produced tightness of the chest.

Vigliani and Zurlo (6) found no adverse effects in workers exposed several years at 30 to 35 ppm oxides of nitrogen, and Patty (7) states that concentrations of 10 to 20 ppm NO_2 are mildly irritant to the eyes, nose and upper respiratory tract, and that 5 ppm and slightly below has a distinct odor.

On the basis of information from animal studies a limit of 5 ppm should result in little discomfort and is probably sufficiently low to insure against adverse physiologic effects from prolonged daily exposures. Industrial data are somewhat at variance with this conclusion, but are not sufficiently precise to be conclusive.

References

1. Gray, E.LeB., MacNamee, J.K., Goldberg, S.B.: Arch. Ind. Hyg. & Occ. Med. 6, 20 (1952).
2. Gray, E.LeB., Goldberg, S.B., Patton, F.M.: Arch. Ind. Hyg. & Occ. Med. 10, 423 (1954).
3. Vigdortschik, N.A. et al.: J. Ind. Hyg. & Tox. 19, 469 (1937).
4. Ripperton, L.A., Johnston, D.R.: Am. Ind. Hyg. Assn. J. 20, 324 (1959).
5. Adley, F.E.: J. Ind. Hyg. & Tox. 28, 17 (1946).
6. Vigliani, E.C., Zurlo, N.: Abstr. in Arch. Ind. Health 13, 403 (1956).
7. Patty, F.A.: Industrial Hygiene and Toxicology, Interscience Press, New York (1949), p. 610.

NITROGLYCERINE

0.5 ppm (Approximately 5 mg/m^3)

The report of the U.S.P.H.S. Division of Industrial Hygiene study made in nitroglycerine plants during World War II found no systemic effects from work exposures below 10 ppm; 0.5 ppm, however, resulted in severe headache. Elkins (2) mentions 0.04 ppm to be productive of headache. It is not known whether the cutaneous or inhalative route constitutes the greater source of exposure; however, both routes are probably of considerable importance.

There is some indication that removal from long-term nitroglycerin exposure may be followed by cardiovascular irregularities of a poorly defined nature.

The threshold limit value of 0.5 ppm may be excessive in that it triggers a definite physiologic response, - namely a vascular dilation resulting in headache. In addition, long-term exposures to 0.5 ppm nitroglycerine may condition the cardiovascular system in such a way that withdrawal from nitroglycerine influence is attended by cardiovascular abnormalities.

References

1. McConnell, W.J., Flinn, R.H., Brandt, A.D.: Occ. Med. 1, 551 (1946).
2. Elkins, H.B.: Chemistry of Industrial Toxicology, 2nd Ed., Wiley & Sons, New York (1959), p. 167.

NITROMETHANE

100 ppm (Approximately 250 mg/m^3)

Nitromethane at a concentration of 1000 ppm for 48 hours was lethal to

one exposed monkey, but a concentration of 5000 ppm for three hours was required to kill guinea pigs; lethal exposure concentrations for rabbits were 2500 ppm for 12 hours or 5000 ppm for 6 hours. On the other hand, a concentration of 500 ppm was tolerated for 140 hours in repeated daily exposures by guinea pigs, rabbits and a monkey, according to Machle, Scott and Treon (1).

Industrial health experience with nitromethane presumably at the recommended level of 100 ppm has been reported (2) to be good. Plant operators who have worked with nitroparaffins for several years, and who have had periodic physical examinations, have had no ill effects attributable to nitroparaffins generally; exposure to nitroparaffins included nitromethane.

References
1. Machle, W., Scott, E.W., Treon, J.F.: J. Ind. Hyg. & Tox. 22, 315 (1940).
2. Technical Data Sheet, New Series, No. 23A, June 20, 1956, Commercial Solvents Corporation, New York.

2-NITROPROPANE

25 ppm (Approximately 90 mg/m3)

The limiting air concentration of 2-nitropropane considered to be tolerable, but probably not without disagreeable effects, is 50 ppm according to Treon and Dutra (1). This opinion was based on extensive vapor exposure studies of 5 species of laboratory animals (2 nonrodent species) involving air concentrations from about 9000 ppm to 83 ppm. No histologic changes occurred in tissues of monkeys, rabbits, guinea pigs and rats exposed to air containing 328 ppm nitropropane and below, for 130, 7-hour periods; however, 328 ppm caused severe damage to the liver and moderate injury to the kidneys and heart of the cat. These effects in this species were slight and reversible at 83 ppm.

Skinner (2) has reported that 2 men working for 1 year with exposures not exceeding 4 hours/day and no more than 3 days/week showed no ill effects at concentrations of 2-nitropropane between 10-30 ppm. Others, exposed to concentrations of between 25 and 40 ppm, showed ill effects consisting of nau sea, vomiting, diarrhea and anorexia, particularly those with long-continued exposures.

It would appear from the above rather limited information that a limit of 25 ppm would provide freedom from systemic injury and probably is sufficiently low to prevent the occurrence of disturbing symptoms in most exposed individuals.

The Russian maximal concentration published January 10, 1960 for 2-nitropropane is 8.3 ppm.

References
1. Treon, J.F., Dutra, F.R.: Arch. Ind. Hyg. & Tox. 5, 52 (1952).
2. Skinner, J.B.: Ind. Med. 16, 441 (1947).

MONONITROTOLUENE (ALL ISOMERS)

5 ppm (Approximately 30 mg/m3)

von Oettingen (1), in a review of the toxicity of aromatic amino and nitro

compounds notes observed differences in the toxicity of m- and p-nitrotoluene as compared to that of nitrobenzene. Investigators cited in the review found that o-nitrotoluene is probably as toxic as nitrobenzene, whereas the meta compound was much less harmful and the para compound being of intermediate effect.

Gafafer (2) suggests a threshold limit for mononitrotoluene of 5 ppm.

References
1. von Oettingen, W.F.: Pub. Health Bull. 271 (1941).
2. Gafafer, W.M.: Manual of Industrial Hygiene, Chapter II, Engineering Control of Air Contamination of the Working Environment, W.B. Saunders Co., Philadelphia (1943), p. 264.

OCTANE

500 ppm (Approximately 2350 mg/m^3)

This value is based on analogy with heptane, pentane, and gasoline.

OZONE (O_3)

0.1 ppm (Approximately 0.2 mg/m^3)

The downward revision of the former threshold limit for ozone of 1 ppm to 0.1 ppm is justified on the basis of the following information reported for both animals and man. Acutely, O_3 is a highly injurious and lethal gas at relatively low concentrations (a few ppm) and at short exposure periods (a few hours) (1). The primary site of acute injury is the lung which is characterized by pulmonary congestion, edema and hemorrhage. There are indications in man that there are secondary sites of reaction of O_3; this is characterized by a defect in oxygen dissociation from oxyhemoglobin in the tissues (2). Chronically, O_3 has been reported to result in bronchiolitis and bronchitis in animals exposed daily (6 hours) for 1 year at concentrations slightly in excess of 1 ppm (3).

The susceptibility of man to O_3 appears to be at least equal to that of the most susceptible animal species (mouse and rat) from the report of Griswold et al. (4); exposure for 2 hours to an average concentration of 1.5 ppm O_3 resulted in a 20% reduction in timed vital capacity of the lung and other effects. Kleinfeld et al. (5) reported pulmonary congestion in welders using the inert-gas shielded-arc process in which the O_3 concentration reached a maximum of 9 ppm. Challen et al. (6) found similar effects in welders from exposures somewhat under 2 ppm, but which disappeared when O_3 levels were reduced to around 0.2 ppm.

In addition to these serious effects of O_3, air concentrations of O_3 in excess of a few tenths ppm occasion discomfort to exposed individuals in the form of headache, dryness of throat and mucous membranes of nose and eyes following exposures of short duration (7,8).

References
1. Stokinger, H.E.: Arch. Ind. Health 15, 181 (1957).
2. Brinkman, R., Lamberts, H.B.: Nature 181, 1202 (1958).
3. Stokinger, H.E., Wagner, W.D., Dobrogorski, O.J.: Arch. Ind. Health 16, 514 (1957).
4. Griswold, S., Chambers, L.A., Motley, H.L.: Arch. Ind. Health 15, 108 (1957).

5. Kleinfeld, M., Giel, C.P.: Am. J. Med. Sci. 231, 638 (1956).
6. Challen, P.J.R., Hickish, D.E., Bedford, J.: Brit. J. Ind. Med. 15, 276 (1958).
7. Wilska, S.: Acta. Chem. Scand. 5, (1) 359 (1951).
8. Truche, M.R.: Arch. mal profess. 12, 55 (1951).

PARATHION

(O,O-DIETHYL O-p-NITROPHENYL THIOPHOSPHATE)

0.1 mg/m^3

Parathion has an acute oral LD_{50} of 3 mg/kg for female rats, and 6 mg/kg for male rats. Brown and Bush (1), in the United States, found parathion in a concentration range of 0.1-0.8 mg/m3 in a processing plant. Cholinesterase determinations on blood from exposed workers showed decreased activity. Barnes (2) found that some factory workers manufacturing parathion had slight but statistically lowered cholinesterase levels, but did not measure parathion concentrations. American Cyanamid Company investigators (3) found levels of parathion in California orchards up to 0.3 mg/m^3 during spraying. They performed no cholinesterase determinations. Kay and co-workers (4) measured both air concentrations of parathion at the human breathing zone in orchards and the cholinesterase levels of the workers engaged in the spraying. In this investigation, workers had been in contact with parathion for periods of from 2 to 5 days on 5 occasions during a period of 2 months. No precautions were taken, other than to stay up-wind from the spray. Levels of 2-15 mg/m^3 of parathion were found in the air. Cholinesterase levels of workers were decreased about 25% below controls by the end of the season. It would appear that marginal exposure had occurred in this case. An estimate of the average exposure received cannot be more than approximate; however, if an average exposure of about 8 mg/m^3 is assumed on working days and that spraying was done every fourth day, the average daily exposure was not more than 2.0 mg/m^3 for a period of two months.

Based on these calculations, 2 mg/m^3 would appear to be an excessive exposure. From the work of Brown and Bush (1), 0.5 mg appears excessive. It is concluded that the figure of 0.1 mg/m^3 provides the best estimate for a threshold limit from available data.

References

1. Brown, H.V., Bush, A.F.: Arch. Ind. Hyg. Occup. Med. 1, 633 (1950).
2. Barnes, J.M., Davies, D.R.: Ministry of Supply, Tech. Paper No. 241.
3. American Cyanamid Company: Parathion Vapor Concentrations in the Atmosphere of California Groves During and After Application, Report of Study made in 1950.
4. Kay, K., Monkman, L., Windish, J.P., Doherty, T., Pare, J., Racicot, C: Arch. Ind. Hyg. & Occup. Med. 6, 252 (1952).

PENTACHLORONAPHTHALENE

0.5 mg/m^3

Based on inhalation studies on rats, Drinker (1) concluded that the toxic action of this compound is on the liver only, and proposed a permissible limit for repeated inhalations of 0.5 mg/m^3. The compound in the solid state or in oil solutions penetrates the skin, and repeated contact leads to chloracne.

It is believed that the value of 0.5 mg/m^3 is sufficiently low to prevent a health hazard.

Reference
1. Drinker, C.K.: J. Ind. Hyg. & Tox. 21, 155 (1939).

PENTACHLOROPHENOL

0.5 mg/m^3

The most important effect of pentachlorophenol inhalation is acute poisoning centering in the circulatory system. Kehoe, Deichmann-Gruebler, and Kitzmiller (1) found no evidence of chronic poisoning in rabbits. The smallest lethal intravenous dose was 22 mg/kg. The compound penetrates the skin readily. Physiologic injury is mainly vascular with heart failure.

