ASBESTOS AND SILICA DUST

OSHA Regulations and Exposure in Drywall Operations

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Introduction

This two-part article is intended to acquaint drywall contractors with the current and proposed regulations governing the use of products containing asbestos and crystalline silica.

The concluding article in the next issue will present data on the exposure to airborne asbestos and crystalline silica (quartz) during the sanding of tape joint compound. A total of seven industrial locations were tested. Exposures to asbestos during the wet-out of dry-mix compounds and during cleanup will also be shown.

BACKGROUND AND CURRENT STATUS— OSHA ASBESTOS REGULATIONS

The Williams-Steiger Occupational Safety and Health Act was passed in 1970 with the stated objective of assuring, insofar as feasible, every American worker a safe and healthy workplace. Under the provisions of this act, the Secretary of Labor issued an emergency temporary standard for exposure to asbestos dust on December 7, 1971. After extensive public hearings, a permanent standard, effective July 7, 1972, was promulgated.

The asbestos standard and the methods used by OSHA to develop it were immediately subjected to a massive legal attack by the Industrial Union Department, AFL-CIO. In addition to the law suit, OSHA was under continued pressure from other labor groups, public interest groups, and spurred on by the news media to make revisions. It was also recognized that this was the first health standard written. As such, there were parts that were vague, parts that were impractical to enforce, and parts that were overly restrictive without a corresponding benefit in protection for the worker.

During 1973, OSHA decided that the asbestos standard should be altered. The initial concept was to replace it with a series of mandatory work practices that would minimize the admittedly cumbersome monitoring requirements. The asbestos industry was asked to submit proposed work practices and a technical committee was formed under the auspices of the Asbestos Information Association/ North America. This committee consisted of representatives from about a dozen asbestos producers and large manufacturers of asbestos-containing products. Communication was also maintained with trade associations that used asbestos or its products. A draft work practice for joint taping was drawn up and submitted to the GDCI for comment.

The technical committee drafted several broad work practices relating to the handling of asbestos. It soon became evident that a large number of specific work practices would be needed to cover the wide range of industrial situations where asbestos or asbestos-containing products were used. The committee also examined and recommended changes in the portions of the regulations that were vague or overly restrictive.

The IUD decision was announced in mid 1974 by the United States Court of Appeals for the District of Columbia. The court generally upheld the OSHA position in the matter and noted that, although the Congress had poorly defined the procedures to be used to set such standards, OSHA had used proper methods to collect and evaluate the conflicting evidence presented. The judgments made to arrive at the standard were within the discretion granted to OSHA; and, more particularly, the court said that it was correct and proper to consider economic factors. Two points were remanded for further consideration; those relating to record retention and the time allowed for compliance.

After the court decision, OSHA materially altered their position on the revision of the asbestos regulations. Under heavy pressure to issue health regulations for other substances, a decision was made to amend the asbestos regulations only to the extent needed to clarify ambiguities. No changes were to be proposed in the allowable exposure levels. Many of the suggestions for clarifying language made by the AIA/NA Technical Committee were understood to have been accepted.

The redrafting of the regulation along these lines was apparently completed in late 1974 and the results were submitted for review to various governmental departments as required by law and policy. During 1975 key personnel changes occurred at policy making levels in both OSHA and NIOSH. At some point, apparently quite recently, the decision was made to drop the amendment concept and reopen the entire asbestos and health controversy. This information became

public when the proposed changes were published in the Federal Register on October 9, 1975.

The asbestos standard that was promulgated on June 7, 1972 and which is still in effect can be divided into seven main categories:

1. Sets the maximum allowable airborne asbestos concentrations in the workplace at a ceiling level of 10 fibers/cc longer than 5 micrometers and at a time-weighted average (TWA) for an 8-hour shift of 5 fibers/cc longer than 5 micrometers. The TWA drops to 2 fibers/cc longer than 5 micrometers in July 1976.
2. Defines the acceptable procedures to meet these standards.
3. Defines where personal protective equipment may be used and specifies the types available.
4. Specifies monitoring requirements and the procedures to be used.
5. Specifies requirements for caution signs, caution labels, and housekeeping procedures.
6. Requires medical examinations for all employees "exposed to asbestos."
7. Sets requirements for keeping of medical and monitoring records.

The standard was written in language that fits conventional fixed manufacturing locations. It presents some very real problems, however, when applied to the construction industry where the job site and the work force are transient. The areas of particular difficulty to drywall contractors are those dealing with monitoring and medical examinations. The AIA/NA Technical Committee recommended a cutoff level below which medical examinations were not required. It was also proposed that monitoring could be dropped where monitoring experience had demonstrated the levels to be consistently below the cutoff or where the asbestos had been properly modified by a bonding agent to prevent excessive dust.

The revised standard proposed on October 9, 1975 follows the same general pattern but differs in the following critical points:

1. The allowable exposure level is reduced to 5 fibers/cc longer than 5 micrometers ceiling and 0.5 fiber/cc longer than 5 micrometers time-weighted average (TWA).
2. Monitoring and record keeping requirements are increased substantially although a provision to discontinue monitoring under certain circumstances is included.
3. There is no cutoff level on the medical examination requirement.

OSHA has reviewed the recent medical literature on asbestos and has proposed regulations based on a very strict interpretation thereof. They have not assessed the economic (inflationary) impact of the proposed regulations but have stated their intention to do so or certify that there is no impact before public hearings are started. The burden of proof has been placed on industry to demonstrate that these regulations are overly restrictive. There is no question that if they are promulgated as proposed, they will place a very heavy burden on asbestos producers and users. Appropriate responses will be submitted by various segments of the asbestos industry and other interested parties.

OSHA has stated in the Federal Register that the construction industry will *not* be covered by the newly proposed regulations. They will continue to operate under the present regulations until a new vertical standard for that industry is developed. This should not lead to a false sense of security, however, because the same medical conclusions on allowable exposure levels are applicable regardless of the industry where they occur. Also, the OSHA health regulations are rapidly moving towards a fixed format that will embody all of the same basic concepts regardless of the substance being regulated. It should be noted that the development of an asbestos standard for the construction industry is in progress and recommendations have been submitted to OSHA by the Advisory Committee for the Construction Industry.

PROPOSED OSHA REGULATIONS— CRYSTALLINE SILICA

Asbestos products do not constitute the only potential health hazard for the drywall industry. Tape joint muds contain crystalline silica which has long been recognized as the cause of a disabling lung disease called silicosis. The National Institute for Occupational Safety and Health (NIOSH) has prepared a Criteria Document relating to occupational exposure to crystalline silica and submitted it to OSHA on November 11, 1974. A proposed silica regulation has been drafted by OSHA and was to have been published during September 1975. The pressure on OSHA to prepare other regulations has delayed this publication but it will undoubtedly appear in a few months.

NIOSH recommended an allowable maximum exposure level to airborne crystalline silica of 50 micrograms per cubic meter of air (50$\mu g/M^3$). Medical examinations, extensive monitoring, record keeping, signs, warning labels, and other provisions similar to the asbestos regulations were also recommended. An action level of one half the allowable exposure limit was also defined as a cutoff point below which the regulations would not apply.

OSHA REGULATIONS—INERT OR NUISANCE DUST

Table G-3 of Section 1910.93 of the OSHA regulations as revised on June 7, 1972 lists the maximum allowable airborne concentrations of inert or nuisance dust as 5 milligrams/cubic meter (mg/M³) in the respirable fraction and 15 mg/M³ in the total dust. If a dust is below the allowable levels for asbestos and silica but above that for nuisance dust, the regulations have been violated. This regulation has been less widely publicized than those for asbestos and silica but has been in effect for a number of years. It must also be considered when job-site dust conditions are examined.

COMPOSITION OF TAPE JOINT COMPOUNDS

Tape joint mud, either dry in bags or already mixed in five-gallon containers, is a well-known material at the job site. Few applicators realize, however, what goes into a mud and how carefully the ingredients must be balanced to give the critical blend of properties necessary to make the mud work properly during application and after it has dried.

The ingredients in a typical ready-mix tape joint compound are listed below:

COMPOSITION OF TYPICAL READY-MIX TJC

Ingredient	Percent by Weight Wet Basis	Dry Basis
Water	31	—
Limestone	41	60
Mica (and Clay)	16	23
Binder	7	10
Asbestos	3	4
Miscellaneous	2	3
	100	100

Looking at the dry basis, which represents the condition when the mud is cured, it can be seen that the principle ingredient is limestone. This is the bulk filler that keeps the cost of the product down. It does not impart any handling properties to the wet mud.

The next largest ingredient is finely-ground mica which is in the form of tiny flat plates. These tend to form a loose structure in the wet mud and have an important bearing on how the mud flows when trowelled and how it shrinks when it dries.

The other mineral ingredient is asbestos. It is present at a level of 3-5% and performs the function of controlling shrinkage and cracking when the mud dries. It is also very important to trowelling properties which allow the mud to form easily in thick sections and permits feathering of the wet edge. The most critical function of asbestos in most muds is to provide freeze-thaw stability. Muds which do not contain asbestos will generally be unusable after they have been frozen.

The binder in ready-mix is usually vinyl acetate, while casein, starch, or a similar "glue" is used in the dry mixes. It cures to hold the compound rigid and firmly attached to the wall.

The miscellaneous ingredients include such items as additives, fungicides, surfactants, cellulosic thickeners, and proprietary materials. These are important ingredients but will not overcome the effects of an improperly balanced blend of major components.

A compounder who wishes to formulate a mud without asbestos will have to replace it with a material that will impart similar properties. The mica can be increased or some other fiber-like material, such as certain clays, may also be used. Additional cellulosic thickener to give the necessary viscosity is also likely to be required. This has a tendency to make the viscosity unstable, i.e., correct at the plant when manufactured but either too high or too low when the mud arrives at the job site.

The reformulation problem becomes much more complicated when silica is considered. Four different limestones commonly used in the manufacture of TJC have been analyzed for crystalline silica content and found to range from 0.3 to 2%. Similarly, three different micas had silica contents of 2, 5, and 9%. While asbestos is usually free of crystalline silica, clays often contain substantial quantities.

