

**ENGINEERING STANDARD**  
**FOR**  
**AIR POLLUTION CONTROL**

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## **0. INTRODUCTION**

Air pollution is waste remaining from the many ways as production of goods, process of hydrocarbon and petrochemicals, use of transport and generation of energy to heat and light.

The major cause of all air pollution is combustion. When perfect or theoretical combustion occurs, the hydrogen and carbon in the fuel combine with oxygen from the air to produce heat, light, carbon dioxide, and water vapor. Impurities in the fuel, poor fuel-to-air ratio, or too high or too low combustion temperatures cause the formation of such side products as carbon monoxide, sulfur oxides, nitrogen oxides, fly ash and unburned hydrocarbons.

In this Standard, methods of reducing air pollution and means to decrease the pollution of the environment is discussed.

## 1. SCOPE

This Standard represents the minimum requirements for air pollution control and covers the following main topics:

- Pollution sources
- Types of emission
- Standard levels
- Measurement of air pollution
- Consideration in the selection of the pollution control equipment
- Process control
- Threshold limit values (TLV)

## 2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of Changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/Consultant.

EPA-650/9-75-001b                      "The World Air Quality Management Standards Volume II"  
 oct. 1974

### IPS    (IRANIAN PETROLEUM STANDARDS)

IPS-C-SF-860	"Air Pollution Control"
IPS-E-PR-460	"Process Design of Flare and Blowdown System"
IPS-E-ME-210	"Flare and Flare Stacks"
IPS-E-PR-810	"Process Design of Furnaces"

### ISO    (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 6584                      "Cleaning Equipment for Air and other Gases-Classification of Dust Separator"

Louis Theodore, Anthony J. Bounicore, Air Pollution Control Equipment: Prentice-Hall, Inc 1982.

## 3. DEFINITIONS AND TERMINOLOGY

### ABSORPTION

A physico-chemical process in which a substance associates with another to form a homogeneous mixture presenting the characteristics of a solution.

### ADSORPTION

A physical process in which the molecules of a gas, of dissolved substances or of liquids, adhere in extremely thin layers to the exposed surface of solid substances with which they come into contact.

**AEROSOL**

A suspension, in a gaseous medium, of solid particles, liquid particles, or solid particles and liquid particles, having a negligible falling velocity.

**Note:**

In physics, an upper value is arbitrarily assigned to the dimensions of particles capable of constituting an aerosol, adopting for the place being considered a maximum limit for the falling velocity. It is defined as being that of a spherical particle of density equal to  $10^3 \text{ kg/m}^3$  and of diameter  $100 \text{ }\mu\text{m}$ , falling under the effect of its own weight in an immobile gas at a temperature of  $20^\circ\text{C}$  and at a pressure of  $101.3 \text{ kPa}$ . In air, under a gravitational acceleration of  $9,81 \text{ m/s}^2$ , this speed is  $0.25 \text{ m/s}$ .

**AGGLOMERATE**

A collection of solid particles adhering to each other.

**AGGLOMERATION**

The action leading to the formation of agglomerates.

**AGGLUTINATION**

The action of joining, by impact, solid particles coated with a thin adhesive layer or of trapping solid particles by impact on a surface coated with adhesive.

**AGGREGATE**

A relatively stable assembly of dry particles, formed under the influence of physical forces.

**ASH**

The solid residue of effectively complete combustion.

**CLEANING (after clogging)**

The removal of the deposit of solid or liquid particles which has produced clogging.

**CLEANING FACTOR**

The ratio of the quantity of pollutants entering a separator to the quantity leaving it.

**CLOGGING**

The deposition, progressive or otherwise, of solid or liquid particles on or within a filter medium, causing the flow to be obstructed.

**CLOGGING CAPACITY; HOLDING CAPACITY**

The particle mass that can be retained by equipment up to the point at which one of the specified operational limits is reached.

**COALESCENCE**

The action by which liquid particles in suspension unit to form larger particles.

**COLLECTION EFFICIENCY**

With regard to filters, dust separators and droplet separators, the ratio of the quantity of particles retained by a separator to the quantity entering it (generally expressed as a percentage).

**CONCENTRATION; CONTENT**

The quantity of a solid, liquid or gaseous material expressed as a proportion of another material in which it is contained in the form of a mixture, a suspension or a solution.

**CONTAMINANT**

See pollutant.

**CONTAMINATION**

See pollution.

**CONTENT**

See concentration.

**CYCLONE**

A dust separator or droplet separator utilizing essentially the centrifugal force derived from the motion of the gas.

**DISPERSION**

An operation as a result of which solid particles or liquid particles are distributed in a fluid. Also applied to a two-phase system in which one phase, known as the "dispersed medium", is distributed throughout the other, known as the "dispersion medium".

**DROPLET**

A liquid particle of small mass, capable of remaining in suspension in a gas. In some turbulent systems, for example clouds, its diameter can reach 200  $\mu\text{m}$ .

**DROPLET SEPARATOR**

An apparatus for separating liquid particles from a gas stream in which they are suspended.