The 0.5 mg/m^3 threshold limit is derived by analogy with other compounds of similar action and toxicity in addition to the specific available information.

Reference
1. Kehoe, R.A., Deichmann-Gruebler, W., Kitzmiller, K.V.: J. Ind. Hyg. & Tox. 21, 160 (1959).

PENTANE

1000 ppm (Approximately 3000 mg/m^3)

Patty and Yant (1) found no effect on humans from 10 minutes of exposure at 5,000 ppm.

Fairhall (2) concluded that narcosis and irritation are the only effects.

References
1. Patty, F.A., Yant, W.P.: U.S. Bureau of Mines Rpt. of Invest. 2979 (1929).
2. Fairhall, L.T.: Industrial Toxicology, 2nd Ed., Williams & Wilkins, Baltimore (1957), p. 268.

PENTANONE (METHYL PROPYL KETONE)

200 ppm (Approximately 700 mg/m^3)

Yant and associates (1) concluded from exposure of animals that the maximal concentration of pentanone for several hours exposure with slight or no symptoms was 1500 ppm, though this level was severely irritating to man.

Specht et al. (2) found the toxicity of pentanone vapors similar to that of butanone (methyl ethyl ketone).

References
1. Yant, W.P., Patty, F.A., Schrenk, H.H.: Pub. Health Rept. 51, 392 (1936).
2. Specht, H., Miller, J.W., Valaer, P.J., Sayers, R.R.: Public Health Service Nat'l Inst. Health Bull. No. 176 (1940).

PERCHLOROETHYLENE (TETRACHLOROETHYLENE)

100 ppm (Approximately 670 mg/m^3)

Carpenter (1) reported that there were no deaths as a direct result of

exposure to tetrachloroethylene vapors among 136 rats exposed for varying intervals at 70, 230, 470 and 7000 ppm. Exposures were continued over a 7-month period, 8 hours a day, 5 days per week, the maximal exposure of any animal being 150 days or 1,200 hours. The pathology of the liver, kidney, spleen, adrenal, heart, lung, eye, peripheral and central nervous tissue indicated only slight effects on liver, kidney and spleen with other tissues appearing normal. On the basis of his findings, the author considers a concentration somewhere between 100 and 500 ppm safe for daily exposures not in excess of 40 hours a week.

Humans exposed to various vapor concentrations were able to detect the odor at 50 ppm, experienced slight eye irritation and increased secretion of mucus from the nasal passages at 500 ppm, developed light narcosis and stinging of the eyes at 1000 ppm and became nauseated at 5000 ppm. The most important effect of perchloroethylene vapor inhalation is narcosis (2).

Rowe and his associates (3) found on repeated inhalation at 400 ppm, no evidence of adverse effect on rats, rabbits and monkeys. Concentrations of 100 ppm had no effect on guinea pigs. Single exposure of man at 100 ppm had no effect, while exposure at 200 ppm produced minimal effects. A subsequent report by the same research group (4) concluded that vapor exposures to perchloroethylene should never exceed 200 ppm. A limit of 100 ppm is recommended on the basis of prevention of minimal narcotic effects in man.

References
1. Carpenter, C.P.: J. Ind. Hyg. & Tox. 19, 323 (1937).
2. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).
3. Rowe, V.K.: Arch. Ind. Hyg. & Occ. Med. 5, 566 (1952).
4. Stewart, R.D., et al: Arch. Envir. Health 2, 516 (1961).

PHENOL

5 ppm (Approximately 19 mg/m^3)

Deichman (1) reported results of animal experimentation in which guinea pigs were severely injured by inhalation of phenol vapor in concentrations of from 25 to 50 ppm for 20 days. Post-mortem evidence of acute toxicity to the lungs, heart, liver and kidney was found.

Intermittent industrial exposure (2) (5 to 10 minutes per hour) inside a conditioning room for phenol-impregnated asbestos resulted in marked irritation of the nose, throat and eyes. The average phenol concentration in the room was 48 ppm, although formaldehyde (8 ppm) also was found. Urine sulfate ratios were 79.4 and 86.7 percent.

Workers, at the same plant, continuously exposed during winding operations experienced no respiratory irritation, although the odor of phenol was noticeable. The average concentration found was 4 ppm. Urine sulfate ratios averaged 74 percent.

Elkins (3) has found that phenol is not sufficiently volatile to constitute a respiratory hazard under normal conditions. It is a strong irritant, however, and causes numerous dermatoses. If large areas of the skin are wet with pure or concentrated phenols, serious and even fatal poisoning may result.

References
1. Deichman, W.B., Kitzmiller, K.V., Witherup, S.: Am. J. Clin. Path. 14, 273 (1944).

2. Connecticut Bur. of Ind. Hygiene - Unpublished Data.
3. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York, 2nd Edition (1959), p. 116.

PHENYLHYDRAZINE

5 ppm (Approximately 22 mg/m^3)

It has been demonstrated repeatedly that phenylhydrazine produces anemia when fed to or injected into animals (1,2,3). Allen and Page (3) concluded that the erythrolytic effect of phenylhydrazine was due to the benzene nucleus and not to the hydrazine portion of the molecule. In acute poisoning of the rabbit and guinea pig, hemolysis is well marked (4), the urine is diminished in quantity and is dark in color. Intense anemia, loss of appetite and asthenia mark the general condition. Chronic poisoning of young animals results in a checked and irregular growth, anemia and asthenia (5). No alteration in the volume of urine was noted however. At autopsy an increased deposition of iron in the liver, spleen and kidney was revealed. According to Hesse and his associates (6), 0.02 gram of phenylhydrazine per kilogram of body weight when administered subcutaneously in dogs invariably results in death in about 22 days. According to these investigators, the cause of death is a result of depletion of glycogen, especially in the heart muscle. An experimental study of the mechanism of detoxication revealed that glycogen formers, or substances promoting glycogen synthesis, are certain remedies against fatality, the animals remaining obviously healthy following this treatment. No industrial fatalities have been recorded from contact with phenylhydrazine. Cases of skin contact occasionally occur in industry, however, and it should be emphasized that phenylhydrazine is not only a skin poison, but that absorption from the skin occurs very readily. Dermatitis from exposure to phenylhydrazine-zinc chloride was reported by Dowing (7) in a rubber mill employee. Tests showed this individual to be sensitized to this material following a brief previous exposure.

The complication of being an active skin poison makes the setting of a threshold limit value for phenylhydrazine a difficult matter; however, on the available evidence, a reasonable value is that assigned to aniline and phenol, namely, 5 ppm.

References

1. Kanamori, T.: Biochem. Z. 175, 330 (1926).
2. Hayaski, K.: Compt. rend. soc. de Biol. 94, 653 (1926).
3. Allen, E.V., Page, I.H.: Arch. F. exp. Path. u. Pharmak. 147, 211 (1930).
4. Lang, S.: Zeitschr. exp. Med. 80, 637 (1932).
5. Lande, P., Dervillee, P., Challier, A.: Compt. rend. Soc. de Biol. Paris 111, 172 (1932).
6. Hesse, E., Franke, H., Hering, H.: Klin. Wochnschr. 14, 1425 (1935).
7. Downing, J.G.: New Eng. J. Med. 216, 240 (1937).

PHOSGENE

1 ppm (Approximately 4 mg/m^3)

Fieldner and associates (1) refer to the Chemical Warfare Service as the authority for the value of 1 part of phosgene per million parts of air as the maximal concentration considered safe for prolonged exposure.

Henderson and Haggard (2) cite this and other references on effects of phosgene at various concentrations; 3 ppm is claimed to be the least amount to cause immediate irritation of the throat, 4 ppm to cause immediate irritation of the eyes, 4.8 ppm to cause coughing, 5.6 ppm as the least detectable odor, 25 ppm as dangerous for even short exposure, and 50 ppm or more as rapidly fatal for short exposure.

The threshold limit value of 1 ppm is believed to be sufficiently low to cause no more than minimal effects.

References
1. Fieldner, A.C., Katz, S.H., Kinney, S.P.: U.S. Bureau of Mines Technical Paper 248 (1921).
2. Henderson, Y. and Haggard, H.W.: Noxious Gases, Reinhold Publishing Corp., New York, 2nd and Rev. Ed. (1943), p. 138.

PHOSPHINE

0.05 ppm (Approximately 0.07 mg/m^3)

Müller (1) found phosphine concentrations of 5 ppm could be tolerated by laboratory animals for 2 months of 4-hour daily exposures, but animals died after 7 exposures of 4 hours each at 10 ppm. Man appears to have a similar susceptibility to phosphine according to Gessner (2); 12 individuals became ill and 1 died from residing in a house near a warehouse in which was stored moist aluminum phosphide. Phosphine poisoning occurs only through the respiratory tract (3). Chronic poisoning from phosphine is recognized and is characterized by anemia and nervous disorders. According to Patty (4) phosphine at 1 ppm produces only a slight odor.

The threshold limit of 0.05 ppm would seem, on the basis of animal studies, to provide a reasonably safe level for control of health effects.

References
1. Müller, W.: Arch. exptl. Pathol. Pharmakol. 195, 1884 (1940).
2. Gessner, O.: Samml. Vergiftungsfallen 8, 13 (1937).
3. Barillet, F.: Ind. Chim. Belge 27, 123 (1940).
4. Patty, F.A., Ed.: Industrial Hygiene and Toxicology, Interscience Pub. Co., New York (1949), p. 576.

PHOSPHORIC ACID

1 mg/m^3

The recommended threshold limit is based by analogy from comparable experience and data for sulfuric acid. Fumes of phosphorus pentoxide at concentrations ranging from 0.8 to 5.4 mg/m^3 were noticeable, but not uncomfortable, and concentrations between 3.6 and 11.3 mg/m^3 caused coughing among the inexperienced, but could be tolerated. Concentrations of 100 mg/m^3 were unendurable, except to hardened workers (1).

Reference
1. Rushing, D.E.: Written Communication to Committee Member April 1957.

PHORPHORUS (YELLOW)

0.1 mg/m^3

Fairhall (1) provides a summary of the literature on phosphorus, including effects of chronic poisoning upon bone metabolism. One mg/kg of body weight is usually fatal. Inhalation of yellow phosphorus vapor by rabbits for 30 minutes daily at 150-160 mg/m^3 led to decreased hemoglobin and erythrocyte counts. Effects on the lung, liver, and kidney were marked (2). Buchannan (3) confirmed this by producing chronic poisoning in 10 kg dogs by subcutaneous injection of 0.1 mg phosphorus per kilogram per day. Some dogs died after about two months exposure.

It appears from the work of Buchannan on dogs that the limit of 0.1 mg/m^3 is probably sufficiently low to prevent serious injury, but may not provide a large margin of safety from undesirable effects.

References
1. Fairhall, L.T.: Industrial Toxicology (2nd Edition), The Williams and Wilkins Co., Baltimore (1957).
2. Maruo, T.: Fukuoka Acta Med. 46, 604 (1955).
3. Buchannan, D.J., Robinson, C.S., Pope, K., Ferguson, M.E., Thompson, J.B.: Arch. Ind. Hyg. and Occ. Med. 9, 1 (1954).

PHOSPHORUS PENTACHLORIDE

1 mg/m^3

Smyth (1) considers the most important effect of phosphorus pentachloride to be respiratory tract irritation and lung edema. Flury and Zernik (2) state that its effects are similar to those of the trichloride. The limit of 1 mg/m^3 appears to be sufficiently low to prevent injury.

References
1. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).
2. Flury, F., Zernik, F.: Schadliche Gase, J. Springer, Berlin (1931), p. 172.

PHOSPHORUS PENTASULFIDE

1 mg/m^3

Smyth (1) states that the most important effect of phosphorus pentasulfide inhalation is respiratory tract irritation. The limit of 1 mg/m^3 is apparently an estimate without quantitative support. It appears low enough to prevent injury.