By proper selection of ingredients, it is possible to produce a mud with a silica content as low as 0.3%. Unless the low silica ingredients are readily available mud costs will increase. Since silica appears everywhere in nature, it is unlikely that a tape joint mud can be prepared without detectable levels. If the proposed regulations are promulgated, workplace monitoring can be extensive and a considerable financial burden can be imposed on contractors.

Eleven commercially available muds were found to contain from 0.3 to 2.5% of crystalline silica which is consistent with the silica content of the raw materials. Very few mud suppliers appear to be aware of the potential silica problem.

It is well known that the major tape-joint compounders have had extensive research programs underway for the past several years to develop asbestos-free muds that work as well as those with asbestos. So far, the programs have had limited success. The muds developed are more expensive and generally do not perform as well. The formulations now in use evolved to their present high-performance level over many years and it is, obviously, difficult to replace the key functional ingredient.

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associations and other special interest groups do it...so, why can't we do it?

Much has been said about involvement and participation. However, we cannot too often repeat that, if we are to solve the problems facing us in these turbulent times, we must all work together to understand the nature of our age and the world in which we live. Many of the problems affecting our Industry today stem from very basic roots. We have created a society founded on science and technology, yet have not found a meaningful place for many of the younger generation nor successfully employed the abilities of a large part of the older generation. We are in a crisis over values and aims of our culture; our efforts have been centered on materialism and striving for world leadership, rather than concentrating on values and the full development of human resources in our homes and in our own communities. As surely as day follows night, it is an inescapable fact that we are all affected by the events of our times. There is no longer a place to run and hide, and we cannot afford to accept complacency or trust in the security of our own backyards. We must take responsibility for more than our own concerns so that each person may have the opportunity to develop his own potential for good and thereby strengthen the entire nation. We must, in short, be motivated toward involvement.

You ask what GDCI will do for you? It will do what you ask of it and demand of it, for you as a member do indeed have a voice. The association has now been in existence some 20 years and is recognized as the spokesman of the Drywall Industry, both by government and those within the Industry. So let's all get involved... let's not be like a shot from a 16 ga. shotgun, but let's be a cannon ball, moving through the halls of Congress and showing that our Industry is a unified group from one end of the nation to the other and spanning the seas. For, if you don't get involved, the new laws and regulations, the growing lack of concern for quality, the steadily decreasing productivity rate and the escalating prices will eventually put your Industry—and you—out of the market. And sooner than you may think, one morning you will awake to find another product in its stead. Not reasonable, you say?

Then, isn't it reasonable that you, who have made a living from this great Industry, should contribute to the well-being of that Industry and stand shoulder-to-shoulder with confidence, 6,000-strong across the nation and throughout the world, to assure that the Drywall Industry does endure and will continue to make this world a better place in which to live, work and play?

Howard R. Leederman
Editor

(Continued from page 8)

ASBESTOS EXPOSURE IN THE TAPE JOINT INDUSTRY

The tape joint industry had their attention drawn forcibly to the asbestos standard in the Spring of 1974. A group at Mt. Sinai Hospital, led by Dr. Selikoff, announced the results of a study of 59 tapers who were members of Local Union 1974, Drywall Tapers and Pointers of Greater New York. The fiber counts found during sanding were generally very high and one long-time worker in the industry had a clearly recognizable case of lung fibrosis. The same data were transmitted to NIOSH who issued an alert to the industry.

At the time of this publicity, a major supplier of asbestos and other products to tape joint compound manufacturers had collected dust count samples during sanding at two locations in Florida. In contrast to the New York City results, the fiber levels found were low and well within the regulations. A possible reason for the difference can be found in the application and sanding conditions, i.e., hand-tool applied and heavily sanded in New York City compared with Ames tools and light sanding in Florida.

The question of different work practices was pursued further with various contractors. It was found that the amount of sanding done varied widely, even within a geographical area. It depended on the way the mud was applied, i.e., Ames vs. hand tools, the skill of the operator running the mud, the type of finishing coat to be applied to the wall, the size and quality of the job, i.e., custom or "mass production," the amount of ventilation, and the personal preference of the contractor. In addition to these mechanical factors, different mud formulations appeared to vary widely in their tendency to generate dust when sanded. In general sanding was minimized to reduce costs.

It was obvious that more information from other parts of the country was needed to better define the levels of asbestos exposure to be expected. With the assistance of the GDCI and the excellent cooperation of various individual contractors, field tests have now been run in New York, Texas, Michigan, and Minnesota. The New York, Michigan, and Minnesota sites were carefully selected to cover as wide a range as possible in the "intensity" of the sanding operation. Conditions varied from one man sanding lightly to three men sanding heavily in the same apartment. The New York tests also provide information on hand tool application. In addition to asbestos tests, air samples were collected at several of the locations to check the airborne concentration of crystalline silica (quartz) in the respirable fraction of the dust. The results of these tests will be presented in the January-February Issue.

PLAINTIFF'S EXHIBIT GP-206

GEORGIA-PACIFIC

INTERDEPARTMENTAL COMMUNICATION

DATE: March 1, 1974

TO: *See Below

LOCATION:

FROM: M. F. Fink

LOCATION: Tigard

SUBJECT: AIRBORNE SUBSTANCES - DUSTS, MISTS, ETC.

*TO: Mr. K. W. Brown - Acme ← THIS COPY FOR
Mr. J. D. Rauch - Akron
Mr. J. S. Jorgensen - Blue Rapids
Mr. C. G. Terry - Brunswick
Mr. E. H. Allen - Buchanan
Mr. O. B. Covington, Jr. - Fort Dodge
Mr. R. W. Nielsen - Grand Rapids
Mr. C. R. Coats - Lovell
Mr. C. F. Hummel - Sigurd
Mr. M. S. Jorgensen - Wilmington
Mr. J. E. Becker - Delair
Mr. E. M. Rigby - Pryor
Mr. M. A. Palmowski - Chicago
Mr. R. V. Favero - Marietta
Mr. H. W. Scharf - Milford

cc: Mr. G. E. Wilson - Portland
Mr. E. B. Hollingsworth - Wilmington
Mr. T. W. Richards - Tigard
Mr. C. W. Lehnert - Tigard
Mr. J. W. Hart - Wilmington
Mr. K. L. Gipson - Portland
Mr. J. R. Hurd - Portland
Mr. H. W. Peele - Wilmington
Mr. J. DiLorenzo - Portland

After months of controversy the Threshhold Limit Values recommended by Governmental Industrial Hygienists has been approved and accepted by Federal and a majority of State agencies responsible for enforcement of industrial hygiene regulations. One exception is the State of New York. They have proposed their own standards which have been reviewed and will be adopted very soon. This will create a hardship unless an agreement is negotiated between the State and OSHA. New York State Department of Labor and U. S. Bureau of Mines do have an agreement, however, this agreement does not extend past the calcining or when heat is applied to the rock. The plant will be exposed to two separate agencies, one State and the other Federal. At Buchanan, the U. S. Bureau of Mines has no jurisdiction, the entire operation will be subject to two agencies. OSHA regulations specifies that unless an accord is reached with state agencies or the state plan is approved

by OSHA the federal regulations must be adopted. When an accord is reached and approval given, the agency having the most stringent regulations shall prevail. This condition may change but as of this date we doubt if any action has been taken by the state or OSHA.

Fortunately the standards include gypsum dust in the nuisance category and allowable limit is 50 MPPCF (Million Particles Per Cubic Foot). At times the readings may specify million particles per cubic meter. This can be obtained by using the conversion factor namely:

MPPCF X 35.3 equals MPPCM

We will refer to Threshhold Limit Value or Permissable as TLV.

You will note that gypsum TLV is 50 MPPCF when the free silica is less than 1%. This should not be confused with combined silica. Free silica (alpha quartz) will be considerably lower than the silicate content. Gypsum may carry 25 to 35% combined silica but very rarely exceeds 2% free silica. Rock determinations were made in all of our domestic mining operations, the alpha quartz content averaged 0.89% to approximately 2.00%.

When the free silica is less than 1% the permissable allowable is 50 MPPCF. When it exceeds 1% the following conversion factor is used:

TLV divided by % alpha quartz + 10.

If a reading of 35 MPPCF is obtained and the free content is 3%, the permissable value would be 30 divided by 3% + 10 or 13. The hygienists recommend that when the alpha quartz is 1% the allowable should not exceed 30 MPPCF. Based on 3% free silica this would result in an allowable of 23.1 MPPCF.

Roof drilling samples taken in the Akron mine were analyzed and free silica determinations averaged between 3.9% to an occasional 5.1% in the high range. Most recent sampling indicated that TLV should not exceed 19.0 MPPCF.

It must be understood that dust particles larger than 10 microns are not considered injurious, i.e., in the nuisance dust varieties. Also 10 microns is not visible to the naked eye. We could have an excessive count although the air may appear clear of dust. Free silica particles remain suspended in the air considerably longer than other dusts due to size and weight. As a rule dust counts are averaged out to the time exposure or length of the shift. This is acceptable when an employee works

on different jobs during the shift and dust exposure may fluctuate. Note paragraph, "Nuisance Particulates" Page A. A spot test may be taken during the first hour of the shift and a low count will be obtained. Samples taken during the latter part of the shift resulted in free silica 3 and 4 times the previous tests. Samples analyzed of settled dust exceeded 5.00%, however, samples taken by the driller's position were less than 1.00%. This example was more pronounced in the milling operations. Airborne samples averaged from 4.8 to 8.1 MPPCF, free silica determination 0.89%. Settled dust samples, taken from window sills, ledges, etc. resulted in concentrations of 11.90% alpha quartz.