**DUST**

Small solid particles conventionally taken as those particles below 75  $\mu\text{m}$  in diameter which settle out under their own weight but which may remain suspended for some time...(see dust, and, grit): A general term applied to solid particles of different dimensions and origin generally remaining suspended in a gas for a certain time.

## DUST CONTROL

The whole of the processes for the separation of solid particles from a gas stream in which they are suspended. (By extension, also the activities involved in the construction and commissioning of a dust separator.)

## DUST SEPARATOR

An apparatus for separating solid particles from a gas stream in which they are suspended.

### Note:

Dust separators working on the following principles are given as examples:

- gravity;
- inertia;
- centrifugal force;
- electricity;
- fibrous layer;
- packed tower;
- bubble washer;
- spray washer;
- venturi-scrubber.

## EFFLUENT

Any fluid discharged from a given source into the external environment. A general term describing any fluid discharged from a given source.

### Note:

By extension and if properly qualified, the work "effluent" in English may also sometimes be used with this meaning.

## ELUTRIATION

A method of separating particles using the difference in apparent weight which may exist between the particles when they are suspended in a fluid.

## EQUIVALENT DIAMETER

The diameter of a spherical particle the size of which will give identical geometric, or optical, or electrical or aerodynamic behavior to that of the particle being examined.

For sieves, the equivalent diameter is the diameter of the holes in a round hole sieve which will pass the same proportion of material as will a specified square mesh sieve. It is dependent upon the shape and size of the particles under examination.

## CAPTURE

The extraction of solid particles, liquid particles or gases close to their sources.

**FILTER**

An apparatus for separating solid or liquid particles from a gas stream in which they are suspended. This apparatus is generally formed of a porous or fibrous layer or of an assembly of porous and/or fibrous layers. (By extension, applied also to some oil-bath devices and some electrical devices.)

**FILTER MEDIUM**

The part of a filter on or within which the particles are retained.

**FILTRATION**

The separation by a filter of solid particles or liquid particles from a gas stream in which they are suspended. (By extension, also the whole of the activities involved in the construction and commissioning of a filter installation.)

**FLY ASH**

Ash entrained by combustion gases.

**FUME**

An aerosol of solid particles, usually from metallurgical processes, generated by condensation from the gaseous state generally after volatilization from melted substances and often accompanied by chemical reactions such as oxidation.

**FUMES**

In popular usage, gaseous effluents, often unpleasant and malodorous; which might arise from chemical processes.

**GAS-PURIFIER**

An apparatus for totally or partially removing one or more constituents from a gas mixture.

**GRIT**

Airborne solid particles in the atmosphere or flues. of sizes greater than 75  $\mu\text{m}$  (see dust).

**HOOD**

An inlet device for an extraction system.

**IMPACT**

A collision of two particles with each other or of a particle with a solid or liquid surface.

**IMPACTION**

The action of particles entering into contact with a surface.

**MIST**

A suspension of droplets in a gas.

**PARTICLE**

A small discrete mass of solid or liquid matter.

**PARTICLE SIZE ANALYSIS**

The science which deals with the measurement of the dimensions and determination of the shape of particles.

**PARTICLE SIZE ANALYSIS; GRANULOMETRIC ANALYSIS**

The whole of the operations by which a particle size (granulometric) distribution may be obtained.

**PARTICLE SIZE DISTRIBUTION; GRANULOMETRIC DISTRIBUTION**

A presentation, in the form of tables of numbers or of graphs, of the experimental results obtained using a method or an apparatus capable of measuring the equivalent diameter of particles in a sample or capable of giving the proportion of particles for which the equivalent diameter lies between defined limits.

**PENETRATION; TRANSMISSION**

The ratio of the quantity of particles leaving a filter, dust separator or a droplet separator, to the quantity entering it.

**POLLUTANT; CONTAMINANT**

Any undesirable solid, liquid or gaseous matter in a gaseous or liquid medium.

**POLLUTION; CONTAMINATION**

The introduction of pollutants into a liquid or gaseous medium, the presence of pollutants in a liquid or gaseous medium, or any undesirable modification of the composition of a liquid or gaseous medium.

**POROUS LAYER**

A permeable layer of solid material in any form having interstices of small size, generally known as "pores".

**PRECIPITATION**

An operation in which particles are separated from a gas stream in which they are suspended, by the action of an electrical field or a thermal gradient.

**PURIFICATION**

The total or partial removal of unwanted constituents from a gaseous medium.

**RATED FLOW**

The gas flow rate through a separator either as stated by the manufacturer for defined conditions of use or as agreed between the interested parties for a particular installation.

**SEDIMENTATION**

Separation under the action of gravity of particles from the fluid in which they are suspended.

**SEPARATOR**

An apparatus for separating, from a gaseous stream in which they are suspended or mixed, solid particles (filter and dust separator), liquid particles (filter and droplet separator) or gases (gas-purifier).

**SERVICE FLOW**

The gas flow rate through a separator under given service conditions.

**SMOKE**

A visible aerosol resulting from combustion.