Reference
1. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 192 (1956).

PHOSPHORUS TRICHLORIDE

0.5 ppm (Approximately 3 mg/m^3)

Phosphorus trichloride vapor may produce marked irritation to the upper and lower respiratory passages, probably due in part at least to hydrolysis of phosphorus trichloride to hydrochloric and phosphoric acids (1). Butjagin,

cited by Cook (2), reported that, based on animal experimentation, 0.7 ppm caused only slight irritation. From these data, a threshold limit value of 0.5 ppm is inferred.

References
1. Henderson, Y. and Haggard, H.W.: Noxious Gases and the Principles of Respiration Influencing Their Action, Reinhold Publishing Corp., New York, 2nd and Rev. Ed. (1943), p. 134.
2. Cook, W.A.: Ind. Med. 14, 936 (1945).

PICRIC ACID

0.1 mg/m^3

Picric acid, (2,4,6-trinitrophenol), is toxic, and the ingestion of 1 or 2 grams in man causes severe poisoning. Exposure in industry is by skin contact or by inhalation of the dust of picric acid or its salts. The toxicology is of practical importance in the manufacture of munitions. Skin contact with the dry powder of picric acid or ammonium picrate powder causes sensitization dermatitis among workers exposed to it (1). The face is usually involved, especially around the mouth and sides of the nose. Edema, papules, vesicles, and finally, desquamination develops (2). The systemic poisoning following the absorption of picric acid causes symptoms of headache, vertigo, nausea, vomiting and diarrhea. Yellow coloration of the skin and conjunctiva may occur and there may be darkened or port wine colored urine and albuminuria. Toxic doses cause destruction of the erythrocytes and produce gastroenteritis, hemorrhagic nephritis, and acute hepatitis. So far as systemic poisoning from picric acid in industry is concerned, Perkins (3) and Koelsch (4) state that this substance is not a severe industrial poison. Sunderman and associates (2) made a study of the health hazards of exposure to ammonium picrate dust in a plant where 71 individuals were exposed at concentrations of 0.0088 to 0.1947 mg/m^3. Dermatitis developed only among workers least exposed. This lends support to the opinion that desensitization or adaptation may occur following exposure similar to that occurring with tetryl.

As is the case with other industrial skin poisons, it is difficult to set an arbitrary figure of permissible exposure. Since the effects on the skin are marked in concentrations far below those associated with systemic poisoning resulting from administration by mouth, a threshold limit value of 0.1 mg/m3 is recommended.

References
1. Schwartz, L.: J. Am. Med. Assn. 125, 186 (1944).
2. Sunderman, F.W., Weidman, F.D., Batson, O.V.: J. Ind. Hyg. & Tox. 27, 241 (1945).
3. Perkins, R.G.: Pub. Health Repts. 34, 2355 (1919).
4. Koelsch, F.: Zentralbl. Gew. Hyg. Unfallverhutung 8, 186, 223 (1919).

PORTLAND CEMENT

50 mppcf

Portland cement refers to a class of hydraulic cements in which the two essential constituents are tricalcium silicate, ($3CaO.SiO_2$, and dicalcium silicate, ($2CaO.SiO_2$), with varying amounts of alumina, tricalcium

aluminate, and iron oxide. The quartz content of most finished cements is low, below 1 per cent.

Miller and Sayers described an absorptive reaction when cement dust was introduced intraperitoneally in guinea pigs (1).

The threshold limit for Portland Cement has been set at the level of an inert dust, based on a number of studies. Gardner, et al. (4) found no pneumoconiosis due to exposure to finished Portland Cement in 17 cement plants with 2,278 workers, despite heavy and prolonged exposures. This has been confirmed by other studies (2,3,5,7,9,10). Conflicting reports (6,8) appear related to exposures having occurred in mining, quarrying, or crushing silica-containing raw materials.

References
1. Miller, J.W., Sayers, R.R.: Pub. Health Rept. 56, 264 (1941).
2. Thompson, L.R., Brundage, D.K., Russell, A.E., Bloomfield, J.J.: The Health of Workers in Dustry Trades, Pub. Health Bull. No. 176, (1928).
3. Russell, A.E.: Am. J. Med. Sci. 185, 330 (1933).
4. Gardner, L.U., Durkan, T.M., Brumfiel, D.M., Sampson, H.L.: J. Ind. Hyg. & Tox. 21, 279 (1939).
5. Vaccarezza, R.A.: Buenos Aires, Ed. Guillermo Kraft Lts. 1950, quoted by Sander.
6. Parmeggiani, L.: Rass. Med. Indust., Turin. 20, 400 (1951).
7. Guiliani, V., Belli, R.: Med. d. Lavoro. 46, 715 (1955). Abstr. Bull. Hyg. 31, 544 (1956).
8. Prosperi, G., Barsi, C.: Rass. Med. Indust., Turin. 1, 16 (1957).
9. Sander, O.A.: Arch. Ind. Health. 17, 96 (1958).
10. Bloomfield, J.J.: Personal communication quoted in reference.

PROPYL ACETATE

200 ppm (Approximately 840 mg/m^3)

In a review of the work of Flury and Wirth (1), Browning (2) concluded that propyl acetate is less toxic than methyl or ethyl acetates on inhalation for long periods. On exposure to concentrations below levels producing narcosis, propyl acetate caused respiratory irritation and some liver injury. Baldi (3) has reported that exposures of men to propyl acetate at levels of 20 to 60 mg/l caused within 1 week, conjunctival irritation, a feeling of oppression in the chest, and cough. Cessation of exposure was followed by prompt recovery. Smyth (4) mentions unpublished data to the effect that inhalation of the vapor at 32,000 ppm for 4 hours killed 4 of 6 rats.

The threshold limit value of 200 ppm is inferred from analogy with ethyl acetate.

References
1. Flury, F., Wirth, W.: Arch. Gewerbepath. Gewerbehyg. 5, 1 (1934).
2. Browning, E.: Toxicity of Industrial Organic Solvents, The Chemical Publishing Co., Inc., New York, Revised American Edition (1953), p 293.
3. Baldi, G.: Med. Lavoro. 44, 469 (1953). From Fairhall, L.: Industrial Toxicology, The Williams and Wilkins Co., Baltimore, 2nd Ed. (1957), p. 326.
4. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. J. 17, 129 (1956).

PROPYL ALCOHOL (ISOPROPYL ALCOHOL)

400 ppm (Approximately 980 mg/m^3)

Nelson and co-workers (1) found that 400 ppm of propyl alcohol caused mild irritation of the eyes, nose and throat; 800 ppm intensified the symptoms.

Fairhall (2) believed it to be similar in action to ethyl alcohol with no delayed action, but about twice as toxic.

Smyth (3) found that rats survived four hours at 12,000 ppm but half the animals were killed by eight hours of exposure.

The most important toxic action of propyl alcohol is narcosis.

The 400 ppm value is considered to be low enough to prevent narcosis, although slight irritation may occur.

References
1. Nelson, K.W., Ege, J.F., Jr., Ross, M., Woodman, L.E., Silverman, L.: J. Ind. Hyg. & Tox. 25, 282 (1943).
2. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins, Baltimore (1949), p. 428.
3. Smyth, H.F., Jr.: Unpublished work by Chemical Hygiene Fellowship, Mellon Institute, Pittsburgh (1937-55).

PROPYL ETHER (ISOPROPYL ETHER)

500 ppm (Approximately 2100 mg/m^3)

Machle and associates (1) studied the physiologic response of rabbits, monkeys and guinea pigs to various concentrations of isopropyl ether vapor. Concentrations of 1000 ppm and 300 ppm did not noticeably effect rabbits and monkeys exposed for 20 periods of either 2 or 3 hours duration. Animals exposed at fatal concentrations showed specific pathologic lesions, although animals exposed at 30,000 ppm showed no pathologic changes and lived for some weeks after exposure.

Reference
1. Machle, W., Scott, E.W., Treon, J.: J. Ind. Hyg. & Tox. 21, 72 (1939).

PROPYLENE DICHLORIDE (1,2-DICHLOROPROPANE)

75 ppm (Approximately 350 mg/m^3)

Heppel and co-workers (1) found that repeated inhalation of 1000 ppm of this compound caused death of animals in seven days with severe liver damage. They concluded that it is less toxic than carbon tetrachloride but more toxic than ethylene chloride.

The 75 ppm threshold limit, although supported by the above experimental work, is based also on propylene dichloride's intermediate position between carbon tetrachloride and ethylene chloride which have been assigned threshold limit values of 25 and 100 ppm respectively.

Reference
1. Heppel, L.A., Neal, P.A., Highman, B., Porterfield, V.T.: J. Ind. Hyg. & Tox. 26, 8 (1944).

PROPYLENE IMINE

25 ppm (Approximately 60 mg/m^3)

This substance resembles ethylene imine in its physiologic action but has been found to be from one-fourth to one-eighth as toxic as the latter on the basis of very limited study of the effects of the vapor by inhalation in rats (1). The physiologic action of ethylene imine, however, has been well studied both experimentally and industrially in man. (See ethylene imine).

Accordingly, the suggested threshold level for propylene imine is 25 ppm.

References

1. Carpenter, C.P., Smyth, H.F., Jr., Shaffer, C.B.: J. Ind. Hyg. & Tox. 30, 2 (1948).

PROPYLENE OXIDE

100 ppm (Approximately 240 mg/m^3)

Rowe and co-workers (1) found that repeated daily exposures of several species of animals at 200 ppm caused no ill effects. Female guinea pigs only were found to have a slight increase in lung weight after about six months. All animals tolerated 100 ppm without adverse effects. These authors suggest a threshold limit of 150 ppm.

Jacobson et al. (2) found propylene oxide to be over half to one-third as toxic as ethylene oxide, based on the response to single exposures.

References

1. Rowe, V.K., et al.: Arch. Ind. Health 13, 228 (1956).
2. Jacobson, K.H., Hackley, E.B., Feinsilver, L.: Arch. Ind. Health 13, 237 (1956)

PYRETHRUM

2 mg/m^3

Carpenter and co-workers (1) found the oral LD_{50} of two samples of pyrethrum to be 820 and 1870 mg/kg respectively for rats. No gross effects were observable in animals fed diets containing less than 5000 ppm pyrethrins. Carpenter and co-workers (1) exposed rats to 6000 mg/m^3 of pyrethrum in peanut oil for 30 minutes. Moderate lung congestion resulted. Rats and dogs inhaled a concentration of 16 mg/m^3 for thirty minute periods during 31 calendar days with only slight lung irritation. Lehman (2) estimated that the fatal human dose might be 100 grams (1430 mg/kg) for 70-kg man.

The recommended value of 2 mg/m^3 is sufficiently low to prevent injury.

References

1. Carpenter, C.P., Weil C.S., Pozzani, U.C., Smyth, H.F., Jr.: Arch. Ind. Hyg. & Occ. Med. 2, 420 (1950).
2. Lehman, A.J.: Assn. Food Drug Off. of U.S. Quart. Bull. 13, 65 (1949).

PYRIDINE

5 ppm (Approximately 15 mg/m^3)

Pollock and associates (1) using pyridine for human therapy found that 0.83 ml. to 2.46 ml. was toxic, with one death from liver and kidney damage.

Fairhall (2) states that when ingested, it affects the central nervous system. Large doses act as a heart poison, whereas smaller doses stimulate the bone marrow to increased production of blood platelets. The fumes are irritating to mucous surfaces, causing eye and nasal irritation.

H. F. Smyth, Jr. (3) considers the most important effect of pyridine inhalation is chronic poisoning, centering in the liver, kidney and bone marrow. Mild symptoms may result from exposure to 10 ppm.