This condition is pointed out to emphasize the need for good housekeeping in all areas. Fortunately the dusts in the mining operations contain moisture reducing the odds of having dust disturbed and blown about the working areas. When the air seems to contain heavy concentrations of dust, a check of the operations shall be made to seal off any leaks. In addition dust masks must be worn until the condition is corrected. The MSA 8000 series has been approved by the U. S. Bureau of Mines and OSHA for non toxic dusts. This mask is preferable to others as they can be discarded at the end of the shift compared to an expensive and time consuming hygiene program when the more elaborate respirators or masks are used. Cost of the MSA 8000 series is less than 20 cents purchased in quantity lots. They are approved for all nuisance dusts, mica, asbestos and limestone. The MSA 8500 is standard in the Tigard Lab. This may seem lengthy and somewhat technical but we want to stress the importance of good housekeeping and enforcement of respiratory protection.

Perlite TLV permissable 30 MPPCF. Here again the free silica is a factor. Dust masks shall be worn when exposed to perlite dusts, unloading cars, expanding and adding to mixes. Based on tests by U. S. Bureau of Mines, free silica contents of perlite averaged 3 to 4%. Combined silica averaged 72.00, 73.00 and 74.00%. Perlite, because it is a volcanic glass having a chemical composition similar to the volcanic ash and obsidion should be considered potentially capable of producing adverse reactions in lung tissue. Further studies are being made to determine the physiological effects on the respiratory system. It has been proven that there is an increase in the silica content and alpha quartz during the expanding process. A dust mask program shall be enforced.

Mica TLV has been lowered from 50 to 20 MPPCF. This TLV carries a conversion factor when the free silica exceeds 1%. When purchasing mica a request should be made to the supplier for

an analysis of the product especially the percentage of free silica. We believe that the grades of mica used in our plants do not exceed 1%. The dust mask program is a must when handling the product.

Talc, non fibrous or non asbestos form. 20 TLV.

Talc (fibrous) Cristobalite and Tremolite use. Asbestos TLV based on length of fibers. Asbestos. At the present time TLV 8 hour time weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed five fibers longer than five micrometers per cubic centimeter of air as determined by the method prescribed and approved by OSHA and NIOSH. The TLV is subject to change on 1/1/1976. Two fibers or less per cubic centimeter of air based on five micrometers.

Based on recent surveys we are in compliance at all operations, however, a lot of static has developed at Akron. We do believe that this is the result of the lack of cooperation between OSHA and the state.

Attached is an outline of safety practices for asbestos fibers. In addition a copy of the approved and adopted Threshhold Limit Values is attached. Review the charts and if you wish to have more information regarding any of the substances please advise.

Although the value reductions may seem drastic, the greater part of the problem can be eliminated by education, enforcement of respiratory equipment, personal hygiene and cooperation with the rules. The employer is responsible for rule enforcement. Special attention must be given to housekeeping, especially in the asbestos operations. All spillage shall be immediately cleaned up. Bags of asbestos in storage shall be covered and finally dust masks must be worn. To repeat the earlier statement, the one-day use MSA masks have been approved by OSHA to prevent breathing asbestos dust.

M. F. F.

MFF:jg

Attachments

IV SAFETY PRACTICES FOR ASBESTOS FIBERS

The following recommendations for asbestos handling have been adapted from the safety practices instituted by Johns-Manvile:

1. In all stages of handling -- packaging, transporting, unloading, storing and in-plant moving -- asbestos fiber bags should be handled carefully and in such a manner as to prevent the generation of dust.
2. Unitized loads should be lifted intact to and from holds of ships, and off and on land transport by fork lift trucks or other suitable handling equipment.
3. Care should be taken to avoid puncturing the asbestos fiber bags during unloading from ships, railroad cars, trucks or other modes of transportation. No hooks or other sharp instruments should be used. Loose fiber accumulated during transit should be picked up by vacuum cleaner before unloading.
4. Damaged bags should be immediately repaired, resealed or put into suitably closed receptacles. Any spillage of asbestos fiber should be picked up either by vacuum equipment or after thoroughly wetting, by sweeping, and should be deposited in suitable closed receptacles.

5. For storage, fiber bags should be stacked and moved with care to avoid breakage, protected from puncture by moving vehicles and, if possible, should be isolated from traffic in the warehouse and covered to prevent dust generation. To prevent deterioration of stored bags, the principle of first-in, first-out should be followed.

6. Maximum possible enclosure and fully effective dust control hoods should be provided at all stages of in-plant handling where dust is unavoidably created, such as at bag opening, fiber dumping and bag disposal operations. Loose fiber should be cleaned from work areas as described in 4, above, to prevent dust regeneration.

7. The wearing of respiratory protective equipment approved by the U.S. Bureau of Mining for protection against asbestos dust should be required at all stages of asbestos fiber handling where quantities of dust are generated which cannot be kept within the Threshhold Limit Value by dust control equipment or other methods.

8. Waste materials, such as collected dust and empty fiber bags, should be placed in special closed receptacles and disposed of in such a way as to prevent the release of dust. Methods applicable uner 6 and 7 above, should be used during these operations.

9. All dust from exhaust systems should be collected and safely disposed of. It should not be released into the outside air. Particular attention should be paid to the protection of the employees whose job it is to dispose of the collected dust.

10. Storage piles of bags of asbestos shall be covered with a non-clinging cover or tarp. Plastic is recommended. All spillage shall be vacuum cleaned to prevent so called fugitive fiber release.

Threshold Limit Values for 1973

Adopted at the 35th Annual Meeting of the American Conference of Governmental Industrial Hygienists Boston, Massachusetts, May 21-25, 1973.

Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit, a smaller percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness.

Simple tests are now available (*J. Occup. Med. 9: 537,* 1967; Ann. N.Y. Acad. Sci., *151, Art. 2:* 968, 1968) that may be used to detect those individuals hypersusceptible to a variety of industrial chemicals (respiratory irritants, hemolytic chemicals, organic isocyanates, carbon disulfide). These tests may be used to screen out by appropriate job placement the hyperreactive worker and thus in effect improve this "coverage" of the TLVs.

Threshold limit values refer to time-weighted concentrations for a 7 or 8-hour workday and 40-hour workweek. They should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations. (Exceptions are the substances listed in Appendices B and F and those substances designated with a "C" or Ceiling value, Appendix D)

Time-weighted averages permit excursions above the limit provided they are compensated by equivalent excursions below the limit during the workday. In some instances it may be permissible to calculate the average concentration for a workweek rather than for a workday. The degree of permissible excursion is related to the magnitude of the threshold limit value of a particular substance as given in Appendix D. The relationship between threshold limit and permissible excursion is a rule of thumb and in certain cases may not apply. The amount by which threshold limits may be exceeded for short periods without injury to health depends upon a number of factors such as the nature of the contaminant, whether very high concentrations – even for short periods – produce acute poisoning, whether the effects are cumulative, the frequency with which high concentrations occur, and the duration of such periods. All factors must be taken into consideration in arriving at decision as to whether a hazardous condition exists.

Threshold limits are based on the best available information from industrial experience, from experimental human and animal studies, and, when possible, from a combination of the three. The basis on which the values are established may differ from substance to substance; protection against impairment of health may be a guiding factor for some, whereas reasonable freedom from irritation, narcosis, nuisance or other forms of stress may form the basis for others.

The amount and nature of the information available for establishing a TLV varies from substance to substance; consequently, the precision of the estimated TLV is also subject to variation and the latest *Documentation* should be consulted in order to assess the extent of the data available for a given substance.

The committee holds to the opinion that limits based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that physical irritation may initiate, promote or accelerate physical impairment through interaction with other chemical or biologic agents.

In spite of the fact that serious injury is not believed likely as a result of exposure to the threshold limit concentrations, the best practice is to maintain concentrations of all atmospheric contaminants as low as is practical.

These limits are intended for use in the practice of industrial hygiene and should be interpreted and applied only by a person trained in this discipline. They are *not* intended for use, or for modification for use, (1) as a relative index of hazard or toxicity, (2) in the evaluation of air pollution nuisances, (3) in estimating the toxic potential of continuous, uninterrupted exposures, (4) as proof or disproof of an existing disease or physical condition, or (5) for adoption by countries whose working conditions differ from those in the United States of America and where substances and processes differ.

Ceiling vs Time-Weighted Average Limits. Although the time-weighted average concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the limits, there are certain substances for which it is inappropriate. In the latter group are substances which are predominantly fast acting and whose threshold limit is more appropriately based on this particular response. Substances with this type of response are best controlled by a ceiling "C" limit that should not be exceeded. It is implicit in these definitions that the manner of sampling to determine compliance with the limits for each group must differ; a single brief sample, that is applicable to a "C" limit, is not appropriate to the time-weighted limit; here, a sufficient number of samples are needed to permit a time-weighted average concentration throughout a complete cycle of operations or throughout the work shift.

Whereas the ceiling limit places a definite boundary which concentrations should not be permitted to exceed, the time-weighted average limit requires an explicit limit to the excursions that are permissible above the listed values. The magnitude of these excursions may be pegged to the magnitude of the threshold limit by an appropriate factor shown in Appendix D. It should be noted that the same factors are used by the Committee in making a judgment whether to include or exclude a substance for a "C" listing.

"Skin" Notation. Listed substances followed by the designation "Skin" refer to the potential contribution to the overall exposure by the cutaneous route including mucous membranes and eye, either by airborne, or more particularly, by direct contact with the substance. Vehicles can alter skin absorption. This attention-calling designation is intended to suggest appropriate measures for the prevention of cutaneous absorption so that the threshold limit is not invalidated.

Mixtures. Special consideration should be given also to the application of the TLVs in assessing the health hazards which may be associated with exposure to mixtures of two or more substances. A brief discussion of basic considerations involved in developing threshold limit values for mixtures, and methods for their development, amplified by specific examples are given in Appendix C.

Nuisance Particulates. In contrast to fibrogenic dusts which cause scar tissue to be formed in lungs when inhaled in excessive amounts, so-called "nuisance" dusts have a long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. The nuisance dusts have also been called (biologically) "inert" dusts, but the latter term is inappropriate to the extent that there is no dust which does not evoke some cellular response in the lung when inhaled in sufficient amount. However, the lung-tissue reaction caused by inhalation of nuisance dusts has the

following characteristics: 1) The architecture of the air spaces remains intact. 2) Collagen (scar tissue) is not formed to a significant extent. 3) The tissue reaction is potentially reversible.