**Note:**

**In some literature, smoke is referred to quantitatively in terms of a Ringelmann Number, a smoke shade, a darkness of stain or a mass of deposit collected.**

**.....(see fume, fumes, and especially smoke, for approximate terms)**

The whole of the combustion gases and the particles entrained by them. (By extension, also the gases charged by particles resulting from a chemical process or from a metallurgical operation.)

**SOOT**

Agglomerates of carbonaceous particles formed by incomplete combustion and deposited before emission.

**SUSPENSION**

A two-phase system in which one phase, known as the "dispersed medium", is distributed throughout the other, known as the "dispersion medium".

**THRESHOLD LIMIT VALUES (TLVs)**

Refer to air borne concentration of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.

**TEST FLOW**

The gas flow rate through a separator during a rig test or a site test. This flow, which can differ from the rated flow, shall be specified or, failing this, agreed between the interested parties.

**WASHER**

Any dust separator, droplet separator or gaspurifier that depends for its operation on a liquid acting as a collecting medium.

**SITE**

Works or plant where sampling is to be carried out.

**DUCT**

An enclosed structure through which gases travel from one point to another.

**SAMPLING POSITION**

A place in a duct where sampling is carried out.

**SAMPLING PLANE**

The cross section of the duct in which all sampling is carried out.

**SAMPLING LINE**

The line across the sampling plane on which the sampling points are located.

**SAMPLING POINT**

A specific location on a sampling line at which an individual sample is extracted.

**ACCESS HOLE**

A hole in the duct, at the extremity of a sampling line, through which sampling is undertaken.

**ISOKINETIC SAMPLING**

Sampling at such a rate that the average velocity of the gas entering the sample nozzle is the same as that of the gas in the duct at the sampling point.

**NORMAL TEMPERATURE AND PRESSURE (NTP)**

15°C and 101325 N/m<sup>2</sup>.

**PARTICULATES**

Solid matter, in a gas stream, that is solid at normal temperature and pressure.

**GAS**

A mixture of gaseous compounds or elements flowing in a duct, carrying particulate matter.

**4. UNITS**

This standard is based on International System of Units, (SI) except where otherwise specified.

## 5. GENERAL

Serious damage can be caused by polluting material discharged into environment from various sources. Such emission can adversely affect agricultural land and crops and can spoil clothing and buildings, as well as corrode metal installations and can have harmful effect on the health of community.

## 6. AIR POLLUTION

Air pollution is defined as the addition to our atmosphere of any material which will have a deleterious effect to life upon our planet. The material might be a toxic gaseous hydrocarbon with some long-lasting effect on an organism ingesting it or perhaps a particulate irritant which could cause similar problems. It might be atomic radiation in a form that we cannot see which would be damaging to animal or plant cells. A pollutant can be anything which when put into the atmosphere either purposely or through some act of nature reduces the oxygen content or significantly changes the composition of the air.

An air pollutant does not have to be inhaled. It becomes a pollutant merely by being in the air. Smog, made up of gases and particulate matter in large quantities, and seen over many of our major cities in the last fifteen years, forms a blanket which shields some of the sun's radiation so necessary to life on earth. This blanket changes heat absorption patterns on the surface of the earth and can prohibit reradiation of the earth's heat to the sky, resulting in the "greenhouse effect" which ultimately changes weather and temperature patterns across the entire surface of the planet.

### 6.1 Clean Air

The earth is surrounded by approximately 500 billion tons of air, of which 20.9 percent is oxygen, 78.0 percent is nitrogen, and 0.9 percent is argon. Excluding water vapor, these gases make up all but 0.04 percent of the atmosphere and three-quarters of the remainder is carbon dioxide. The last 0.01 percent contains the other noble gases, hydrogen, nitrogen oxides, ozone, and traces of many other gases. Table 1 summarizes the major gases, and their concentrations on a dry basis. These figures remain essentially constant as long as water vapor is not included, since it varies in a range from as high as 3 percent by volume to less than 1 percent. In ambient air measurements this variation is normally within the reproducibility limits of the determinations and can be ignored. Despite this, samples are often dried before testing.

Water vapor normally cannot be considered as an air pollutant even though it is produced in great quantities in combustion processes. Natural evaporation and precipitation move far greater amounts of water than any man-made process. One exception to this may occur in the near future with the advent of the supersonic transport. This plane may release large amounts of water vapor into the stratosphere causing increased cloudiness and a temperature rise.

Water vapor has a synergistic effect upon air pollutants, increasing many deleterious effects. For example, sulfur dioxide, which itself is an irritating and corrosive pollutant, can combine with water vapor and atmospheric oxygen to form highly corrosive sulfuric acid mist. Smog also depends upon water vapor for its formation. Monitoring of pollution in urban areas must consider the humidity and predict its effect on pollutants.