Teisinger (4) reported chronic poisoning with mild symptoms of central nervous system injury in a plant where pyridine vapor concentrations ranged from 6 to 12 ppm.

References
1. Pollock, L.J., Finkelman, K., Arieff, A.J.: Arch. Internat. Med. 71, 95 (1943).
2. Fairhall, L.T.: Industrial Toxicology, 2nd Ed. (1957), p. 331.
3. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).
4. Teisinger, J.: Czech. Med. J. 39 (1947). Abstr. in J. Ind. Hyg. & Tox. 30, 58 (1948).

QUINONE

0.1 ppm (Approximately 0.4 mg/m^3)

Sterner, Oglesby and Anderson (1) have reported that vapors of quinone and dust of hydroquinone arising in the manufacture of the latter produced characteristic eye injuries in workmen. The injuries developed gradually over a period of years with no serious cases appearing from exposures of durations shorter than five years. No systemic effects were found associated with these injuries. Quinone was believed to be the chief causative agent, although hydroquinone dust was suspected as a contributory cause.

Since this report, a large number of clinical and enviromental studies (2), made on workers in plants where these two substances were produced, confirm the findings of the original report that no systemic effects arise at a level of 0.1 ppm quinone vapor.

References
1. Sterner, J.A., Oglesby, F.L., Anderson, B.: J. Ind. Hyg. & Tox. 29, 60 (1947).
2. Fasset, David W.: Personal Communication.

ROTENONE

5 mg/m^3

Lehman (1) on the basis of his own work and a literature survey, estimates the fatal human dose of this compound to be about 200 grams by mouth. It is

thus about half as toxic as pyrethrum and by analogy, a threshold limit of 5 mg/m^3 appears to be satisfactory.

Reference
1. Lehman, A.J.: Assn. Food Drug Off. of the U.S. Quart. Bull. 13, 65 (1949).

SELENIUM COMPOUNDS (as Se)

0.1 mg/m^3

Fairhall (1) summarizes the work of Fitzhugh and associates in which rats were fed selenium in a grain diet at concentrations of 3, 5, 7, 10, 20, and 40 ppm and which showed toxic effects at all levels. A concentration of 10 ppm killed most of the animals within eight weeks. Lower concentrations produced chronic symptoms, which included a decreased growth rate, a restriction of food consumption and slight to severe pathologic lesions.

Dudley and Miller (2) and Buchan (3) found deleterious effects resulting from free exposures at approximately 0.2 to 0.3 ppm H_2Se. Symptoms were largely referable to the liver in the industrial cases reported by Buchan. The value of 0.1 mg/m^3 is derived from feeding experiments with animals and on observations based on the inhalation of H_2Se by man.

References
1. Fairhall, L.T.: Industrial Toxicology, The Williams & Wilkins Company, Baltimore, (1957), p. 103.
2. Dudley, H.C. and Miller, J.W.: J. Ind. Hyg. & Tox. 23, 470 (1941).
3. Buchan, R.F.: Occup. Med. 3, 439 (1947).

SILICA (AMORPHOUS)

20 mppcf

The following recommendation was made in the report of a Public Health Service study of pneumoconiosis in the diatomite industry (1). "Atmospheric exposures to amorphous silica dust should be kept under 20 million particles per cubic foot of air based on good engineering dust control practices, until additional data are available to define biologic activity."

Reference
1. Cooper, W.C., Cralley, L.J.: Pneumoconiosis in Diatomite Mining and Processing, Pub. Health Serv. Publ. No. 601 (1958).

SILICA (CRISTOBALITE) (above 5%)

5 mppcf

Cristobalite, one of the three major crystalline forms of silicon dioxide is stable at high temperatures and is formed when quartz or amorphous silica is heated, as in the calcining of diatomaceous earth or in the silica brick industry.

Gardner (1) reported on experiments in which rabbits were injected intravenously, and guinea pigs intraperitoneally with various mineral dusts. Response to cristobalite were more severe than from quartz, and the fibrosis that followed was diffuse rather than nodular. King, Mohanty, Harrison, and

Nagelschmidt (2) had similar results in rats given intratracheal injections of cristobalite, fused silica, quartz and tridymite.

The present recommended threshold limit is based on studies in the diatomite industry (3,4) and by analogy with the threshold limit for quartz. Recent experimental studies (5) in animals with diatomaceous earth of 61% cristobalite content at levels of 2, 5 and 50 mppcf have presented strong evidence for the need to review the present limit. Although no frank fibrosis of the lung developed from any level of exposure in 2.5 years, there was considerable cellular infiltration in the lung and hyalinized fibrotic nodules developed in the pulmonary lymph nodes in 1 animal species at the 5 mppcf level with scattered nodules at the 2 mppcf level.

References
1. Gardner, L.U.: Am. Inst. Mining & Metal. Engrs. Tech. Pub. No. 929, (1938).
2. King, E.J., Mohanty, G.P., Harrison, C.V., Nagelschmidt, G.: Brit. J. Ind. Med. 10, 9 (1953).
3. Smart, R.H., Anderson, W.M.: Ind. Med. & Surg. 21, 509 (1952).
4. Cooper, W.C., Cralley, L.J.: Pneumoconiosis in Diatomite Mining and Processing, Pub. Health Serv. Publ. No. 601 (1958).
5. Wagner, W.D., et al., to be published in Am. Ind. Hyg. Assn. J.

SILICA (QUARTZ)

High (above 50 percent free silica)	5 mppcf
Medium (5 to 50 per cent free silica)	20 mppcf
Low (below 5 per cent free silica)	50 mppcf

The threshold limits for silica rest primarily upon the considerable body of evidence, first systematically developed by Collis (1), confirmed by Gardner (2) and many others, pointing to free silica as being the major pneumoconiosis-producing hazard in industrial dusts. Fundamental early work on the biologic effects of quartz and other mineral dusts are contained in reports by Miller and Sayers (3) and Gardner (2). They demonstrate the ability of quartz, as well as other forms of free crystalline silica to induce a proliferative and eventually fibrous reaction when introduced into the peritoneal cavity, the blood-stream, or into the lungs by inhalation.

The present threshold limits for concentrations of silica-containing dust were developed largely from data obtained in a series of studies of various dusty trades by the Public Health Service during the period 1919 to 1945. These included investigations of granite workers (4,5), hard coal miners (6), pottery workers (7), and metal miners (8). It cannot be emphasized too strongly that the limits proposed in these studies were based upon samples collected by impinger techniques and counted by light-field methods (9); they represent an approximation of the number of particles in the size range 0.5 to 5.0 microns, and cannot be translated into figures applicable to other dust-counting techniques.

A re-evaluation of the control of silicosis in the Vermont Granite Industry by the Division of Occupational Health, USPHS and the Vermont Department of Health in 1955 (10) showed the following: Counts averaged generally less than 10 mppcf for dust containing an average of 24.9% silica and were in most cases from one-quarter to one-half those in 1938 after improved dust control procedures had been started. Based on chest x-ray films, but one new questionable case of silicosis was diagnosed among men who had entered the granite

industry since 1937. Within the limitations of the x-ray technics, it would appear that the present recommended standards for free silica are sufficiently low to prevent significant numbers of cases of silicosis within 18 years. At these control levels, 18 years is probably insufficient to make a final evaluation of the recommended limits.

References
1. Collis, E.L.: Milroy Lectures 1915, Pub. Health 28, 252 (1915).
2. Gardner, L.U.: J. Am. Med. Assn. 111, 1925 (1938).
3. Miller, J.W., Sayers, R.R.: Pub. Health Rept. 56, 264 (1941).
4. Russell, A.E., Britten, R.H., Thompson, L.R., Bloomfield, J.J.: Pub. Health Bull. No. 187, USPHS (1929).
5. Russell, A.E.: Pub. Health Bull. No. 269, USPHS (1941).
6. Sayers, R.R., Bloomfield, J.J., DallaValle, J.M., Jones, R.R., Dreessen, W.C., Brundage, D.K., Britten, R.H.: Pub. Health Bull. No. 221, USPHS, (1935).
7. Flinn, R.H., Dreessen, W.C., Edwards, T.I., Riley, E.C., Bloomfield, J.J., Sayers, R.R.: Pub. Health Bull. No. 244 (1939).
8. Dreessen, W.C., Page, R.T., Hough, J.W., Trasko, V.M.: Pub. Health Bull. No. 277 (1942).
9. Bloomfield, J.J., DallaValle, J.M.: Pub. Health Bull. No. 217, USPHS (1935).
10. Hosey, A.D., Ashe, H.B., Trasko, V.M.: Public Health Serv. Publ. No. 557 (1957).

SILICON CARBIDE

50 mppcf

Silicon carbide (SiC) of commerce is an artifically produced abrasive and refractory and is sold under a number of trade names, including Carborundum, Crystolon Carbonite and Electrolon. Although originally synonymous with SiC "Carborundum" is a trade name sometimes applied to other products of the same manufacturer.

Gardner in 1923 (1) showed that SiC produced no fibrosis of the lungs in normal experimental animals, but that it profoundly altered the course of inhalation tuberculosis, leading to extensive fibrosis and progressive disease. Miller and Sayers (2) found that an inert reaction resulted when SiC was injected intraperitoneally in guinea pigs.

The only published evidence of pulmonary disease associated with inhalation of silicon carbide dust are the reports of Smith and Perina (1948) (3) and of Bruusgaard (1949) (4). The former's patients had both silicon carbide and alumina exposures; the latter observer described slight radiographic changes in 10 of 32 workers exposed exclusively to SiC. Most of the affected individuals had worked for 15 years or more in dusty atmospheres with an average dust count of 1,200 particles/cc (34 mppcf) and an average particle diameter of 1μ. All cases were tuberculin positive. Those presenting pulmonary changes had only slight respiratory symptoms.

References
1. Gardner, L.U.: Am. Rev. Tuberc. 7, 344 (1923).
2. Miller, J.W., Sayers, R.R.: Pub. Health Rept. 56,264 (1941).
3. Smith, A.R., Perina, A.E.: Occ. Med. 5, 396 (1948). Pneumoconiosis Abstracts Vol. II (1939-50) p. 267.

4. Bruusgaard, A.: Proc. Ninth Intl. Cong. Ind. Med. London, Wright, Briston, p. 676 (1949).

SOAPSTONE

20 mppcf

Soapstone does not have a precise mineralogic connotation. Many rocks of variable composition are sometimes so designated. Massive talc is sometimes called soapstone, or steatite. The terms are not synonymous, and some forms of soapstone have as little as 50 per cent talc.

Miller and Sayers (1) tested two samples of soapstone, one 65 per cent talc, 30 per cent tremolite and 5 per cent dolomite; the other 55 per cent talc, 30 per cent dolomite, 15 per cent tremolite, no quartz. Inert reactions were observed after intraperitoneal injection in guinea pigs.

The threshold limit for soapstone prior to 1949 was set at the level of a nuisance or inert dust, 50 mppcf, but in 1949 the limit was reduced to the present 20 mppcf. This was presumably based on the work of Dreessen and DallaValle (2) who studied workers in two Georgia mills in which dust exposures were to massive or steatite talc, also called soapstone, with a 10 per cent tremolite content (cf. Talc).

References

1. Miller, J.W., Sayers, R.R.: Pub. Health Rept. 56, 264 (1941).
2. Dreessen, W.C., DallaValle, J.M.: Pub. Health Rept. 50, 131 (1935).

SODIUM FLUOROACETATE (1080)

0.1 mg/m^3

Lehman (1) has placed the oral LD_{50} of 1080 at 1.7 mg/kg for rats. On the basis of this value, its threshold limit should not be higher than 0.1 mg/m^3.