Excessive concentrations of nuisance dusts in the workroom air may seriously reduce visibility (iron oxide), may cause unpleasant deposits in the eyes, ears and nasal passages (Portland Cement dust), or cause injury to the skin or mucous membranes by chemical or mechanical action per se or by the rigorous skin cleansing procedures necessary for their removal.

A threshold limit of 10mg/m^3, or 30 mppcf, of total dust < 1% quartz is recommended for substances in these categories and for which no specific threshold limits have been assigned. This limit, for a normal workday, does not apply to brief exposures at higher concentrations. Neither does it apply to those substances which may cause physiologic impairment at lower concentrations but for which a threshold limit has not yet been adopted. Some nuisance particulates are given in Appendix E.

Simple Asphyxiants - "Inert" Gases or Vapors. A number of gases and vapors, when present in high concentrations in air, act primarily as simple asphyxiants without other significant physiologic effects. A TLV may not be recommended for each simple asphyxiant because the limiting factor is the available oxygen. The minimal oxygen content should be 18 percent by volume under normal atmospheric pressure (equivalent to a partial pressure, pO_2 of 35 mm Hg). Atmospheres deficient in O_2 do not provide adequate warning and most simple asphyxiants are odorless. Several simple asphyxiants present an explosion hazard. Account should be taken of this factor in limiting the concentration of the asphyxiant. Specific examples are listed in Appendix F.

Physical Factors. It is recognized that such physical factors as heat, ultraviolet and ionizing radiation, humidity, abnormal pressure (altitude) and the like may place added stress on the body so that the effects from exposure at a threshold limit may be altered. Most of these stresses act adversely to increase the toxic response of a substance. Although most threshold limits have built-in safety factors to guard against adverse effects to moderate deviations from normal environments, the safety factors of most substances are not of such a magnitude as to take care of gross deviations. For example, continuous work at temperatures about 90°F for overtime extending the workweek more than 25% might be considered gross deviations. In such instances judgment must be exercised in the proper adjustments of the threshold limit values.

"Notice of Intent." At the beginning of each year, proposed actions of the Committee for the forthcoming year are issued in the form of a "Notice of Intended Changes." This Notice provides not only an opportunity for comment, but solicits suggestions of substances to be added to the list. The suggestions should be accompanied by substantiating evidence. The list of Intended Changes follows the Adopted Values in the TLV booklet.

Legal Status. By publication in the Federal Register (Vol. 36, No. 105, May 29, 1971) the Threshold Limit Values are now official federal standards for industrial air.

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ADOPTED VALUES (In Alphabetic Order)

	Substance	ppm[a]	mg/M^3[b]
	Abate	–	10
+	Acetaldehyde	100	180
	Acetic acid	10	25
C	Acetic anhydride	5	20
	Acetone	1,000	2,400
	Acetonitrile	40	70
	2-Acetylaminofluorene – Skin	–	A[2]
	Acetylene	F	–
	Acetylene dichloride, see 1, 2-Dichloroethylene	–	–
	Acetylene tetrabromide	1	14
	Acrolein	0.1	0.25
	Acrylamide – Skin	–	0.3
	Acrylonitrile – Skin	20	45
	Aldrin – Skin	–	0.25
	Allyl alcohol – Skin	2	3
	Allyl chloride	1	5
	Allyl glycidyl ether (AGE)	(10)	(45)
	Allyl propyl disulfide	2	12
	Alundum (Al_2O_3)	–	E
	4-Aminodiphenyl – Skin	–	A[1b]
	2-Aminoethanol, see Ethanolamine	–	–
	2-Aminopyridine	0.5	2
	Ammonia	25	18
	Ammonium chloride, fume	–	10
	Ammonium sulfamate (Ammate)	–	10
	n-Amyl acetate	100	525
	sec-Amyl acetate	125	650
	Aniline – Skin	5	19
	Anisidine (o, p-isomers) – Skin	–	0.5
	Antimony & compounds (as Sb)	–	0.5
	ANTU (alpha naphthyl thiourea)	–	0.3
	Argon	F	–
	Arsenic & compounds (as As)	–	0.5
	Arsine	0.05	0.2
	Asphalt (petroleum) fumes	–	5
	Azinphos methyl – Skin	–	0.2
	Barium (soluble compounds)	–	0.5
	Benzene (benzol) – Skin	25	80
	Benzidine – Skin	–	A[1b]
	p-Benzoquinone, see Quinone	–	–
	Benzoyl peroxide	–	5
	Benzyl chloride	1	5
	Beryllium	–	0.002

	Substance	ppm[a]	mg/M^3[b]
	Biphenyl, see Diphenyl	–	–
+	Bismuth telluride	–	10
+	Bismuth telluride (se-doped)	–	5
	Boron oxide	–	10
	Boron tribromide	1	10
C	Boron trifluoride	1	3
	Bromine	0.1	0.7
	Bromine pentafluoride	0.1	0.7
	Bromoform – Skin	0.5	5
	Butadiene (1, 3-butadiene)	1,000	2,200
+	Butane	500	1,200
	Butanethiol, see Butyl mercaptan	–	–
	2-Butanone	200	590
	2-Butoxy ethanol (Butyl Cellosolve) – Skin	50	240
	Butyl acetate (n-butyl acetate)	150	710
	sec-Butyl acetate	200	950
	tert-Butyl acetate	200	950
	Butyl alcohol	100	300
	sec-Butyl alcohol	150	450
	tert-Butyl alcohol	100	300
C	Butylamine – Skin	5	15
C	tert-Butyl chromate (as CrO_3) – Skin	–	0.1
	n-Butyl glycidyl ether (BGE)	50	270
	Butyl mercaptan	0.5	1.5
	p-tert-Butyltoluene	10	60
	Caumium (Metal dust and soluble salts)	–	0.2
**C	Cadmium oxide fume (as Cd)	–	0.1
	Calcium carbonate	–	E
	Calcium arsenate	–	1
	Calcium oxide	–	5
	Camphor (Synthetic)	2	12
	Carbaryl (Sevin®)	–	5
	Carbon black	–	3.5
**	Carbon dioxide	5,000	9,000
	Carbon disulfide – Skin	20	60
	Carbon monoxide	50	55
	Carbon tetrachloride – Skin	10	65
	Cellulose (paper fiber)	–	E
	Chlordane – Skin	–	0.5
	Chlorinated camphene – Skin	–	0.5
	Chlorinated diphenyl oxide	–	0.5

	Substance	ppm[a]	mg/M[3][b]
	Chlorine	1	3
	Chlorine dioxide	0.1	0.3
C	Chlorine trifluoride	0.1	0.4
C	Chloroacetaldehyde	1	3
∝	∝-Chloroacetophenone (phenacylchloride)	0.05	0.3
	Chlorobenzene (monochlorobenzene)	75	350
	o-Chlorobenzylidene malononitrile (OCBM) – Skin	0.05	0.4
	Chlorobromomethane	200	1,050
	2-Chloro-1, 3-butadiene: see Chloroprene	–	–
	Chlorodiphenyl (42% Chlorine) – Skin	–	1
	Chlorodiphenyl (54% Chlorine) – Skin	–	0.5
	1-Chloro, 2, 3- epoxy-propane, see Epichlorhydrin	–	–
	2-Chloroethanol, see Ethylene chlorohydrin	–	–
	Chloroethylene, see Vinyl chloride	–	–
+	Chloroform (trichloromethane)	25	120
	1-Chloro- 1-nitropropane	20	100
	Chloropicrin	0.1	0.7
	Chloroprene (2-chloro-1, 3-butadiene) – Skin	25	90
	Chromic acid and chromates (as CrO_3)	–	0.1
	Chromium, sol. chromic, chromous salts as Cr.	–	0.5
••	Metal & insol. salts	A[10]	(1.0)
+	Coal dust (bituminous) (Respirable dust fraction <5% quartz) (If >5% quartz use respirable mass formulas)	–	2
	Coal tar pitch volatiles (benzene soluble fraction) anthracene, BaP, phenanthrene, acridine, chrysene, pyrene)	A[10]	0.2
	Cobalt, metal fume & dust	–	0.1
••	Copper fume	–	0.1
	Dusts and Mists	–	1
	Corundum (Al_2O_3)	–	E
••	Cotton Dust (raw)	–	(1)
	Crag® herbicide	–	10
	Cresol (all isomers) – Skin	5	22
	Crotonaldehyde	2	6
	Cumene – Skin	50	245
	Cyanide (as CN) – Skin	–	5
	Cyanogen	10	–
	Cyclohexane	300	1,050
	Cyclohexanol	50	200
	Cyclohexanone	50	200
	Cyclohexene	300	1,015
	Cyclopentadiene	75	200
	2,4-D	–	10
	DDT	–	1
	DDVP, see Dichlorvos	–	–
	Decaborane – Skin	0.05	0.3
	Demeton® – Skin	–	0.1
	Diacetone alcohol (4-hydroxy-4-methyl- 2-pentanone)	50	240
	1, 2-Diaminoethane, see Ethylenediamine	–	–
	Diazinon – Skin	–	0.1
	Diazomethane	0.2	0.4
	Diborane	0.1	0.1
+	1, 2-Dibromoethane (ethylene dibromide) – Skin	20	145
	Dibrom®	–	3
*	2-N Dibutylaminoethanol – Skin	2	14
	Dibutyl phosphate	1	5
	Dinutylphthalate	–	5
C	Dichloracetylene	0.1	0.4
C	o-Dichlorobenzene	50	300
	p-Dichlorobenzene	75	450
••	Dichlorobenzidine – Skin	–	A[10]
	Dichlorodifluoromethane	1,000	4,950
	1, 3-Dichloro-5, 5-Dimethyl hydantoin	–	0.2
+	1, 1-Dichloroethane	200	820
	1, 2-Dichloroethane	50	200
	1, 2-Dichloroethylene	200	790
+	Dichloroethyl ether – Skin	5	30
	Dichloromethane, see Methylene chloride	–	–
	Dichloromonofluoromethane	1,000	4,200
C	1, 1-Dichloro-1-nitroethane	10	60
	1, 2-Dichloropropane, see Propylenedichloride	–	–
	Dichlorotetrafluoroethane	1,000	7,000
	Dichlorvos (DDVP) – Skin	–	1
	Dieldrin – Skin	–	0.25