**TABLE 1 - COMPOSITION OF NATURAL AIR**

CONSTITUENT	APPROXIMATE CONCENTRATION	
NITROGEN (N <sub>2</sub> )	78.03	volume percent
OXYGEN (O <sub>2</sub> )	20.99	volume percent
CARBON DIOXIDE (CO <sub>2</sub> )	0.03	volume percent
ARGON (A)	0.94	volume percent
NEON (Ne)	0.00123	volume percent
HELIUM (He)	0.0004	volume percent
KRYPTON (Kr)	0.00005	volume percent
XENON (Xe)	0.000006	volume percent
HYDROGEN (H <sub>2</sub> )	0.01	volume percent
METHANE (CH <sub>4</sub> )	0.0002	volume percent
NITROUS OXIDE (N <sub>2</sub> O)	0.0005	volume percent
WATER VAPOR (H <sub>2</sub> O)	Variable	
PARTICULATE MATTER	a)Variable type and quantity	
OZON (O <sub>3</sub> )	b)Variable	
FORMALDEHYDE (HCHO)	c)Uncertain	

a) The types and concentrations of these substances may vary substantially from one region to another and within any period of time from natural conditions.

b) From ultraviolet radiation and probably thunderstorms, concentrations will vary from 0 to 0.07 ppm.

c) From biological sources or oxidation of CH<sub>4</sub>; possible concentrations not determined.

## 6.2 Pollution Sources

Major categories of air pollution is considered to be caused by:

- 1) Transportation
- 2) Domestic heating
- 3) Electric power generation
- 4) Industrial fuel burning and process emission.

Major industrial polluters have been classified relative to the type of industry. Generally they can be catergorized as follows:

- a) Petroleum refineries; particulate, sulfur oxide hydrocarbons, and carbon monoxide.
- b) Petrochemical industries;hydrocarbon, carbon mono oxide particulate.
- c) Fertilizer industries particulates, Nox, gaseous floride compounds.

## 6.3 Types of Emissions in Oil and Gas Industries

### 6.3.1 Refinery

Potential sources of refinery emissions are given in Table 2.

**TABLE 2 - POTENTIAL SOURCES OF SPECIFIC EMISSIONS FROM OIL REFINERIES**

TYPES OF EMISSION	POTENTIAL SOURCES
Oxides of sulfur	Boilers, process heaters, catalytic cracking unit regenerators, treating units, H <sub>2</sub> S flares, decoking operations, etc.
Hydrocarbons	Loading facilities, turnarounds, sampling, storage tanks, waste water separators, blowdown systems, catalyst regenerators, pump, valves, blind changing, cooling towers, vacuum jets, barometric condensers, air blowing, high pressure equipment handling volatile hydrocarbons, process heaters, boilers, compressor engines, etc.
Oxides of nitrogen	Process heaters, boilers, compressor engines, catalyst regenerators, flares, etc.
Particulate matter	Catalyst regenerators, boilers, process heater decoking operations, incinerators, etc.
Aldehydes	Catalyst regenerators
Ammonia	Catalyst regenerators
Odors	Treating units (air blowing, steam blowing) drains, tank vents, barometric condenser sumps, waste water separators.
Carbon monoxide	Catalyst regeneration, decoking, compressor engines, incinerators.
Arsene	Regeneration hydro de sulfurize
Phosgene	Regeneration hydro de sulfurize
Cyanides	Regeneration hydro de sulfurize
HCl	Platformers isomerization
HF	HF alkylation
H <sub>2</sub> SO <sub>4</sub>	Alkylation acid plant

**6.3.1.1 Atmospheric pollution in refineries**

Emission factor for major atmospheric pollution in refinery are given in Table 3.

**TABLE 3 - EMISSION FACTORS FOR PETROLEUM REFINERY**

PROCESSES	UNITS OF EMISSION FACTORS	EMISSION FACTOR
a. boiler and processheater	gram Hydrocarbon/m <sup>3</sup> oil burned	399
	gram Hydrocarbon/m <sup>3</sup> gas burned	0.416
	gram Particulate/m <sup>3</sup> oil burned	2280
	gram Particulate/m <sup>3</sup> gas burned	0.32
	gram NO <sub>2</sub> /m <sup>3</sup> oil burned	8265
	gram NO <sub>2</sub> /m <sup>3</sup> gas burned	3.68
	gram CO/m <sup>3</sup> oil burned	negligible
	gram CO/m <sup>3</sup> gas burned	negligible
	gram HCHO/m <sup>3</sup> oil burned	400
	gram HCHO/m <sup>3</sup> gas burned	0.0496
b. fluid catalytic unit	gram Hydrocarbon/m <sup>3</sup> of fresh feed	627
	gram Particulate/ton of catalyst circulation	783
	gram NO <sub>2</sub> /m <sup>3</sup> of fresh feed	179.5
	gram CO/m <sup>3</sup> of fresh feed	39045
	gram HCHO/m <sup>3</sup> of fresh feed	54.15
	gram NH <sub>3</sub> /m <sup>3</sup> of fresh feed	153.9
c. moving bed catalytic cracking units	gram Hydrocarbon/m <sup>3</sup> of fresh feed	248
	gram Particulate/ton of catalyst circulation	1740
	gram NO <sub>2</sub> /m <sup>3</sup> of fresh feed	14.25
	gram CO/m <sup>3</sup> of fresh feed	10830
	gram HCHO/m <sup>3</sup> of fresh feed	34.2
d. Compressor internal combustion engines	gram Hydrocarbon/m <sup>3</sup> of fuel gas burned	19.2
	gram NO <sub>2</sub> /m <sup>3</sup> of fuel gas burned	13.76
	gram CO/m <sup>3</sup> of fuel gas burned	negligible
	gram HCHO/m <sup>3</sup> of fuel gas burned	1.76
	gram NH <sub>3</sub> /m <sup>3</sup> of fuel gas burned	3.2
e. Miscellaneous process equipment		
1. Blow down system	gram Hydrocarbon/m <sup>3</sup> refinery	
a. with capacity control		14.25
b. without control		855
2. Process drains	gram Hydrocarbon/m <sup>3</sup> waste water	
a. with control		22.8
b. without control		598.5