Reference

1. Lehman, A.J.: U.S. Food & Drug Adm. Quart. Rept. October (1951).

SODIUM HYDROXIDE

2 mg/m^3

Caustic dusts are irritating to the upper respiratory system. Although prolonged exposure to high concentrations may cause discomfort and even ulceration of nasal passages, subjective symptoms are often relied upon as an indication for the need of control. Patty (1), on the basis of the irritant effects of caustic mists, encountered in concentrations of 1 to 40 mg/m^3 air, believes that 2 mg sodium hydroxide/m^3 air represents a concentration that is noticeably, but not excessively, irritant.

Reference

1. Patty, F.A.: Industrial Hygiene and Toxicology, Interscience Publishers, Inc. (1949), p. 561.

STIBINE (ANTIMONY HYDRIDE)

0.1 ppm (Approximately 0.5 mg/m^3)

An investigation reported by Webster (1) shows that stibine is a lung irritant and hemolytic agent, and injures also both kidney and liver. After one hour of inhalation at 40 ppm, some animals die. Its action is similar to that of arsine.

The threshold limit of 0.1 ppm is based on analogy with arsine, which is reportedly somewhat more toxic than stibine.

Reference
1. Webster, S.H.: J. Ind. Hyg. & Tox. 28, 167 (1946).

STODDARD SOLVENT

500 ppm (Approximately 2900 mg/m^3)

The threshold limit is based on studies made with gasoline and its components. The limit was set up primarily to avoid subjective symptoms.

Nelson et al. (1) found that 400 ppm produced no marked effects on unacclimated subjects and conclude that a somewhat higher exposure would be satisfactory.

Reference
1. Nelson, K.W., Ege, J.F., Jr., Ross, M., Woodman, L.E., Silverman, L.: J. Ind. Hyg. & Tox. 25, 282 (1943).

STRYCHNINE

0.15 mg/m^3

McNally (1) reported a human death from swallowing 33 mg of this poison. Strychnine has an oral MLD of approximately 5 mg/kg for rats. Its threshold limit is recommended at 0.15 mg/m^3.

Reference
1. McNally, W.D.: Toxicology, Industrial Medicine Pub. Co., Chicago, Illinois, (1937) p. 595.

STYRENE (MONOMER) (PHENYL ETHYLENE)

100 ppm (Approximately 420 mg/m^3

Spencer and co-workers (1) reported that repeated exposures at 650 ppm of styrene were well tolerated by guinea pigs. They believed that 400 ppm should present no serious industrial hazard and suggested that value tentatively as the permissible limit.

Carpenter, et al. (2), compared the effects of styrene with those of other hydrocarbons. They found 800 ppm more objectionable and the narcotic effect greater, than a similar concentration of toluene.

The Dow Chemical Company (3) suggests 400 ppm as a hygienic standard,

and 100 ppm as an engineering standard, to avoid complaints of odor and eye and nose irritation.

References
1. Spencer, H.C., Irish, D.D., Adams, E.M., Rowe, V.K.: J. Ind. Hyg. & Tox. 24, 295 (1942).
2. Carpenter, C.P., Shaffer, C.B., Weil, C.S. and Smyth, H.F., Jr.: J. Ind. Hyg. & Tox. 26, 69 (1944).
3. Dow Chemical Company: Styrene (Mimeographed Bulletin) (1955).

SULFUR DIOXIDE

5 ppm (Approximately 13 mg/m^3)

The threshold limit value for sulfur dioxide was reduced from 10 ppm to 5 ppm on the basis of data presented by Greenwald in a review of effects of sulfur dioxide on man and animals (1) and as the result of reports on human exposures in Michigan and Oregon. The Michigan Bureau of Industrial Health reported that a concentration of 10 parts of sulfur dioxide per million parts of air causes definite discomfort in exposed workers. The Occupational Health Section of Oregon reported upper respiratory irritation and some nosebleed in workers exposed to 10 ppm. Symptoms disappeared at levels of 5 ppm.

Reference
1. Greenwald, I.: Arch. Ind. Hyg. 10, 455 (1954).

SULFUR HEXAFLUORIDE

1000 ppm (Approximately 6000 mg/m^3)

This compound has been reported by Lester and Greenberg (1) and by Palmes (2) to be an essentially nontoxic gas. Fifty rats exposed to a mixture of sulfur hexafluoride atmosphere (80% with 20% oxygen for periods of from 16 to 24 hours) showed no effects from the exposure. Accordingly, this compound is considered to be pharmacologically inactive.

References
1. Lester, D., Greenberg, L.A.: Arch. Ind. Hyg. & Occ. Med. 2, 348 (1950).
2. Palmes, E.D.: The Toxicity of Sulfur Hexafluoride. Paper presented at A.I.H.A. Meetings, Los Angeles, April 1953.

SULFUR MONOCHLORIDE

1 ppm (Approximately 6 mg/m^3)

As a result of its ability to release hydrochloric acid on contact with moisture, this compound is considered to be an upper respiratory irritant, but rarely injures the lungs according to Henderson and Haggard (1).

Fairhall (2) stated that mice die from one-minute exposures of 150 ppm, and cats from exposures of 15 minutes at 48 ppm. He believed that chronic effects did not occur.

Elkins (3) states that 2 to 9 ppm of sulfur monochloride are mildly irritating to man.

It is believed that the 1 ppm threshold limit value is low enough to avoid human injury and discomfort.

References
1. Henderson, Y., Haggard, H.W.: Noxious Gases, Reinhold Press, New York, 2nd Ed. (1943), p. 130.
2. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins, Baltimore (1949), p. 161.
3. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York (1950), p. 81.

SULFUR PENTAFLUORIDE (DISULFUR DECAFLUORIDE)

0.025 ppm (Approximately 0.25 mg/m^3)

On the basis of the work reported by Greenberg and Lester (1), the experience of the Army Chemical Center and a report by Saunders, et al. (2) on this compound which classifies it as from 3 to 20 times more toxic than phosgene, a value of 0.025 parts per million appears to be a reasonable threshold limit.

References
1. Greenberg, L.A., Lester, G.: Arch. Ind. Hyg. 2, 350 (1950).
2. Saunders, J.P., et al: Arch. Ind. Hyg. & Occ. Med. 8, 436 (1953).

SULFURIC ACID

1 mg/m^3

Amdur (1) and associates, reported results of exposure of normal human subjects to the inhalation of sulfuric acid mist. The concentrations ranged from 0.35 to 5 mg/m^3. Exposures were from 5 to 15 minutes.

In this study it was found that concentrations below 1 mg/m^3 could not be detected by odor, taste or irritation; for two persons the threshold was 1 mg/m^3, a concentration of 3 mg/m^3 was noticed by all, and that a concentration of 5 mg/m^3 was very objectionable to some, but less so to others. A deep breath at the last concentration usually produced coughing. Pneumotachograph tracings showing respiratory changes in 15 subjects exposed to measured sulfuric acid mist concentrations are presented in the paper.

Reference
1. Amdur, M.O., Silverman, L., and Drinker, P.: Arch. Ind. Hyg. & Occup. Med. 6, 305 (1952).

TALC

20 mppcf

Although the term talc in its mineralogic sense refers to a specific substance, a hydrous magnesium silicate, commercially it is applied to a variety of products with similar properties. Some of these contain only a small talc component. Accessory minerals commonly found are tremolite, serpentine, anthophyllite, magnesite, dolomite, calcite, diopside, chlorite and quartz. Pyrophyllite has similar uses and is often grouped with talc in commercial statistics.

Miller and Sayers (1) obtained an inert reaction with two samples of talc upon intraperitoneal injection into guinea pigs. One sample contained about 75 per cent talc, 25 per cent tremolite and about 1 per cent calcite or

dolomite; the other was about 40 per cent talc and 60 per cent tremolite. Schepers and Durkan (2) have studied the effects on animal tissue of relatively pure talc, dolomite, serpentine, tremolite, anthophyllite, and quartz, separately and in combination, by intravenous and intratracheal routes. Dolomite and serpentine were relatively inert, talc was dominantly cytogenic, tremolite and anthophyllite were both cytogenic and fibrogenic. Lone fibers of the latter two minerals, which are types of asbestos, produced rapid and grave peribronchiolar lesions.

A number of clinical studies, beginning with those of Dreessen in 1933 have associated talc exposures with pneumoconiosis (3-16). In most of these it was recognized that the dust being inhaled contained varying amounts of tremolite or other accessory minerals. Hogue and Mallette (18) have emphasized that workers exposed from 15 to 25 years to pure talc at average dust concentrations of 30 to 150 mppcf showed no evidence of pneumoconiosis. Schepers and Durkan (19) on the basis of human histopathologic studies developed evidence as to the complex interplay between talc, tremolite and quartz, and many reported cases of talc pneumoconiosis resembling asbestosis. The present threshold limit should be construed as applying to talc in its commercial sense, and is based largely upon work by Dreessen and DallaValle (4), who studied 66 individuals who had been exposed to dust in 2 mills and mines handling Georgia steatite talc (soapstone) with a 10 per cent tremolite content; they found no pneumoconiosis in those who worked at average dust concentrations of 17 mppcf, but cases of severe and disabling pneumoconiosis in groups working at average dust concentrations of 135 and 300 mppcf. The recent studies of Kleinfeld, et al. (13, 17) in tremolite talc workers suggest the figure of 20 mppcf is of the proper order of magnitude.

REFERENCES

1. Miller J.W., Sayers, R.R.: Pub. Health Rept. 56, 264 (1941).
2. Schepers, G.W.H., Durkan, T.M.: Arch. Ind. Health 12, 317 (1955).
3. Dreessen, W.C.: J. Ind. Hyg. 15, 66 (1933).
4. Dreessen, W.C., DallaValle, J.M.: Pub. Health Rept. 50, 131 (1935).
5. Porro, F.W., Patton, J.R., Hobbs, A.A.: Am. J.Roentgenol. 47, 507 (1942).
6. Siegal, W., Smith, A.R., Greenburg, L.: Am. J. Roentgenol. 49, 11 (1943).
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9. Jaques, W.E., Benirschke, K.: Arch. Ind. Hyg. 5, 451 (1952).
10. Friedman, P.S., Bell, M.A., Solis-Cohen, L.: J. Amer. Med. Assn. 148, 1418 (1952), Abstr. Bull. Hyg. 27, 864 (1952).
11. Alivasatos, G.P., Pontikakis, A.E., Terzis, B.: Brit. J. Ind. Med. 12, 43 (1955), Abst. Bull. Hyg. 30, 241 (1955).
12. Mann, B., Deasy, J.B.: Brit. Med. J., Dec. 18, 1954, p. 1460; Abstr. Bull. Hyg. 30, 241 (1955).
13. Kleinfeld, Morris, Messite, J., Tabershaw, I.R.: Arch. Ind. Health 12, 66 (1955).
14. Hunt, A.C.: Thorax 11, 287 (1956). Abstr. Bull. Hyg. 32, 340 (1957).
15. Hubner, O., Muller, G.: Arch. f. Gewerbepath u. Gewerbehyg. 15, 440 (1957). Abstr. Bull. Hyg. 32, 1168 (1957).
16. Seeler, A.O., Gryboski, J.S., MacMahon, H.E.: Arch. Ind. Health 19, 392 (1959).

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18. Hogue, W.L., Jr., Mallette, F.S.: J. Ind. Hyg. & Tox. 31, 359 (1949).
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TEDP (TETRAETHYL DITHIONOPYROPHOSPHATE)

0.2 mg/m^3

TEDP with an oral LD_{50} for the rat of 5 mg/kg (1) is about half as toxic as parathion acutely. Its principal toxic sign is cholinesterase inhibition. By analogy, its threshold limit value has been set at 0.2 mg/m^3.