	Substance	ppm[a]	mg/M[3][b]
	Diethylamine	25	75
	Diethylamino ethanol – Skin	10	50
•	Diethylene triamine – Skin	1	4
	Diethylether, see Ethyl ether	–	–
	Difluorodibromomethane	100	860
C	Diglycidyl ether (DGE)	0.5	2.8
	Dihydroxybenzene, see Hydroquinone	–	–
+	Diisobutyl ketone	25	150
	Diisopropylamine – Skin	5	20
	Dimethoxymethane, see Methylal	–	–
	Dimethyl acetamide – Skin	10	35
	Dimethylamine	10	18
	4-Dimethylaminoazobenzene	–	A[2]
	Dimethylaminobenzene, see Xylidene	–	–
	Dimethylaniline (N-dimethylaniline) – Skin	5	25
	Dimethylbenzene, see Xylene	–	–
	Dimethyl 1, 2-dibromo- 2-dichloroethyl phosphate, see Dibrom	–	–
	Dimethylformamide – Skin	10	30
	2, 6-Dimethylheptanone, see Diisobutyl ketone	–	–
	1, 1-Dimethylhydrazine – Skin	0.5	1
	Dimethylphthalate	–	5
••	Dimethylsulfate – Skin	(1)	(5)
	Dinitrobenzene (all isomers) – Skin	–	1
	Dinitro-o-cresol – Skin	–	0.2
	Dinitrotoluene – Skin	–	1.5
••	Dioxane (Diethylene dioxide) – Skin	100	360
	Diphenyl	0.2	1
	Diphenyl amine	–	10
	Diphenylmethane diisocyanate (see Methylene bisphenyl isocyanate (MDI)	–	–
	Dipropylene glycol methyl ether – Skin	100	600
+	Diquat	–	0.5
	Di-sec, octyl phthalate (Di-2-ethylhexylphthalate	–	5
	Emery	–	E
	Endosulfan (Thiodan®) – Skin	–	0.1
	Endrin – Skin	–	0.1
	Epichlorhydrin – Skin	5	19
	EPN – Skin	–	0.5
	1, 2-Epoxypropane, see Propyleneoxide	–	–
	2, 3-Epoxy-1-propanol, see Glycidol	–	–
	Ethane	F	–
	Ethanethiol, see Ethylmercaptan	–	–
	Ethanolamine	3	6
+	2-Ethoxyethanol – Skin	100	370
	2-Ethoxyethylacetate (Cellosolve acetate) – Skin	100	540
	Ethyl acetate	400	1,400
	Ethyl acrylate – Skin	25	100
	Ethyl alcohol (ethanol)	1,000	1,900
	Ethylamine	10	18
	Ethyl sec-amyl ketone (5-methyl-3-heptanone)	25	130
	Ethyl benzene	100	435
	Ethyl bromide	200	890
	Ethyl butyl ketone (3-Heptanone)	50	230
	Ethyl chloride	1,000	2,600
	Ethyl ether	400	1,200
	Ethyl formate	100	300
	Ethyl mercaptan	0.5	–
	Ethyl silicate	100	850
	Ethylene	F	–
	Ethylene chlorohydrin – Skin	5	16
	Ethylenediamine	10	25
	Ethylene dibromide, see 1, 2-Dioromoethane	–	–
	Ethylene dichloride, see 1, 2-Dichloroethane	–	–
C	Ethylene glycol dinitrate and/or Nitroglycerin – Skin	0.2[d]	–
	Ethylene glycol monomethyl ether acetate (Methyl cellosolve acetate) – Skin	25	120
+	Ethylene glycol, particulate	–	10
+	Ethylene glycol, vapor	100	260
	Ethylene imine – Skin	0.5	1
	Ethylene oxide	50	90
	Ethylidine chloride, see 1, 1-Dichloroethane	–	–
	N-Ethylmorpholine – Skin	20	94
	Ferbam	–	10
	Ferrovanadium dust	–	1
	Fluoride (as F)	–	2.5

Substance	ppm[a]	mg/M³[b]
Fluorine	1	2
Fluorotrichloromethane	1,000	5,600
Formaldehyde	2	3
Formic acid	5	9
Furfural – Skin	5	20
Furfuryl alcohol	(50)	(200)
Gasoline	–	B[2]
Germanium tetrahydride (Germane)	0.2	0.6
Glass, fibrous[c] or dust	–	E
Glycerin mist	–	E
Glycidol (2, 3-Epoxy-1-propanol)	50	150
Glycol monoethyl ether, see 2-Ethoxyethanol	–	–
Graphite (Synthetic)	–	E
Guthion®, see Azinphosmethyl	–	–
Gypsum	–	E
Hafnium	–	0.5
Helium	F	–
Heptachlor – Skin	–	0.5
Heptane (n-heptane)	500	2,000
Hexachloroethane – Skin	1	10
Hexachloronaphthalene – Skin	-	0.2
Hexafluoroacetone	0.1	0.7
Hexane (n-hexane)	500	1,800
2-Hexanone	100	410
Hexone (Methyl isobutyl ketone)	100	410
sec-Hexyl acetate	50	300
Hydrazine – Skin	1	1.3
Hydrogen	F	–
Hydrogen bromide	3	10
Hydrogen chloride	5	7
Hydrogen cyanide – Skin	10	11
Hydrogen fluoride	3	2
Hydrogen peroxide	1	1.4
Hydrogen selenide	0.05	0.2
Hydrogen sulfide	10	15
Hydroquinone	–	2
Indene	10	45
Indium and compounds, as In	–	0.1
Iodine	0.1	1
Iron oxide fume	–	10
Iron pentacarbonyl	0.01	0.08
Iron salts, soluble, as Fe	–	1
Isoamyl acetate	100	525
Isoamyl alcohol	100	360
Isobutyl acetate	150	700
Isobutyl alcohol	100	300
Isophorone	–	–
Isopropyl acetate	250	950
Isopropyl alcohol	400	980
Isopropylamine	5	12
Isopropylether	250	1,050
Isopropyl glycidyl ether (IGE)	50	240
Kaolin	–	E
Ketene	0.5	0.9
Lead, inorganic compounds fumes & dusts	–	0.15
Lead arsenate	–	0.15
Limestone	–	E
Lindane	–	0.5
Lithium hydride	–	0.025
L.P.G. (Liquefied petroleum gas)	1,000	1,800
Magnesite		E
Magnesium oxide fume		
Malathion – Skin		
Maleic anhydride		
Manganese and compounds, as Mn		
Marble		E
Mercury (Alkyl compounds) – Skin		0.01
Mercury (All forms except alkyl)		0.05
Mesityl oxide	25	100
Methane	F	–
Methanethiol, see Methyl mercaptan	–	–
Methoxychlor	–	10
2-Methoxyethanol – Skin (Methyl cellosolve)	25	80
Methyl acetate	200	610
Methyl acetylene (propyne)	1,000	1,650
Methyl acetylene-propadiene mixture (MAPP)	1,000	1,800
Methyl acrylate – Skin	10	35
Methylacrylonitrile – Skin	1	3
Methylal (dimethoxymethane)	1,000	3,100
Methyl alcohol (methanol)	200	260
Methylamine	10	12
Methyl amyl alcohol, see Methyl isobutyl carbinol	–	–
Methyl 2-cyanoacrylate	2	8
Methyl isoamyl ketone	100	475

Substance	ppm[a]	mg/M³[b]
Methyl (n-amyl) ketone (2-Heptanone)	100	465
Methyl bromide – Skin	15	60
Methyl butyl ketone, see 2-Hexanone	–	–
Methyl cellosolve – Skin see 2-Methoxyethanol	–	–
Methyl cellosolve acetate – Skin, see Ethylene glycol monomethyl ether acetate	–	–
Methyl chloride	100	210
Methyl chloroform	350	1,900
Methylcyclohexane	500	2,000
Methylcyclohexanol	50	235
Methylcyclohexanone – Skin	50	230
Methylcyclopentadienyl manganese tricarbonyl (as Mn)	0.1	0.2
Methyl demeton – Skin	–	0.5
Methyl ethyl ketone (MEK) see 2-Butanone	–	
Methyl formate	100	250
Methyl iodide – Skin	5	28
Methyl isobutyl carbinol – Skin	25	100
Methyl isobutyl ketone, see Hexone	–	–
Methyl isocyanate – Skin	0.02	0.05
Methyl mercaptan	0.5	1
Methyl methacrylate	100	410
Methyl parathion – Skin	–	0.2
Methyl propyl ketone, see 2-Pentanone	–	–
C Methyl silicate	5	30
C α Methyl styrene	100	480
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2
•• Methylene chloride (dichloromethane)	(500)	(1,740)
Molybdenum (soluble compounds)	–	5
(insoluble compounds)	–	10
Monomethyl aniline – Skin	2	9
C Monomethyl hydrazine – Skin	0.2	0.35
Morpholine – Skin	20	70
Naphtha (coal tar)	100	400
Naphthalene	10	50
β Naphthylamine	–	A[1b]
Neon	F	–
Nickel carbonyl	0.001	(A[1a])0.007