(to be continued)

**TABLE 3 - (continued)**

<b>PROCESSES</b>	<b>UNITS OF EMISSION FACTORS</b>	<b>EMISSION FACTOR</b>
3. Vacuum Jets	gram Hydrocarbon/m <sup>3</sup> vacuum distillation capacity	
a. with control		negligible
b. without control		370.5
4. Cooling tower	gram Hydrocarbon/3,785,000 liters cooling water	2616
5. Pipeline valves and flanges	gram Hydrocarbon/m <sup>3</sup> refinery capacity	79.8
6. Vessel relief valves	gram Hydrocarbon/m <sup>3</sup> refinery capacity	31.35
7. Pump seal	gram Hydrocarbon/m <sup>3</sup> refinery capacity	48.45
8. Compressor seal	gram Hydrocarbon/m <sup>3</sup> refinery capacity	14.25
9. Others (air blowing)	gram Hydrocarbon/m <sup>3</sup> refinery capacity	28.5

**Note:**

Table 3 is compiled from IRVIN SAX. N.

Industrial pollution, vannos trand reinhold company.

**6.3.1.2 Odors in refineries**

Some Typical Refinery Smells, their possible source, and the most probable compounds contributing to the odors are summarized as follows:

**"REFINERY ODORS AND SOURCES"**

TYPE OF SMELL	SOURCE	ODORS COMPOUNDS
BAD EGGS	CRUDE STORAGE  DISTILLATION OF GASES SULPHUR REMOVAL, FLARE STACKS (COLD FLARE)	H <sub>2</sub> S + TRACE OF DISULPHIDES
SEWER SMELL	EFFLUENT WATER, BIOLOGICAL TREATMENT PLANTS LPG ODOR- IZING SPENT CAUSTIC LOADING AND TRANSFER	DIMETHYL SULPHIDE, ETHYL AND METHYL MERCAPTANS
BURNT OIL	CATALYTIC CRACKING UNIT COKING ASPHALT BLOWING ASPHALT STORAGE	UNSATURATED HYDROCARBONS
GASOLINE	PRODUCT STORAGE, CPI & API SEPARATORS	HYDROCARBONS
AROMATICS (BENZENE)	AROMATIC PLANTS, NAPHTHA REFORMERS	BENZENE , TOLUENE
HOT TAR	ASPHALT STORAGE	HYDROCARBONS MERCAPTANS, H <sub>2</sub> S

A table of the most common odor-causing compounds found in the refinery emission is given hereunder:

**ODORS OF COMPOUNDS WHICH MAY BE FOUND IN REFINERY EMISSIONS**

<u>Chemical</u>	<u>Odor Threshold (ppb)*</u>	<u>Odor Description</u>
Acetic acid	1,000	Sour
Acetone	100,000	Chemical, sweet
Amine, monomethyl	21	Fishy, pungent
Amine, dimethyl	47	Fishy
Amine, trimethyl	0.2	Fishy, pungent
Ammonia	46,800	Pungent
Benzene	4,700	Solvent
Benzyl sulphide	2	Sulphidy
Carbon disulphide	210	Vegetable-like, sulphidy
Chlorine	314	Bleach, pungent
Chlorophenol	0.03	Medicinal
Dimethyl sulphide	1-2	Vegetable-like, sulphidy
Diethyl sulphide	6	Garlic-like, foul
Diphenyl sulphide	5	Burnt, rubbery
Hydrogen sulphide	5	Rotten eggs
Methyl ethyl ketone	10,000	Sweet
Mercaptan, methyl	1-2	Sulphidy, decayed cabbage
Mercaptan, ethyl	0.4-1	Sulphidy, decayed cabbage
Mercaptan, n-propyl	0.7	Sulphidy
Mercaptan, n-butyl	0.7	Strong, sulphidy
Paracresol	1	Tarry, pungent
Paraxylene	470	Sweet
Phenol	47	Medicinal
Phosphine	21	Oniony, mustard
Sulphur Dioxide	470	Sharp, Pungent
Toluene	2,000 - 4,700	Solvent, moth balls
Butane	6,000	
Heptane	18,000	
Amylenes and pentenes	170 - 2,100	

\*Units in parts per billion by volume.