Reference

1. Lehman, A.J.: Quart. Bull. Assn. Food & Drug Off. 15, 122 (1951).

TEPP (TETRAETHYL PYROPHOSPHATE)

0.05 mg/m^3

This cholinesterase inhibitor is about twice as toxic as parathion in single doses, its acute oral LD_{50} for male rats being 3 mg/kg. By analogy, its threshold limit value has been set at 0.05 mg/m^3 compared with parathion 0.1 mg/m^3.

TELLURIUM

0.1 mg/m^3

Tellurium and its compounds, when added to the diet of rats, have shown tellurite and tellurate to be toxic when administered at concentrations of 25 to 50 parts per million. Elementary tellurium, on the other hand, had only a slight effect on growth at a concentration of 1500 ppm (1).

The hydride of tellurium, hydrogen telluride (H_2Te), has been shown to be highly toxic, causing pulmonary irritation and destruction of red blood cells (2). This gas is highly unstable, however, and its occurrence as an actual industrial hazard is very doubtful.

There have been no reports of serious illness or death to workers exposed to tellurium and its compounds in industry. The physical complaints and findings which have been reported are sleepiness, loss of appetite, nausea, metallic tastes, and a garlic odor to the breath and perspiration. Of these, the latter is the most troublesome symptom. It is often the only sign that tellurium has been absorbed into the body, and it does not indicate that other symptoms and illness are imminent (3). Some workmen find the odor to be highly objectionable and a handicap socially; others do not seem to mind it.

The recommended threshold limit for Te and its compounds (except H_2Te) as dust or fume in air is 0.1 mg Te/m^3. Although this concentration is safe, so far as poisoning is concerned, it will probably result in garlic breath among exposed employees. Ingestion or inhalation of as little as 40 micrograms of Te in soluble form has caused breath odor (4).

References

1. DeMeio, R.H.: J. Ind. Hyg. & Tox. 28, 229 (1946).
2. Webster, S.H.: J. Ind. Hyg. & Tox. 28, 167 (1946).

3. Amdur, M.L.: Occup. Med. 3, 386 (1947).
4. Nelson, K.W., Pinto, S.S.: Unpublished experiments.

1,1,2,2-TETRACHLOROETHANE

5 ppm (Approximately 35 mg/m^3)

Tetrachloroethane (1,1,2,2-tetrachloroethane, acetylenetetrachloride) is a highly toxic compound whose industrial uses have resulted mainly from its excellent solvent characteristics. von Oettingen (1) summarizes the results of many reports on tetrachloroethane toxicology. In mild poisoning, symptoms of gastrointestinal irritation and central nervous system depression occur. In more severe poisoning, in addition to more severe gastrointestinal and central nervous system symptoms, there may be liver involvement. White blood cell changes and kidney damage may also occur.

von Oettingen (1) also cites data of Lehmann and Schmidt-Kehl to the effect that 3 ppm is noticeable by odor, 13 ppm may be tolerated for 10 minutes without ill effects, and 146 ppm for 30 minutes, or 335 ppm for 10 minutes cause irritation, vertigo, and fatigue. Elkins (2) cites unpublished information indicating that concentrations below 10 ppm resulted in illness in exposed workers.

References

1. von Oettingen, W.F.: The Halogenated Aliphatic, Olefinic, Cyclic, Aromatic, and Aliphatic-Aromatic Hydrocarbons Including the Halogenated Insecticides, Their Toxicity and Potential Dangers, Pub. Health Serv. Publ. No. 414 (1955), pp. 158-163.
2. Elkins, H.B.: The Chemistry of Industrial Toxicology, John Wiley & Sons, Inc., New York, 2nd Ed. (1959), p. 142.

TETRAHYDROFURAN

200 ppm (Approximately 590 mg/m^3)

Lehmann and Flury (1) have reported irritation of the upper respiratory tract and some injury to the liver and kidneys in a number of experimental animals exposed to concentrations of this substance greater than 3000 ppm for 8 hours daily for 20 days. Tetrahydrofuran was irritating to the skin of rabbits when applied in aqueous solutions exceeding 20% concentration. Stoughton and Robbins (2) found concentrations greater than 25,000 ppm were required to produce anesthesia which had a delayed induction period and recovery with poor relaxation; this was accompanied by a fall in blood pressure and strong respiratory stimulation. There was a small margin of safety between anesthesia and death in dogs and in mice. Severe headaches were noted among the technicians performing the experiment.

Subsequent experimentation (3) showed that 200 ppm tetrahydrofuran in daily, 6-hour exposures produced an observable effect on the pulse pressure of dogs within 3 or 4 weeks but no demonstrable histopathologic changes in the critical organs of the animals despite an exposure of 9 weeks followed by an additional 3-weeks exposure at nearly twice this level. In contrast to literature reports, tetrahydrofuran was found not to

irritate the skin or be a skin sensitizer. Greater validity is believed for these results than those previously reported, because of the greater number of individuals tested.

Oettel (4) exposed cats, rabbits, rats and mice to tetrahydrofuran in concentrations ranging from 3,400 to 60,000 ppm for periods up to 6 hours duration. After ten 3-hour, to thirty 6-hour exposures ranging from 3,400 to 17,000 ppm, there was no evidence of kidney damage and changes in the livers of cats and rabbits. The action of tetrahydrofuran was compared with that of ether.

References
1. Lehmann, K.B. and Flury, F.: Toxicology of Industrial Solvents, Williams and Wilkins, Baltimore (1943), p. 269.
2. Stoughton, R.W., Robbins, B.H.: J. Pharm. Exptl. Therap. 58, 171 (1936).
3. Personal Communication, Dr. John A. Zapp, Jr., Haskell Laboratory, E.I. duPont de Nemours & Co., Wilmington, Delaware.
4. Personal Communication, Dr. H. Oettel, Badische Anilin & Soda-Fabrik, A.G., Ludwigshafen on the Rhine, Germany.

TETRANITROMETHANE

1 ppm (Approximately 8 mg/m^3)

Two dogs and twenty rats were exposed to an average concentration of 6.35 ppm of tetranitromethane for a total period of six months on a six-hour-per-day, five-day-per-week basis (1). An additional two dogs and twenty rats served as controls. During the course of the experiment 11 of the experimental rats died, whereas only one of the controls died. Signs of toxicity in the dogs were minimal and consisted of anorexia during the first three days of exposure. Blood studies, biochemistries and urinalyses were within normal limits for both experimental and control dogs. Pathologic findings indicated that the immediate cause of death in the rats was an overwhelming pneumonia. Pathology of the dogs was not remarkable.

Reference
1. Horn, H.J.: Chemical Corp. Medical Laboratories Contract Report No. 20 (1953).

TETRYL (2,4,6-TRINITROPHENYLMETHYLNITRAMINE)

1.5 mg/m^3

Probst, et al. (1) reported that their most common finding in persons working with tetryl was contact dermatitis, and dermal sensitization. There was no evidence of systemic illness from tetryl under their control procedures. No air concentrations of tetryl were reported. Hardy and Maloof (2) reported effects from accidental exposures of 11 persons to tetryl; 2 died, 1 had a disability, and 8 did not have a detected permanent disability. From these studies, they suggested that irreversible liver damage, dermatitis, and upper respiratory irritation were effects of tetryl exposure; in addition, one worker developed pulmonary pathologic changes, presumably attributable to exposure to tetryl.

Bergman (3) described the effects of tetryl exposure in some detail,

including the epidermal effects, respiratory effects, gastrointestinal symptoms, effects on the nervous system, hematopoietic and circulatory injury, and has reviewed the controversial question of liver and kidney damage. He reported on ten years experience in an arsenal where several thousand people worked with tetryl at one time; the atmospheric concentration was held at 1.5 mg/m^3 or below. No case of systemic poisoning was encountered. Some symptoms were noted, but the most troublesome reaction was skin sensitization.

Based on these reports, a threshold limit value of 1.5 mg/m^3 is recommended; it appears to be sufficiently low to prevent systemic poisoning, but not sensitization.

References
1. Probst, E.W., Mund, M.H., Lewis, L.D.: J. Amer. Med. Assn. 126, 424 (1944).
2. Hardy, H.L., Maloof, C.C.: Arch. Ind. Hyg. & Occup. Med. 1, 545 (1950).
3. Bergman, B.B., Arch. Ind. Hyg. & Occup. Med. 5, 10 (1952).

THALLIUM

0.1 mg/m^3

Thallium is one of the most toxic of the heavy metals. Several reviews (1-4) of the literature provide a basis for the opinion that the toxicity of thallium is greater than that of lead. Moreover, recent animal experimental work by Downs, et al. (5) indicates 1) that there is no evidence for significant distinction between the toxicity of thallous and thallic ions and 2) that thallium is extremely toxic. Despite the work of these authors, the extensive studies of Truhaut (4), and the numerous poisonings in man, no secure data exist on which a threshold limit for thallium may be reasonably derived. Truhaut, however, is of the opinion that 0.1 mg Tl represents a satisfactory limit (6).

References
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3. Fairhall, L.T.: Industrial Toxicology, Williams & Wilkins, Baltimore, Md., (1949).
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6. Personal communication to Threshold Limit Committee member, 1959.

THIRAM (TETRAMETHYL THIURAM DISULFIDE)

5 mg/m^3

Smyth's investigations (1) indicate the acute, oral LD_{50} of this compound to be 1.30 g/kg for rats. Rats survived a cloud of the material estimated to be more concentrated than 500 mg/m^3 for 4 hours. The 5 mg/m^3 value, originally interpolated from the toxicity of similar compounds, seems to represent a satisfactory threshold limit.

Reference
1. Smyth, H.F., Jr.: Unpublished work by Chemical Hygiene Fellowship, Mellon Institute, Pittsburgh, Pennsylvania, 1937-1955.

TITANIUM DIOXIDE

15 mg/m^3

It is the general industrial experience that titanium dioxide is not productive of organic disease. This agrees with its general chemical properties of chemical inertness and insolubility. This experience is in conformity with references quoted by Fairhall (1,2,3,4,5) on the relative innocuousness of titanium dioxide. In accordance, therefore, with the general decision of the committee to limit concentrations for seemingly innocuous particulate matter to 15 mg/m^3, this limit is suggested for this substance.

References
1. Carozzi, L.: Occupation and Health. International Labour Office, Geneva, Vol. II, p. 1058 (1930).
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4. Vernetti, Blina, L.: Riforma Med., Naples, No. 44, 1516 (1928).
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TOLUENE

200 ppm (Approximately 750 mg/m^3)

von Oettingen and co-workers (1) found that exposure of men at 50 ppm of toluene vapor had *minimal effect; 100 ppm, slight effect, and 200 ppm, moderate* effect. With higher concentrations, definite symptoms of nervous system impairment were observed. They suggest that the chief hazard of low level exposure to toluene may be an increased risk of accidents.

Greenburg, et al. (2) reported only slight evidence of intoxication in workers exposed to concentrations ranging from 100 to 1100 ppm of toluene.

References
1. von Oettingen, et al.: Pub. Health Bull. No. 279 (1942).
2. Greenburg, Leonard, Mayers, May R., Heimann, H., Moskowitz, S.: J. Am. Med. Assn. 118, 573 (1942).

o-TOLUIDINE

5 ppm (Approximately 22 mg/m^3)

Smyth (1) found that rats were not killed by eight hours inhalation of saturated vapors of o-toluidine. Henderson and Haggard (2) state that its vapor toxicity is much like that of aniline (slight symptoms after several hours at 6 to 23 ppm and 7 to 53 ppm respectively).

Fairhall (3) also found the symptoms to be similar to those from aniline.

A threshold limit of 5 ppm, the same as that of aniline, is recommended.

References
1. Smyth, H.F., Jr.: Unpublished work by Chemical Hygiene Fellowship, Mellon Institute, Pittsburgh (1937-55).
2. Henderson, Y., Haggard, H.W.: Noxious Gases, 2nd Ed., Reinhold Press, New York (1943), p. 228.