Substance	ppm[a]	mg/M³[b]
Nickel, metal and soluble compounds (as Ni)	–	1
Nicotine – Skin	–	0.5
Nitric acid	2	5
Nitric oxide	25	30
p-Nitroaniline – Skin	1	6
Nitrobenzene – Skin	1	5
p-Nitrochlorobenzene – Skin	–	1
4-Nitrodiphenyl	–	A[1a]
Nitroethane	100	310
Nitrogen	F	–
C Nitrogen dioxide	5	9
Nitrogen trifluoride	10	29
Nitroglycerin – Skin	0.2	2
Nitromethane	100	250
1-Nitropropane	25	90
2-Nitropropane	25	90
N-Nitrosodimethylamine (dimethylnitrosoamine) – Skin	–	A[2]
Nitrotoluene – Skin	5	30
Nitrotrichloromethane, see Chloropicrin	–	–
Nitrous oxide	F	–
Octachloronaphthalene – Skin	–	0.1
Octane	400	1,900
Oil mist, particulate		B[2]
Oil mist, vapor		
Osmium tetroxide	–	0.002
Oxalic acid	–	1
Oxygen difluoride	0.05	0.1
Ozone	0.1	0.2
Paraquat – Skin	–	0.5
Parathion – Skin	–	0.1
Perlite	–	mppcf 30
Pentaborane	0.005	0.01
Pentachloronaphthalene – Skin	–	0.5
Pentachlorophenol – Skin	–	0.5
Pentaerythritol	–	E
Pentane	500	1,500
2-Pentanone	200	700
Perchloroethylene	100	670
Perchloromethyl mercaptan	0.1	0.8
Perchloryl fluoride	3	14

	Substance	ppm[a]	mg/M[3][b]
	Petroleum Distillates (naphtha)	8[g]/B[2]	–
	Phenol – Skin	5	19
	p-Phenylene diamine – Skin	–	0.1
	Phenyl ether (vapor)	1	7
	Phenyl ether-Diphenyl mixture (vapor)	1	7
	Phenylethylene, see Styrene	–	–
	Phenyl glycidyl ether (PGE)	10	60
	Phenylhydrazine – Skin	5	22
+C	Phenylphosphine	0.05	0.25
	Phenothiazine – Skin	–	5
	Phosdrin (Mevinphos®) – Skin	–	0.1
	Phosgene (carbonyl chloride)	0.1	0.4
	Phosphine	0.3	0.4
	Phosphoric acid	–	1
	Phosphorus (yellow)	–	0.1
	Phosphorus pentachloride	–	1
	Phosphorus pentasulfide	–	1
	Phosphorus trichloride	0.5	3
	Phthalic anhydride	2	12
	Picric acid – Skin	–	0.1
	Pival® (2-Pivalyl-1, 3-indandione)	–	0.1
	Plaster of Paris	–	E
	Platinum (Soluble Salts) as Pt	–	0.002
	Polychlorobiphenyls, see Chlorodiphenyls	–	–
	Polytetrafluoroethylene decomposition products	–	B[1]
	Propane	F	–
	β-Propiolactone	–	A[2]
	Propargyl alcohol – Skin	1	–
	n-Propyl acetate	200	840
	Propyl alcohol	200	500
	n-Propyl nitrate	25	110
	Propylene dichloride (1, 2-Dichloropropane)	75	350
*	Propylene glycol monomethyl ether	100	360
	Propylene imine – Skin	2	5
	Propylene oxide	100	240
	Propyne, see Methylacetylene	–	–
	Pyrethrum	–	5
	Pyridine	5	15
	Quinone	0.1	0.4
	RDX – Skin	–	1.5
	Rhodium, Metal fume and dusts(as Rh)	–	0.1
	Soluble salts	–	0.001
	Ronnel	–	10
*	Rosin Core Solder, pyrolysis products (as formaldehyde)	–	0.1
	Rotenone (commercial)	–	5
	Rouge	–	E
	Selenium compounds (as Se)	–	0.2
	Selenium hexafluoride	0.05	0.4
+	Silicon	–	10
	Silicon carbide	–	E
	Silver, metal and soluble compounds	–	0.01
	Sodium fluoroacetate (1080) – Skin	–	0.05
*	Sodium hydroxide	–	2
	Starch	–	E
	Stibine	0.1	0.5
	Stoddard solvent	200	1,150
	Strychnine	–	0.15
	Styrene (Monomer) (Phenyl ethylene)	100	420
*	Subtilisins (Proteolytic enzymes as 100% pure crystalline enzyme)	–	0.0003
	Sucrose	–	E
	Sulfur dioxide	5	13
	Sulfur hexafluoride	1,000	6,000
	Sulfuric acid	–	1
	Sulfur monochloride	1	6
	Sulfur pentafluoride	0.025	0.25
	Sulfur tetrafluoride	0.1	0.4
	Sulfuryl fluoride	5	20
	Systox, see Demeton®	–	–
	2, 4, 5-T	–	10
	Tantalum	–	5
	TEDP – Skin	–	0.2
	Teflon® decomposition products	–	B[1]
	Tellurium	–	0.1
	Tellurium hexafluoride	0.02	0.2
	TEPP – Skin	–	0.05
	Terphenyls	1	9
	1, 1, 1, 2-Tetrachloro-2, 2-difluoroethane	500	4,170
	1, 1, 2, 2-Tetrachloro-1, 2-difluoroethane	500	4,170
	1, 1, 2, 2-Tetrachloroethane – Skin	5	35
	Tetrachloroethylene, see Perchloroethylene	–	–
	Tetrachloromethane, see Carbon tetrachloride	–	–
	Tetrachloronaphthalene – Skin	–	2
	Tetraethyl lead (as Pb) – Skin	–	0.100[h]
	Tetrahydrofuran	200	590
	Tetramethyl lead (as Pb) – Skin	–	0.150[h]
	Tetramethyl succinonitrile – Skin	0.5	3
	Tetranitromethane	1	8
	Tetryl (2, 4, 6-trinitrophenyl-methylnitramine) – Skin	–	1.5
	Thallium (soluble compounds) – Skin (as Tl)	–	0.1
	Thiram®	–	5
	Tin (inorganic compounds, except SnH_4 and SnO_2) as Sn	–	2
	Tin (organic compounds) – Skin (as Sn)	–	0.1
	Tin oxide	–	E
	Titanium dioxide	–	E
+	Toluene	100	375
C	Toluene-2, 4-diisocyanate	0.02	0.14
	o-Toluidine	5	22
	Toxaphene, see Chlorinated camphene	–	–
	Tributyl phosphate	–	5
	1, 1, 1-Trichloroethane, see Methyl chloroform	–	–
	1, 1, 2-Trichloroethane – Skin	10	45
	Trichloroethylene	100	535
	Trichloromethane, see Chloroform	–	–
	Trichloronaphthalene – Skin	–	5
	1, 2, 3-Trichloropropane	50	300
	1, 1, 2-Trichloro 1, 2, 2-trifluoroethane	1,000	7,600
	Triethylamine	25	100
	Trifluoromonobromomethane	1,000	6,100
	Trimethyl benzene	25	120
	2, 4, 6-Trinitrophenol, see Picric acid	–	–
	2, 4, 6-Trinitrophenylmethylnitramine, see Tetryl	–	–
	Trinitrotoluene – Skin	–	1.5
	Triorthocresyl phosphate	–	0.1
	Triphenyl phosphate	–	3
	Tungsten & compounds, as W Soluble	–	1
	Insoluble	–	5
	Turpentine	100	560
	Uranium (natural) soluble & insoluble compounds, as U	–	0.2
	Vanadium (V_2O_5), as V Dust	–	0.5
C	Fume	–	0.05
	Vinyl acetate	10	30
	Vinyl benzene, see Styrene	–	–
*	Vinyl bromide	250	1,100
	Vinyl chloride	200	770
	Vinylcyanide, see Acrylonitrile	–	–
	Vinyl toluene	100	480
	Warfarin	–	0.1
*	Wood dust (nonallergenic)	–	5
	Xylene (xylol)	100	435
	Xylidine – Skin	5	25
	Yttrium	–	1
	Zinc chloride fume	–	1
	Zinc oxide fume	–	5
	Zirconium compounds (as Zr)	–	5

NOTES

Capital letters refer to appendices

* 1972 Addition

** See notice of intended changes

\+ 1973 Addition

a) Parts of vapor or gas per million parts of contaminated air by volume at 25 C and 760 mm. Hg. pressure.

b) Approximate milligrams of substance per cubic meter of air.

d) An atmospheric concentration of not more than 0.02 ppm, or personal protection may be necessary to avoid headache.

e) < 5-7μm in diameter.

f) As sampled by method that does not collect vapor.

g) According to analytically determined composition.

h) For control of general room air, biologic monitoring is essential for personnel control.

Radioactivity: For permissible concentrations of radioisotopes in air, see U.S. Department of Commerce, National Bureau of Standards Handbook 69, "Maximum Permissible Body Burdens and

Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," June 5, 1969. Also, see U.S. Department of Commerce, National Bureau of Standards, Handbook 59, "Permissible Dose from External Sources of Ionizing Radiation," September 24, 1954, and addendum of April 15, 1958. A report, Basic Radiation Protection Criteria, published by the National Committee on Radiation Protection, revises and modernizes the concept of the NCRP standards of 1954, 1957 and 1958; obtainable as NCRP Rept. No. 39, P.O. Box 4867, Washington, D.C. 20008.

MINERAL DUSTS

ubstance	m.p.p.c.f.[l]
ILICA	
Cristobalite, Crystalline	Use one-half the value calculated from the count or mass formulae for quartz.
Amorphous, including natural diatomaceous earth	20
uartz	TLV in mppcf: $\frac{30^{j}}{\%\ \text{quartz} + 10}$
	TLV for respirable dust in mg/m³: $\frac{10\ \text{mg/m}^{3k}}{\%\ \text{Respirable quartz} + 2}$
	TLV for "total dust," respirable and non-respirable: $\frac{30\ \text{mg/m}^3}{\%\ \text{quartz} + 3}$
ica, fused	Use quartz formulae.
idymite	Use one-half the value calculated from formulae for quartz.

ICATES (< 1% quartz)

Asbestos, all types	–
Mica	20
Perlite	30
Portland Cement	30
Soapstone	20
Talc (non-asbestiform)	20
Talc (fibrous) use asbestos limit	–
Tremolite (see Talc, fibrous)	–
Graphite (natural)	15

ee Notice of Intended Changes for Mineral Dusts.

JISANCE PARTICULATES e Appendix E)	30 m.p.p.c.f. or 10 mg/m³ of total dust <1% quartz

nversion factors
ppcf X 35.3 = million particles per cubic meter
= particles per c.c.