**6.3.2 Petrochemicals**

Pollutant from petrochemical plant is given in Table 4.

**TABLE 4 - POLLUTANT FROM PETROCHEMICAL PLANT**

Combustion	<ul style="list-style-type: none"> <li>o SO<sub>x</sub>, NO<sub>x</sub> and other pollutants in waste gas from boiler for power generation, heating furnace (fractionator reboiler) and cracking furnaces (naphtha, EDC, steam reforming)</li> </ul>
Evaporation and Drying	<ul style="list-style-type: none"> <li>o Drying of synthetic rubber, plastics - Emission of dry air containing solvent and monomer</li> <li>o Vaporization from storage tanks (mostly when charging) - Emission of hydrocarbons</li> <li>o Opening of vessel manholes - Emission of hydrocarbons</li> </ul>
Off-gas, Vent Gas, Flare Stack Gas	<ul style="list-style-type: none"> <li>o Air used for oxidation, oxichlorination and ammooxidation changes into a waste gas consisting of nitrogen, carbon dioxide and a bit of byproducts</li> <li>o Non-condensing gas from distillation tower and reactor is accompanied with hydrocarbons and byproducts</li> <li>o Pollutants in combustion gas from flare stack</li> </ul>
Powder Handling	<ul style="list-style-type: none"> <li>o Dispersion of plastics during transportation and storage</li> <li>o Dispersion of catalysts used for fluidized-bed</li> </ul>
Leakage (Loss)	<ul style="list-style-type: none"> <li>o Leakage from pump and compressor shafts and flanges - Emission of hydrocarbons</li> </ul>

Major air contaminants emitted in fertilizer and other petroleum industries are as follow:

**TABLE 4 - (continued)**

<b>Process of Operation</b>	<b>Air Contaminants Emitted</b>
Phosphate fertilizers: crushing grinding and calcining	Particulates (dust)
Hydrolysis of P <sub>2</sub> O <sub>3</sub>	PH <sub>3</sub> P <sub>2</sub> O <sub>5</sub> PO <sub>4</sub> mist
Acidulation and curing	HF, SiF <sub>4</sub>
Granulation	Particulates (dust) (product recovery)
Ammoniation	NH <sub>3</sub> , NH <sub>4</sub> Cl, SiF <sub>4</sub> HF
Nitric acid acidulation	NO <sub>2</sub> gaseous fluoride compounds
Superphosphate storage and shipping	Particulates (dust)
Ammonium nitrate reactor	NH <sub>3</sub> , NO <sub>2</sub>
Prilling tower	NH <sub>4</sub> , NO <sub>3</sub>
NGL units	Hydrocarbon

**(to be continued)**

**TABLE 4 - (continued)**

<b>Process of Operation</b>	<b>Air Contaminants Emitted</b>
Oil production units	H <sub>2</sub> S odor
Gas compression station	" "
Gas injection plant	" "
Sulphur unit	" "
Oil wells	" "

**6.4 Standard Level**

**6.4.1 Ambient air quality standards**

Standard for desirable community levels in term of concentrations and sample arranging time periods, associate with measurements of these pollutants in community air as described in Table 5.

**TABLE 5 - AMBIENT AIR QUALITY STANDARDS**

	Primary	Secondary
Particulates ( $\mu\text{g}/\text{m}^3$ )		
Annual Geometric Mean	75	60
Max. 24-hour Concentration <sup>a</sup>	260	150
Sulfur Oxides ( $\mu\text{g}/\text{m}^3$ )		
Annual Arith. Average	80 (0.03 ppm)	60 (.02 ppm)
Max. 24-hour Concentration <sup>a</sup>	365 (0.14 ppm)	260 (.10 ppm)
Max. 3-hour Concentration <sup>a</sup>		1,300 (.50 ppm)
Carbon Monoxide ( $\text{mg}/\text{m}^3$ )		
Max. 8-hour Concentration <sup>a</sup>	10 (9 ppm)	10
Max. 1-hour Concentration <sup>a</sup>	40 (35 ppm)	40
Photochemical Oxidants ( $\mu\text{g}/\text{m}^3$ )		
One-hour Maximum	160 (0.08 ppm)	160
Hydrocarbons ( $\mu\text{g}/\text{m}^3$ )		
Max. 3-hour Concentration <sup>a</sup>		
6-9 am	160 (0.24 ppm)	160
Nitrogen Oxides ( $\mu\text{g}/\text{m}^3$ )		
Annual Arith. Average	100 (0.50 ppm)	100
24-hour Max. Average		
<sup>a</sup> Not to be exceeded more than once a year		

Certain materials have been designated as "hazardous air pollutants, to which no ambient air quality standard is applicable, and for which national emission standards will be used.

Various pollutants in different sources that should be considered with Emission standard is given in Table 6.