3. Fairhall, L.T.: Industrial Toxicology, Williams and Wilkins, Baltimore, Md., p. 450 (1949).

TOLYLENE-2,4-DIISOCYANATE (TDI)

0.02 ppm (Approximately 0.14 mg/m^3)

Studies in animals by Zapp (1) have shown this isocyanate to have a low oral toxicity (approximate lethal dose 5.8 g/kg), but a high toxicity by inhalation; 1 to 2 ppm for 30, six-hour exposures resulted in tracheobronchitis. The LC_{50} for 3 rodent species for a 4-hour exposure approximated 12 ppm according to Scheel (2); the animals died of pulmonary edema and hemorrhage; effects on the liver, kidneys and gastrointestinal tract also occurred. Dermal effects occur.

The capacity of TDI to produce allergic sensitization of the respiratory tract of man is its most serious toxicologic action and which determines the magnitude of the threshold limit value. A survey of plant experience made in 1960 by Elkins (3) at different sites in 6 states showed cases of respiratory involvement from repeated exposure to TDI not only at or around 0.1 ppm (4,5) but considerably below 0.1 ppm. Threshold limits for minimizing respiratory effects suggested by the participants in the survey were from 0.01 to 0.03 ppm. A threshold limit of 0.02 ppm is recommended. It should be sufficiently low to prevent substantially all primary sensitization and to minimize recurrent allergic attacks.

References

1. Zapp, J.A., Jr.: Arch. Ind. Health. 15, 324 (1957); Toxicity and Safe Handling of Isocyanates, Mobay Chem. Co., Pittsburgh, Pa. (undated).
2. Scheel, L.D.: Unpublished results.
3. Elkins, H.B.: Threshold Limits Committee Report, Mar. 1960.
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5. Munn, A.: Trans. Assn. Ind. Med. Off. 9, 134 (1960).

TRICHLOROETHYLENE

100 ppm (Approximately 520 mg/m3)

Browning (1) makes reference to the work of Lehmann (2), Taylor (3), Barrett, Maclean and Cunningham (4) and Seifter (5) in a summary on the subject of chronic poisoning as related to trichloroethylene exposure.

In his original experiments, Lehmann reported the only effect of inhalation of 760 ppm for 6 hours a day over a period of 10 to 17 days was drowsiness, fatigue and loss of weight, leading in some cases to death. Similar results were obtained by Taylor, using concentrations of 500, 1000, 2000, and 3000 ppm for six hours a day, the exposures totaling up to 122 in the animals which survived. Only the animals exposed to the highest concentration died. No effect on the growth or reproduction of the others was observed. Barrett, Maclean and Cunningham showed no significant effects on guinea pigs or rabbits following the inhalation of 1200 ppm for 473 hours. Seifter reported symptoms of chronic intoxication in dogs in 3 to 8 weeks after inhalation of 500 to 750 ppm for 4 to 8 hours daily, 5 to 6 days per week. The symptoms consisted of lethargy, anorexia, nausea, vomiting and loss of weight. Liver dysfunction was also shown in these dogs.

Browning (1) classifies trichloroethylene as an acute narcotic which causes death from respiratory failure if exposure is severe and prolonged. There appears to be little evidence of a chronic or cumulative effect, but a few cases

threshold limit value of 25 ppm. The most important effects observed were marked irritation of the cornea and of the lung tissues.

Reference
1. Brieger, H., Hodes, W.A.: Arch. Ind. Hyg. & Occ. Health 3, 287 (1951).

TRIFLUOROMONOBROMOMETHANE

1000 ppm (Approximately 6100 mg/m^3)

Comstock, et al. (1) exposed dogs and rats daily for eighteen weeks at an average concentration of 23,000 ppm CF_3Br. Unexposed controls were also observed. No toxic signs were seen nor was there any pathologic change observable on autopsy. The threshold limit of 1000 ppm is recommended on the basis that 1000 ppm represents the maximal limit hygienically desirable for any air contaminant.

Reference
1. Comstock, C.C., Kerschner, J., Oberst, F.W.: Chemical Corps. Medical Laboratories Research Report No. 180 (1953).

TRINITROTOLUENE

1.5 mg/m^3

Fairhall's review (1) of trinitrotoluene (TNT) toxicology, describes dermatitis, cyanosis, gastritis, acute yellow atrophy of the liver, and aplastic anemia as possible effects of exposure. Other occasional effects, according to Sollmann (2) are blood destruction, leucocytosis or leucopenia, varying degrees of central nervous system changes (probably resulting from anoxia, peripheral neuritis and muscular pains, cardiac muscular and menstrual irregularities, and urinary renal irritation). The combined effects of vasomotor changes and methemoglobinemia contribute to some of the signs and symptoms of TNT exposure (1). TNT has irritant properties, and may cause sneezing, sore throat, or skin irritation (3).

The threshold limit value of 1.5 mg/m^3 is based on a recommendation of the U.S. Public Health Service, cited by Cook, (4). Eddy's report (5) of three cases of fatal aplastic anemia in the presence of atmospheric concentrations of 1 to 3.5 mg/m^3 is relevant, but not conclusive; however, it may suggest that this threshold limit value is not sufficiently low to prevent all injuries.

References
1. Fairhall, L.T.: Industrial Toxicology, The Williams & Wilkins Co., Baltimore, Md. 2nd ed., (1957), pp. 352-354.
2. Sollmann, T.: A Manual of Pharmacology and Its Application to Therapeutics & Toxicology, W.B. Saunders Co., Philadelphia, 8th ed. (1957), pp. 827-828.
3. von Oettingen, W.F.: The Aromatic Amino and Nitro Compounds, Their Toxicity and Potential Dangers. A Review of the Literature, Pub. Health Bull. No. 271 (1941), pp. 111-124.
4. Cook, W.A.: Ind. Med. 14, 936 (1945).
5. Eddy, J.H.: J. Amer. Med. Assn. 125, 1169 (1944).

have occurred where there has been a latent period between exposure to trichloroethylene and sudden death after exertion.

Adams and associates (6) found no adverse effects in their animal experimentation when monkeys were exposed repeatedly at 400 ppm, rats and rabbits were exposed to 200 ppm, and guinea pigs exposed at 100 ppm. A concentration of 3000 ppm inhaled repeatedly caused only very minor changes in the liver. They conclude that the effect is narcosis. For human exposures, their observations were that there is little probability of severe effects occurring from daily exposures below 200 ppm and the probability of any effects whatsoever are extremely small if the exposures are kept below 100 ppm.

Several investigators have reported (7) narcotic effects from concentrations below 200 ppm and recommend a limit of 100 ppm.

References
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2. Lehmann, K.B.: Arch. Hyg. Ber. 74, 1 (1911).
3. Taylor, H.: J. Ind. Hyg. 18, 175 (1936).
4. Barrett, H.M., Maclean, D.L., and Cunningham, J.G.: J. Ind. Hyg. 20, 360 (1939).
5. Seifter, J.: J. Ind. Hyg. 26, 250 (1944).
6. Adams, E.M., Spencer, H.C., Rowe, V.K., McCollister, D.D., Irish, D.D.: Arch. Ind. Hyg. & Occ. Med. 4, 469 (1951).
7. Fredrick, W.G., Elkins, H.B., Scovill, R.G.: Communications to the Committee, 1960, 1961.

TRICHLORONAPHTHALENE

5 mg/m^3

Drinker and associates (1) exposed rats to an average concentration of 1.31 mg/m^3 of trichloronaphthalene containing traces of tetrachloronaphthalene for 1896 hours with average daily exposure of 16 hours. Living animals were apparently normal. Autopsies performed near the end of this experiment appeared to show a slight swelling of the liver. Drinker considered that 10 mg/m^3 was a permissible level. In a later article, Drinker (2) concluded that the same concentration was allowable.

Smyth (3) concludes that the limit of 5 mg/m^3 is derivable from repeated animal inhalations and is sufficiently low to prevent injury.

References
1. Drinker, P., Warren, M.F., Bennet, G.A.: J. Ind. Hyg. & Tox. 19, 283 (1937).
2. Drinker, P.: J. Ind. Hyg. & Tox. 21, 155 (1939).
3. Smyth, H.F., Jr.: Am. Ind. Hyg. Assn. Quart. 17, 129 (1956).

TRIETHYLAMINE

25 ppm (Approximately 100 mg/m^3)

Brieger and Hodes (1) showed that the effects of triethylamine on rabbits repeatedly exposed to 50 ppm, corresponded very closely to those resulting from similar exposures to ethylamine and diethylamine, each of which have

TURPENTINE

100 ppm (Approximately 560 mg/m^3)

Smyth & Smyth (1) in testing the effect of turpentine on animals at a concentration of 715 ppm found no significant blood changes nor any pathology indicating that this concentration was unsafe.

Nelson and associates (2) found that 75 ppm turpentine caused nose and throat irritation in several people and 175 ppm was intolerable to the majority.

References
1. Smyth, H.F., Smyth, H.F., Jr.: J. Ind. Hyg. 10, 261 (1928).
2. Nelson, K.W., Ege, J.F., Jr., Ross, M., Woodman, L.E., Silverman, L.: J. Ind. Hyg. & Tox. 25, 282 (1943).

URANIUM

Soluble Compounds 0.05 mg/m^3

The basis for the recommended limit is given in a comprehensive review of pertinent animal data by Hodge, Stokinger, and Neuman, (1) that is summarized as follows:

1. At the end of a year's exposure to soluble uranium compounds suspended as a dust in the atmosphere, the tissues of dogs, rats, rabbits, and guinea pigs contained on the average the amounts of uranium shown in the accompanying table.

Approximate Air Concentration (μg/m3)	Lung (μg/g)	Kidney (μg/g)	Bone Ash (μg/g)
2000	1.3	2.3	5.9
250 - 150	0.6	0.8	1.8
50 - 40	0.4	0.4	0.4

On the average, the lung contains the least, the kidney intermediate amounts, and the bone the highest amounts of uranium. With increasing air concentration, there is a tendency for an increase in the tissue content of uranium.

2. From analyses of the uranium content made during the year, it is evident that with increasing exposure time there is an increase in bone deposition of uranium. This is not a large increase at any concentration, but it is clearly distinguishable in the tests at the higher dust levels. Even at an air concentration of 2000 μgU/m^3, the predicted maximal bone uranium content is only 17 μgU/g.

3. If the figure of 25 μgU/g of tissue is accepted as the uranium tolerance for tissue (considering uranium as an internal alpha emitter), it is evident that the amount deposited in bone following the inhalation of atmospheres containing the maximal allowable concentration will never constitute a radiological hazard.

4. Based on the rate of deposition of uranium in the rat femur when rats are

exposed to an atmosphere containing 2000 μgU/m^3 as uranyl nitrate hexahydrate dust, the predicted "biological half-life" of uranium in rat bone is of the order of 10 months.

5. The known typical uranium injury to the kidney is an extremely sensitive and reliable indicator of toxic effect; the amount of a soluble uranium compound in the air which fails to produce any kidney injury is taken as a physiologically safe concentration.

6. The air concentration of 50 μgU/m^3 of soluble uranium dusts is recommended as a tentative maximal allowable concentration.

7. Studies of the chemical toxicity of UF_6, UO_2F_2, $UO_2(NO_3).6\,H_2O$, and UCl_4 have been summarized and tabulated. Three 30-day studies are available on UF_6, four on UO_2F_2, four on uranyl nitrate hexahydrate, and five on UCl_4. Two, 1-year studies are available on UF_6, four on uranyl nitrate hexahydrate, and two on UCl_4. One 2-year study is summarized in which the exposures during the first year were to several soluble and insoluble uranium dusts and the exposure during the second year was to uranyl nitrate hexahydrate dust. From the standpoint of the toxic effects observed in all these studies, the maximal allowable concentration recommended, viz., 50 μgU/m^3, appears to be a reasonable tentative figure.