Millions of particles per cubic foot of air, based on impinger samples counted by light-field technics.
The percentage of quartz in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.
Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

Aerodynamic Diameter (μm) (unit density sphere)	% passing selector
<2	90
2.5	75
3.5	50
5.0	25
10	0

containing <1% quartz; if quartz content >1%, use formulae for quartz.

NOTICE OF INTENDED CHANGES (for 1973)

These substances, with their corresponding values, comprise se for which either a limit has been proposed for the first time, for which a change in the "Adopted" listing has been proposed. both cases, the proposed limits should be considered trial limits t will remain in the listing for a period of at least two years. If, r two years no evidence comes to light that questions the appro-ateness of the values herein, the values will be reconsidered for the "Adopted" list. Documentation is available for each of these substances.

Substance	ppm[a]	mg/M³[b]
+ Bayrgon	–	0.5
+ Caprolactam (2-Oxohexamethyleniimine)		
Dust	–	1
Vapor	5	25
+ Carbofuran – Skin	–	0.05
• Carbon tetrabromide	0.1	1.4
• Cesium hydroxide	–	2
• Catechol	1	4.5
• Chlorodifluoromethane	1,000	3,500
+ bis-Chloromethyl ether	–	A[1b]
+ Chloromethyl ether	–	A[1b]
• Chloropyrifos (Dursban®) – Skin	–	0.2
+ o-Chlorotoluene	50	–
• o-Chlorostyrene	50	283
• Clopidol (Coyden®)	–	10
• 2-Chloro-6-(trichloromethyl) pyridine (N-Serve®)	–	10
• Crufomate (Ruelene®)	–	5
+ Cotton dust, raw	–	0.2[m]
+ Cyclohexylamine	10	40
• Dicyclopentadienyl iron	–	10
• Diethyl phthalate	–	5
3,5-Dinitro-o-toluamide (Zoalene®)	–	5
+ Dimethyl sulfate – Skin	–	A[2]
+ Dioxane – Skin	50	–
+ Disyston – Skin	–	0.1
+ Ethylidene norbornene	0.2	0.6
• Formamide	–	20
Furfuryl alcohol	5	20
+ Hexachlorocyclopentadiene	0.01	0.1
Isophorone	10	55
+ Manganese cyclopentadienyl tricarbonyl (as Mn) – Skin	–	0.1
+ 4-4'-Methylene bis (2-chloroaniline) – Skin	0.02	A[2]
+C Methylene bis (4-cyclohexylene isocyanate)	0.01	0.11
+ Methylene chloride (Dichloromethane)	250	890
• Methylethyl ketone peroxide	C 0.2	1.5
Mineral wool fiber	–	E
+ Phorate (Thimet®) – Skin	–	0.05
Picloram (Tordon®)	–	10
• Potassium hydroxide	–	C2
+ Silicon tetrahydride (Silane)	0.5	0.7
• Tricyclohexyl tin hydroxide (Plictran®)	–	5
• Vinylidene chloride	10	40
+ Zinc stearate	–	E

NOTES

a) Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 760 mm. Hg. pressure.
b) Approximate milligrams of particulate per cubic meter of air.
m) Lint free dust as measured by the vertical-elutriator, cotton-dust sampler described in the Transactions of the National Conference on Cotton Dust. J.R. Lynch, pg. 33, May 20, 1970.
Capital letters refer to Appendices.
+ 1972 Revision or Addition
• 1973 Revision or Addition

CHANGES IN ADOPTED VALUES – TENTATIVE LISTINGS

All changes that are recommended are based on documented evidence which is available from the chairman.

Substance	From	To
Cadmium oxide fume	0.2 mg/m³	C 0.05 mg/m³
Carbon dioxide	Documentation to permit TLV of 15,000 ppm provided certain stipulated medical criteria are met.	
bisChloroethyl ether	C 15 ppm	5 ppm
Copper fume	0.1 mg/m³	0.2 mg/m³
Iron Oxide fume	10 mg/m³	5 mg/m³
Paraffin wax fume	1 mg/m³	2 mg/m³
Sodium hydroxide	2 mg/m³	C 2 mg/m³

NOTICE OF INTENDED CHANGES MINERAL DUSTS

Substance	TLV
Asbestos (All types)	5 fibers/mL >5μ in length[n] A[1a]

F.

...a flour	Use respirable mass formula for quartz.
poll	Use respirable mass formula for quartz.

...determined by the membrane filter method at 400-450 X ...agnification (4 mm objective) phase contrast illumination. ...ncentrations 5 fibers/ml but not to exceed 10, may be ...rmitted for 15-minute periods each hour up to five times ...lly.

2 Revision or Addition

NOTICE OF INTENDED CHANGES
APPENDIX A

Carcinogens

Committee lists below those substances in industrial use that ...roven carcinogenic in man or have induced cancer in animals ...experimental conditions. Present listing of those substances ...genic for man takes two forms, those for which a TLV has ...ssigned (1a), and those for which environmental conditions ...t been sufficiently defined to assign a TLV (1b).

...man Carcinogens – Substances known to be occupational ...inogens with an assigned TLV: Asbestos, 5 fibers/cc >5μm in ...th; certain insoluble chromates, 0.1 mg/m³; Coal tar pitch ...tiles, 200 ppb; Nickel carbonyl, 1 ppb.

...an Carcinogens – Substances known to be occupational ...inogens without an assigned TLV:
...inodiphenyl
...zidine & its salts
...hloromethyl ether
...romethyl ether
...-Naphthylamine
...trodiphenyl

...he substances in 1 b, no exposure or contact by any route, ...ry, skin or oral, as detected by the most sensitive methods, ...permitted. "No exposure contact" means hermitizing the ...or operation by the best practicable engineering methods, ...tecting the worker by proper equipment that will insure no contact or entry of the carcinogen by any route.

...rimental Carcinogens – Industrial substances found to be ...ich potency in inducing tumors under experimental ...itions in animals:

...tylaminofluorene
...dichlorobenzidine
...methylaminoazobenzene
...thyl sulfate
...enimine
...fethylene bis (2-Chloroaniline)
...rosodimethylamine
...ropiolactone

...e above, worker exposure by all routes should be reduced ...imum in light of the warning of the potency of these ...s to induce tumors in animals. "Reduced to a minimum" ...traordinary care shall be taken both in manufacture and in ...so that worker exposure by all routes is kept to an ...minimum.

APPENDIX B

...trafluoroethylene Decomposition products.* Thermal ...position of the fluorocarbon chain in air leads to the ...tion of oxidized products containing carbon, fluorine and ...n. Because these products decompose in part by hydro... alkaline solution, they can be quantitatively determined ...as fluoride to provide an index of exposure. No TLV is ...mended pending determination of the toxicity of the ...cts, but air concentrations should be minimal.

...ne and/or Petroleum Distillates. The composition of these ...als varies greatly and thus a single TLV for all types of ...materials is no longer applicable. In general, the aromatic ...arbon content will determine what TLV applies. Conse... the content of benzene, other aromatics and additives ...be determined to arrive at the appropriate TLV (Elkins, ...I.H.A.J. *24*: 99, 1963).
...nes: Algoflon, Fluon, Halon, Teflon, Tetran

APPENDIX C

...SHOLD LIMIT VALUES FOR MIXTURES

...o or more hazardous substances are present, their com..., rather than that of either individually, should be given ...nsideration. In the absence of information to the con...ffects of the different hazards should be considered as ...ve, if the sum of the following fractions,

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots \frac{C_n}{T_n}$$

exceeds unity, then the threshold limit of the mixture should be considered as being exceeded. C_1 indicates the observed atmospheric concentration, and T_1 the corresponding threshold limit (See Example 1A.a. and 1A.c.).

Exceptions to the above rule may be made when there is good reason to believe that the chief effects of the different harmful substances are not in fact additive, but *independent* as when purely local effects on different organs of the body are produced by the various components of the mixture. In such cases the threshold limit ordinarily is exceeded only when at least one member of the series

$$\left(\frac{C_1}{T_1} + \text{or} + \frac{C_2}{T_2} \text{etc.}\right)$$

itself has a value exceeding unity (See Example 1 A.c.).

Antagonistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or antagonistic agents are not necessarily harmful by themselves. Potentiating effects of exposure to such agents by routes other than that of inhalation is also possible, e.g. imbibed alcohol and inhaled narcotic (trichloroethylene). Potentiation is characteristically exhibited at high concentrations, less probably at low.

When a given operation or process characteristically emits a number of harmful dusts, fumes, vapors or gases, it will frequently be only feasible to attempt to evaluate the hazard by measurement of a single substance. In such cases, the threshold limit used for this substance should be reduced by a suitable factor, the magnitude of which will depend on the number, toxicity and relative quantity of the other contaminants ordinarily present.

Examples of processes which are typically associated with two or more harmful atmospheric contaminants are welding, automobile repair, blasting, painting, lacquering, certain foundry operations, diesel exhausts, etc. (Example 2 in 1A.a.).

THRESHOLD LIMIT VALUES FOR MIXTURES

EXAMPLES

1A.a. General case, where air is analyzed for each component:

a. Additive effects. (Note: It is essential that the atmosphere be analyzed both qualitatively and quantitatively for each component present, in order to evaluate compliance or noncompliance with this calculated TLV.)

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + \cdots = 1$$

Example No. 1: Air contains 5 ppm of carbon tetrachloride (TLV = 10 ppm) 20 ppm of ethylene dichloride (TLV = 50 ppm) and 10 ppm of ethylene dibromide (TLV = 25 ppm)

Atmospheric concentration of mixture = 5 + 20 + 10 = 35 ppm of mixture

$$\frac{5}{10} + \frac{20}{50} + \frac{10}{25} = \frac{25 + 20 + 20}{50} = 1.3$$

Threshold Limit is exceeded. Furthermore, the TLV of this mixture may be calculated by reducing the total fraction to 1.0; i.e.

$$\text{TLV of mixture} = \frac{35}{1.3} = 27 \text{ ppm}$$

Example No. 2: Air contains 200 ppm of hexane (TLV = 500 ppm) 100 ppm of methylene chloride (TLV = 500 ppm) and 20 ppm of perchloroethylene (TLV = 100 ppm)

Atmospheric concentration of mixture = 200 + 100 + 20 = 320 ppm of mixture

$$\frac{200}{500} + \frac{100}{500} + \frac{20}{100} = \frac{200+100+100}{500} = \frac{400}{500} = 0.8$$

Threshold Limit is not exceeded. The TLV of this mixture = $\frac{320}{0.8} = 400$ ppm

1A.b. Special case when the source of contaminant is a liquid mixture and the atmospheric composition is *assumed* to be similar to that of the original material; e.g. on a time weighted average exposure basis, all of the liquid (solvent) mixture eventually evaporates.