**TABLE 6**

<b>SOURCE</b>	<b>POLLUTANT CONSIDERED</b>
PETROLEUM REFINERIES	PM, NO <sub>x</sub> , TRS, Odor, CO, H <sub>2</sub> S, HC
ASPHALT BATCH PLANTS	PM, NO <sub>x</sub> , Odor, HC
PHOSPHATE FERTILIZER PLANTS	PM, F
PHOSPHORUS REDUCTION PLANTS	PM, F
INDUSTRIAL SIZE FUEL-BURNING PLANTS	PM, SO <sub>2</sub> , NO <sub>x</sub>
STORAGE VESSELS FOR PETROLEUM LIQUIDS	HC
SEWAGE TREATMENT PLANTS	

a) From Wagman, Ref. 113.

b) PM means Particulate Matter.

c) TRS means Total Reduced Sulfur.

**6.4.2 Emission standard**

Emission Standards may be written in several ways:

- 1) Process weight rate or mass of emitted pollutant per mass of raw material (eg, 0.15 kg particulate per metric ton of feed to a kiln).
- 2) Mass of emitted pollutant per mass of product (eg, 1.5 kg of nitrogen oxide per metric ton of nitric acid produced).
- 3) Mass of emitted pollutant per volume of emitted gas (eg, 90 mg of particulate per dry standard cubic meter).
- 4) Mass of emitted pollutant per heat input (eg, 0.34 grams of sulfur dioxide per 10<sup>6</sup> joules of heat input).
- 5) Plume opacity (eg, plume not to exhibit more than 20 % opacity). Other emission standards include the limitation of sulfur content of fuel and the restriction on pollutant mass emitted by new vehicles during a specified dynamometer test cycle.

For emission standard the following figures can be considered.

<b>Pollutant</b>	<b>ppm</b>	
<b>SH<sub>2</sub></b>	<b>10 mg/m<sup>3</sup></b>	<b>6.62 ppm</b>
<b>Carbon monoxide</b>	<b>0.1% (vol %)</b>	<b>1000 ppm</b>
<b>Sulfur oxide</b>		<b>2000 ppm</b>
<b>Particles</b>	<b>50 (mg/m<sup>3</sup>)</b>	
<b>Hydrocarbons</b>	<b>20% opacity</b>	
<b>Photochemical</b>	<b>30 mg/m<sup>3</sup></b>	
<b>Nonphotochemical</b>	<b>300 mg/m<sup>3</sup></b>	
<b>Nitrogen Oxides</b>		<b>210 ppm</b>

The latest Standard of Environmental Protection Organization of Iran should be considered.

**Note:**

Based on the high sulphur content of present fuel oils burned in furnaces the emission standard specified can not be generally achieved. However the subject matter shall be considered in future projects case by case.

**6.5 Measurement of Air Pollution**

Pollution measurements may be divided into two categories: ambient and source measurements. For more details see Appendix F.

**6.6 Cleaning Equipment for Air and Other Gases****6.6.1 Classification of dust separators**

For classification of dust separators refer to ISO 6584.

**6.6.2 Absorbers**

For absorbers see reference No. 4.

**6.6.3 Condensation**

For Engineering Design of TEMA Type Shell and Tube Heat Exchangers refer to IPS-E-PR-770.

**6.6.4 Flare, flare stack and furnaces**

For design of Flare and Blowdown systems, Flare and Flare Stacks, and Furnaces refer to the following standards respectively.

IPS-E-PR-460  
IPS-E-ME-210  
IPS-E-PR-810

**6.7 Process Control****6.7.1 Refineries**

Refinery atmospheric emissions and control procedures are customarily considered by types of equipment employed rather than by refinery process operation.

**6.7.1.1 Storage tanks**

Hydrocarbon vapors may be released through a number of mechanisms in storage tanks, including tank breathing due to temperature changes, direct evaporation, and displacement during filling. The principal source of potential loss is from crude oil and light distillate products. The hydrocarbon content of crude oil is substantially saturated and, as explained above, is not believed to be involved in the photochemical smog complex. Light distillates have considerable value and are normally controlled to a practical economic level. Vapor conservation storage may involve tanks with floating roof covers, pressurized tanks, and connections to vapor recovery systems.

For materials exhibiting a true vapor pressure (TVP) at storage conditions of below (78 mm of Hg), no controls are required; for materials with a TVP between (78 and 570 mm of Hg), the storage vessel shall be equipped with a floating roof or equivalent; for materials with a TVP exceeding 570 mm of Hg, the vessel shall be equipped with a vapor recovery system or equivalent.

#### **6.7.1.2 Catalyst regeneration units**

Coke formed on the surface of catalysts during catalytic cracking, reforming, and hydrogenation is burned off in regenerating vessels by controlled combustion. Flue gases from regenerators may contain catalyst dust, carbon monoxide, hydrocarbon (principally methane), and sulfur and nitrogen oxides. The catalyst dust may be controlled by mechanical or electrical collecting equipment. The carbon monoxide and unburned hydrocarbons are generally dispersed in the atmosphere, but may be eliminated by burning in a waste heat boiler which also generates additional steam. Amount of catalyst emitted from fluid catalytic cracking regenerator should not exceed one kg of catalyst per 1000 kg of coke make, and carbon monoxide to 500 ppm by volume.