Reference

1. Pharmacology & Toxicology of Uranium Compounds, Voegtlin & Hodge, Eds., McGraw-Hill Co., N.Y. (1953), pp. 2170-2241.

URANIUM

Insoluble Compounds 0.25 mg/m^3

The basis for the recommended limit is given by Hodge, Stokinger, Neuman, Bale, and Brandt (1) that is summarized as follows:

1. At the end of a year's exposure to atmospheres containing UO_2 at concentrations averaging about 10 and 1 mg as U/m^3, respectively, the uranium content of lung tissue and of pulmonary lymph nodes was as follows:

Air Content (mg U/m3)	Uranium Content		
	Dog Lung (μg/g)	Dog P.LN. (μg/g)	Rat Lung (μg/g)
10	950	2500	300-600
1	116	198	50-100

2. By a process of interpolation, it is predicted that if conditions comparable to those in the experiments were maintained, except that the dust concentrations were lowered to 500 or 50 μg U/m^3, the uranium content of lung tissue and of pulmonary lymph nodes would be as follows:

Assumed Air Content (μg U/m3)	Predicted Average Uranium Content in Lung or Pulmonary Lymph Nodes (μg/g)
500	50 to 120
50	6 to 12

recommended limit of Roshchin. More recently Lewis (3) has reported no toxic manifestations from vanadium dusts, that included the pentoxide, among workmen exposed to concentrations of from 0.1-0.3 mgV/m^3.

The lower limit of 0.1 mg/m^3 for vanadium pentoxide fume is based on the recognizedly greater toxicity of fume, compared with dusts of larger size and smaller surface area.

References
1. Roshchin, I.V.: Gig. i Sanit. 11, 49 (1953).
2. Stokinger, H.E., Wagner, W.D., et al. To be published.
3. Lewis, C.E.: Arch. Ind. Health 19, 497 (1959).

VINYL CHLORIDE (CHLOROETHYLENE)

500 ppm (Approximately 1300 mg/m^3)

Patty and associates (1) found that guinea pigs inhaling 5000 ppm of vinyl chloride for several hours appeared to suffer no ill effects. Narcosis is the most important effect from inhaling this compound.

The 500 ppm threshold limit appears to be sufficiently low to prevent significant narcosis.

Reference
1. Patty, F.A., Yant, W.F., White, C.P.: Pub. Health Rept. 45, 1963 (1930).

VINYLTOLUENE

100 ppm (Approximately 480 mg/m^3)

This compound is a mixture of the meta and para isomers of methylstyrene. Rats, guinea pigs, rabbits, mice, and monkeys tolerated vapor concentrations of 600 ppm of vinyltoluene given repeated exposures 7 hours a day, 5 days a week for periods ranging from 4 to 5 months. The animals were normal as judged by growth, mortality, hematology, organ weight, gross and microscopic examination of the tissues, blood urea nitrogen values, and qualitative urine tests.

Thus, vinyltoluene is similar in toxicologic properties to monomeric styrene. Like styrene, concentrations of the order of 600 ppm are extremely disagreeable to human subjects. The authors recommended a threshold limit value of 400 ppm based on toxicity, but suggest that atmospheric contamination be maintained at 100 ppm or less in order to avoid discomfort.

Reference
1. Biochemical Dept., Dow Chem. Co., Midland, Mich., unpublished summary.

WARFARIN (3-(α-acetonylbenzyl)-4, hydroxycourmarin)

0.5 mg/m^3

This rodenticide is the prototype of the anticoagulants. Lehman (1) has reported its acute oral toxicity as 160 mg/kg for rats. Its hazard is its cumulative effect and for this reason the threshold limit should be lower than the acute LD_{50} would suggest. A threshold limit of 0.5 mg/m^3 is recommended.

Reference
1. Lehman, A.J.: U.S. Food & Drug Adm. Quart. Rept., October 1951.

3. The uranium tolerance for tissue (considering uranium as an internal alpha radiator) is calculated to be of the order of 25 μg U/g fresh tissue.

4. Based on the predicted uranium deposition in lung tissue and in pulmonary lymph nodes and on the calculated uranium tolerance for alpha radiation, the maximal allowable concentration is tentatively proposed as 100 μg/m^3. This concentration has a probable safety factor of 2 to 5-fold.

5. From the few available analyses of dogs and rats exposed for one year to 10 mg/m^3 as UO_2 and for an additional year to 2 mg/m^3 as uranium nitrate, the biological half-life of UO_2 dust particles in the lung is calculated to be of the order of 2 to 4 months.

6. Only short-term (30-day) exposures to UO_2 dusts of controlled particle sizes are available. These show a marked correlation between decreasing particle size in the range of 2 to 0.5 microns and increasing lung retention of uranium. Large particles (2μ) inhaled at 80 mg/m^3 gave rise to an average lung content of about 150 μg U/g, whereas small particles (0.5μ) at the same concentration produced an average lung content of over 1200 μg U/g.

7. Similar studies to those of UO_2 were made on animals exposed to UF_4 at 3 and 0.5 mg/m^3, respectively. No such high uranium values in lung and in pulmonary lymph nodes were found for UF_4, although this tissue showed unquestionably larger uranium contents than followed an exposure to UNO_3 at 2 mg/m^3.

8. The insoluble UO_2 and, to a much lesser degree, UF_4 tend to accumulate in the lung when animals breathe such dusty atmospheres. A small amount of uranium gets into the body fluids and is deposited in the skeleton or is excreted via the kidneys and the urine. The bone and kidney uranium contents are entirely comparable in magnitude following dust exposures to 10 or 1 mg U/m^3 as UO_2, to 3 or 0.5 mg U/m^3 as UF_4, or to 2 mg U/m^3 as uranium nitrate.

9. Studies of the chemical toxicity of UO_2, UF_4, high-grade ore, and U_3O_8 have been summarized and tabulated. Eight 30-day studies are reported for various air concentrations of UO_2, 5 such studies on UF_4, 3 on high-grade ore, 1 on U_3O_8, and 5 on control groups. Two year-long experiments have been conducted, on UO_2 dusts and 2 on UF_4 dusts; a single chronic control group has been examined in exactly comparable ways. From the standpoint of chemical toxicity, the suggested maximal allowable concentrations range of 200 to 250 mg/m^3 in each case allows a reasonable margin of safety.

Reference

1. Pharmacology & Toxicology of Uranium Compounds, Voegtlin & Hodge, Eds., McGraw-Hill Co., N.Y. (1953), pp. 2104-2170.

VANADIUM

Vanadium Pentoxide Dust - 0.5 mg/m^3

Vanadium Pentoxide Fume - 0.1 mg/m^3

A threshold limit of 0.5 mg/m^3 air for vanadium pentoxide dust, and 0.1 mg/m^3 for the pentoxide as a fume, were suggested by Roshchin (1) on the basis of limited animal studies made in reference to industrial exposures. More extensive studies by Stokinger, et al. (2) in animals, using vanadium pentoxide dust at the recommended limit at respirable particle sizes, substantiated the

XYLENE

200 ppm (Approximately 870 mg/m^3)

Nelson and associates (1) found 200 ppm definitely irritating to the eyes, nose and throat. Fairhall (2) concluded that the effects are like those of toluene, namely, narcosis without damage to the red cells. Mild anemia and some enlargement of the liver have been noted with reference to prolonged exposure. Patty (3) considers the symptoms from xylene exposure to be similar to those of toluene at the same concentrations. Greenburg and Moskowitz (4) suggested a maximal allowable concentration of 200 ppm for xylene.

References
1. Nelson, K.W., et al.: J. Ind. Hyg. & Tox. 25, 282 (1943).
2. Fairhall, L.T.: Industrial Toxicology, 2nd Ed., The Williams & Wilkins Company, Baltimore (1957), p. 468.
3. Patty, F.A.: Industrial Hygiene and Toxicology, Interscience Publishers, New York (1949), p. 762.
4. Greenburg, L.M., Moskowitz, S.: Ind. Med. 14, 359 (1945).

XYLIDINE

5 ppm (Approximately 25 mg/m^3)

Treon and associates (1) have described changes in the blood of animals inhaling xylidine. Safe concentrations for the most susceptible species appeared to be between 8 and 16 ppm. Based on plant-handling experience, and because of the similarity of hazard to that of aniline, Dr. Eckardt (2) has suggested a tentative level of 5 ppm. This value appears satisfactory.

References
1. Treon, J.F., et al.: J. Ind. Hyg. & Tox. 31, 1 (1940).
2. Written communication to committee member.

YTTRIUM

5 mg/m^3

Yttrium nitrate, chloride and oxide, possess an intraperitoneal LD_{50} for rats of 350, 450 and 500 mg/kg body weight respectively, indicating a relatively low order of toxicity by this route (1). A subsequent study was made of the skeletal deposition of yttrium in which rats were injected every other day for 5 months with a dose of 60 mg/kg yttrium (2). No fatalities were observed, and no accumulation of yttrium occurred in the bones, although a total dosage of yttrium of 936 mg/rat was administered; deposition slowed to an insignificant rate when the bone burden reached 150-200 ppm yttrium.

On the basis of this information and the need for establishing a tentative safe air concentration for yttrium, a level of 5 mg/m^3 for yttrium and its inorganic compounds was suggested. This level has now been in use several years on limited industrial basis without evidence of injury to workmen, and is accordingly recommended as a threshold limit for yttrium.

References
1. Cochran, K.W., Doull, J., Mazur, M., DuBois, K.P.: Arch. Ind. Hyg. & Occup. Med. 1, 637 (1950).

2. MacDonald, N.S., Nusbaum, R.E., Alexander, G.V., Ezmirlian, F., Spain, P., Rounds, D.E.: J. Biol. Chem. 195, 2 (1952).

ZINC OXIDE

15 mg/m^3

Drinker, Thomson and Finn (1) reported that metal fume fever, experimentally produced in man, occurs at concentrations in excess of 15 mg/m^3 but not below this limit. In industry, 14 mg/m^3 resulted in no fume fever following an 8-hour exposure, and in the laboratory 45 mg/m^3 for 20 minutes was without effect.

Reference

1. Drinker, P., Thomson, R.M., Finn, J.L.: J. Ind. Hyg. 9, 331 (1927).

ZIRCONIUM COMPOUNDS (as Zr)

5 mg/m^3

Several inhalation toxicity studies of zirconium compounds have been made involving large groups of 4 animal species (1). Short-term studies of 30 and 60 days duration of zirconium oxide dust were made at 75 mg and 11 mg Zr/m^3 respectively. A similar 60-day study of zirconium tetrachloride was performed at an average concentration of 6 mg Zr/m^3. The average particle size of the oxide dust was 1.5 microns; that of the tetrachloride, 0.6 microns. The criteria of toxicity included mortality, weight changes, hematologic observations, blood non-protein nitrogen, urinary protein, and a thorough histologic study of animal tissues obtained either during or at the termination of the exposure. In addition, two, 1-year inhalation exposure studies were carried out, one on the oxide dust, the other with the tetrachloride, both at a concentration of 3.5 mg Zr/m^3.

As a result of these studies, zirconium was concluded to be an element of very low toxicity; the only toxic effects noted were those following the inhalation of high concentrations of the tetrachloride which presumably were caused by the liberated hydrogen chloride.

Thus, a value of 5 mg Zr/m^3 is recommended as the threshold limit.

Reference

1. Unpublished data, University of Rochester, New York, Atomic Energy Project, Div. of Pharmacology, Direction - Dr. Harold C. Hodge.