Additive effects **(approximate solution)**

1. The percent composition (by weight) of the liquid mixture is known, the TLVs of the constituents must be listed in mg/m³.

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... to evaluate compliance with this TLV, field sampling instruments should be calibrated, in the laboratory, for response to this specific quantitative and qualitative air-vapor mixture, and also to fractional concentrations of this mixture; e.g., 1/2 the TLV; 1/10 the TLV; 2 X the TLV; 10 X the TLV; etc.)

LV of mixture =

$$\frac{1}{\frac{f_a}{TLV_a} + \frac{f_b}{TLV_b} + \frac{f_c}{TLV_c} + \cdots \frac{f_n}{TLV_n}}$$

xample No. 1: Liquid solvent contains (by weight) 50% heptane (TLV = 2000 mg/m³), 30% methylene chloride (TLV = 1740 mg/m³) 20% perchloroethylene (TLV = 670 mg/m³)

LV of mixture =

$$\frac{1}{\frac{0.5}{2000} + \frac{0.3}{1740} + \frac{0.2}{670}} =$$

$$\frac{1}{.00025 + .00017 + .0003} = \frac{1}{.00072} =$$

390 mg/m³

this mixture: 50% or 695 mg/m³ is heptane, 30% or 417 mg/m³ is methylene chloride and 20% or 278 mg/m³ is perchlorethylene

ese values can be converted to ppm as follows:

ptane –

2000 mg/m³ = 500 ppm
1 mg/m³ = 0.25 ppm
695 mg/m³ = 174 ppm

thylene chloride –

1740 mg/m³ = 500 ppm
1 mg/m³ = 0.287 ppm
417 mg/m³ = 119 ppm

chloroethylene –

670 mg/m³ = 100 ppm
1 mg/m³ = 0.15 ppm
278 mg/m³ = 42 ppm

TLV of this mixture =

174 + 119 + 42 = 335 ppm.

Independent effects.

Air contains 0.15 mg/m³ of lead (TLV,0.2) and 0.7 mg/m³ of sulfuric acid (TLV,1).

$$\frac{0.15}{0.20} = 0.75; \quad \frac{0.7}{1} = 0.7$$

Threshold limit is not exceeded.

. General Exact Solution for Mixtures of N Components With Additive Effects and Different Vapor Pressures.

$$(1)\ \frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n} = 1;$$

$$(2)\ C_1 + C_2 + \ldots + C_n = T;$$

$$(2.1)\ \frac{C_1}{T} + \frac{C_2}{T} + \ldots + \frac{C_n}{T} = 1.$$

By the Law of Partial Pressures,

) $C_1 = ap_1$,

and by Raoult's Law,

) $p_1 = F_1 p_1^\circ$

Combine (3) and (4) to obtain

) $C_1 = aF_1 p_1^\circ$

Combining (1), (2.1) and (5), we obtain

$$\frac{F_1 p_1^\circ}{T} + \frac{F_2 p_2^\circ}{T} + \ldots + \frac{F_n p_n^\circ}{T} =$$

$$\frac{F_1 p_1^\circ}{T_1} + \frac{F_2 p_2^\circ}{T_2} + \ldots + \frac{F_n p_n^\circ}{T_n}$$

and solving for T,

) $$T = \frac{F_1 p_1^\circ + F_2 p_2^\circ + \ldots + F_n p_n^\circ}{\frac{F_1 p_1^\circ}{T_1} + \frac{F_2 p_2^\circ}{T_2} + \ldots + \frac{F_n p_n^\circ}{T_n}}$$

or $\frac{1}{\sum} = nF_1 p_1^\circ$

) $$T = \frac{1}{\sum_{i=1}^{i=n}}$$

$$i = \frac{F_1 p_1^\circ}{T_1}$$

T – Threshold Limit Value in ppm.
C – Vapor concentration in ppm.
p – Vapor pressure of component in solution.
p° – Vapor pressure of pure component.
F – Mol fraction of component in solution.
a – A constant of proportionality.

Subscripts 1, 2, . . . n relate the above quantities to components 1, 2, . . . n, respectively.

Subscript i refers to an arbitrary component from 1 to n.

Absence of subscript relates the quantity to the mixture.

1B.b. Solution to be applied when there is a reservoir of the solvent mixture whose composition does not change appreciably by evaporation.

Exact Arithmetic Solution of Specific Mixture

Solvent	Mol. wt.	Density	TLV	p° at 25°C	Mol fraction in half-and-half solution by volume
Trichloroethylene(1)	131.4	1.46 g/ml	100	73mm Hg	0.527
Methylchloroform (2)	133.42	1.33 g/ml	350	125mm Hg	0.473

$$F_1 p_1^\circ = (0.527)(73) = 38.2$$

$$F_2 p_2^\circ = (0.473)(125) = 59.2$$

$$TLV = \frac{38.2 + 59.2}{\frac{38.2}{100} + \frac{59.2}{350}} = \frac{(97.4)(350)}{133.8 + 59.2} =$$

$$\frac{(97.4)(350)}{193.0} = 177$$

TLV = 177 ppm (Note difference in TLV when account is taken of vapor pressure and mol fraction in comparison with the above sample where such account is not taken.)

2. A mixture of one part of (1) parathion (TLV, 0.1) and two parts of (2) EPN (TLV, 0.5).

$$\frac{C_1}{0.1} + \frac{C_2}{0.5} = \frac{C_m}{C_m} \qquad C_2 = 2C_1$$

$$C_m = 3C_1$$

$$\frac{C_1}{0.1} + \frac{2C_1}{0.5} = \frac{3C_1}{T_m}$$

$$\frac{7C_1}{0.5} = \frac{3C_1}{T_m}$$

$$T_m = \frac{1.5}{7} = 0.21 \text{ mg/m}^3$$

1C. TLV for Mixtures of Mineral Dusts.

For mixtures of biologically active mineral dusts the general formula for mixtures may be used.

For a mixture containing 80% talc and 20% quartz, the TLV for 100% of the mixture is given by:

$$TLV = \frac{1}{\frac{0.8}{20} + \frac{0.2}{2.5}} = 8.4 \text{ mppcf}$$

Essentially the same result will be obtained if the limit of the more (most) toxic component is used provided the effects are additive. In the above example the limit for 20% quartz is 10 mppcf.

For another mixture of 25% quartz, 25% amorphous silica and 50% talc:

$$TLV = \frac{1}{\frac{0.25}{2.5} + \frac{0.25}{20} + \frac{0.5}{20}} = 7.3 \text{ mppcf}$$

The limit for 25% quartz approximates 8 mppcf.

APPENDIX D

PERMISSIBLE EXCURSIONS FOR TIME-WEIGHTED AVERAGE (TWA) LIMITS

The Excursion TLV Factor in the Table automatically defines the magnitude of the permissible excursion above the limit for those substances not given a "C" designation; i.e. the TWA limits. Exam-

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ples in the Table show that nitrobenzene, the TLV for which is 1 ppm, should never be allowed to exceed 3 ppm. Similarly, carbon tetrachloride, TLV 10 ppm, should never be allowed to exceed 20 ppm. By contrast, those substances with a "C" designation are not subject to the excursion factor and must be kept below the TLV.

These limiting excursions are to be considered to provide a "rule-of-thumb" guidance for listed substances generally, and may not provide the most appropriate excursion for a particular substance. Efforts are being made to develop such specific excursions, when indicated to be significantly different from that recommended by the present excursion factors.

Substance	TLV ppm	Excursion Factor	Max. Conc. Permitted for short time ppm
Nitro-benzene	1	3	3
Carbon tetra-chloride	10	2	20
o-Dichloro-benzene	50	1.5	75
Acetone	1000	1.25	1250
Boron Trifluoride	C1	–	1
Butylamine	C5	–	5
Styrene monomer	C100	–	100

For all substances:

		Excursion
TLV >	0-1 (ppm or mg/m^3),	Factor = 3
TLV >	1-10 "	" = 2
TLV >	10-100 "	" = 1.5
TLV >	100-1000"	" =1.25

BASIS FOR ASSIGNING LIMITING "C" VALUES

By definition in the Preface, a listed value bearing a "C" designation refers to a "ceiling" value that should not be exceeded; all values should fluctuate below the listed value. This, in effect, makes the "C" designation a maximal allowable concentration (MAC). In general, the bases for assigning or not assigning a "C" value rest on whether excursions of concentration above a proposed limit *for periods up to 15 minutes* may result in a) intolerable irritation, b) chronic, or irreversible tissue change, or c) narcosis of sufficient degree to increase accident proneness, impair self-rescue or materially reduce work efficiency.

APPENDIX E

Some Nuisance Particulates q)

Alundum (Al_2O_3)	Kaolin
Calcium carbonate	Limestone
Cellulose (paper fiber)	Magnesite
Portland Cement	Marble
Corundum (Al_2O_3)	Pentaerythritol
Emery	Plaster of Paris
Glass, fibrous r) or dust	Rouge
Glycerin Mist	Silicon Carbide
Graphite (synthetic)	Starch
Gypsum	Sucrose
Vegetable oil mists (except castor, cashew nut, or similar irritant oils)	Tin Oxide
	Titanium Dioxide

q) When toxic impurities are not present, e.g. quartz <1%

r) <5-7μm in diameter

APPENDIX F

Some Simple Asphyxiants – "Inert" Gases and Vapors s)

Acetylene	Hydrogen
Argon	Methane
Butane	Neon
Ethane	Nitrogen
Ethylene	Nitrous Oxide
Helium	Propane

s) As defined under simple asphyxiants, in preface.