In-situ type operation is finding wider use in fluid catalytic cracking unit.

#### **6.7.1.3 Waste water separators**

Waste water gravity separators are commonly used to trap and recover oil discharged to the sewer system from equipment leaks and spills, shutdowns, sampling, process condensate, pump seals, etc. Depending on the quantity and type of oil in the sewers, some hydrocarbon vapors may evaporate from the drainage and separator system. If this vaporization is sizable and control is indicated, the front end of the separators may be covered. Catch basin liquid seals, manhole covers, and good house-keeping practices will likewise control drainage system vapor losses.

#### **6.7.1.4 Loading facilities**

While most petroleum products leave the refinery through pipelines with no emission to the atmosphere, loading into tank trucks, tank cars, and drums can result in hydrocarbon vapor loss by displacement or evaporation. Careful operation to minimize spillage, and vapor collection and recovery equipment will control vapor loss from this operation.

#### **6.7.1.5 Pipeline valves**

The typical refinery contains a maze of piping, mostly above grade. The effects of heat, pressure, vibration, and corrosion may cause leaks in valved connections. Depending on the product carried and the temperature, the leaks may be liquid, vapor, or both. Regular inspection and prompt maintenance will correct vapor loss from this source.

#### **6.7.1.6 Pumps and compressors**

Hydrocarbons can leak at the contact between the moving shaft and stationary casing in pumps and compressors. Asbestos or other fibers are packed around the shaft to retard leakage from shaft motions. Mechanical seals, consisting of two plates, perpendicular to the shaft, forced tightly together, and also used. Wear can cause both packed and mechanical seals to leak product. Inspection and maintenance, sealing glands under pressure, and use of mechanical seals in light hydrocarbon service are useful control measures.

#### **6.7.1.7 Blowdown system, flares, and shutdowns**

Refinery process units and equipment are periodically shut down for maintenance and repair. Since these turnarounds generally occur about once a year, losses from this source are sporadic. Hydrocarbons purged during shutdowns and start-ups may be manifolded to blowdown system for recovery, safe venting, or flaring. Vapors can be recovered in a gas holder or compressor and discharged to the refinery fuel gas system. Flares should be of the smokeless type, utiliz-

ing either steam or air injection. Design data for smokeless flares are readily available from combustion equipment manufacturers and in industry technical manuals. For aesthetic purposes, ground flares are becoming more popular.

#### 6.7.1.8 Boilers and process heaters

Refineries depend on boilers and heaters to supply high pressure steam at elevated temperatures. Fuels may include refinery or natural gas, heavy fuel oil, and coke, often in various changing combinations. Sulfur oxides in the flue gas are, of course, a result of the sulfur in the fuel feed. Nitrogen oxides and small quantities of hydrocarbons, organic acids, and particulate matter are also present. Sulfide stripping of fuel gas prior to burning and selective blending of fuels may be employed to control sulfur emissions. Normally, good combustion practices will control smoke and particulate matter.

Stacks on boilers and heaters are elevated to improve atmospheric dispersion and further diminish resulting ground-level concentrations of gases such as sulfur dioxide and nitrogen oxides.

#### 6.7.1.9 Sulfur recovery units

The potential for  $H_2S$  loss to the atmosphere occurs at two points in the Claus process:

- a) the interface between the  $H_2S$  recovery process and the feed to the unit.
- b) the tail gas from the plant. If the Claus plant breaks down and cannot take the feed,  $H_2S$  has to be flared. Some refineries utilize spare Claus capacity so that flaring is minimized.

The presence of  $H_2S$  in the tail-gas indicates that the conversion of  $H_2S$  to S is not complete. This tail-gas is either incinerated at 538°C to 649°C temperature thus releasing all sulfur compounds as sulfur oxides, or further treated in a tail-gas recovery system. The tail-gas treating systems generally convert all sulfur compounds to  $H_2S$ , after which the stream is scrubbed to remove the  $H_2S$ .

#### 6.7.1.10 Incinerators

There are a number of incineration processes available for the incineration of refinery sludges, solids, and spent caustics. Fluid bed incinerators can be installed in refineries. These fluid bed incinerators operate at temperatures of 704°C. As the sludge is burned, the solids from the sludge remain in the bed while gaseous products of combustion, water vapor and fine particulate matter pass overhead through a cyclone separator and a water scrubber before venting to the atmosphere.

#### 6.7.1.11 Miscellaneous

Various other miscellaneous emission sources, usually of lesser significance, will be found in refinery operations. Pressure relief valves may be manifolded into vapor recovery or flare systems to control leakage and relief discharged. Steam-driven vacuum jets, employed to induce negative pressure in process equipment, may discharge light hydrocarbons with the exhaust steam. These gases may be vented and burned in an adjacent boiler or heater firebox.

Fumes from air blowing operations may be consumed by incineration or absorbed by scrubbing. Gases from spent caustic and mercaptan disposal may be burned in fireboxes.

Hydrogen sulfide and mercaptans are the principal potential pollutants that may cause odors. These gases can be released from process steam condensates, drain liquids, barometric condenser sumps, sour volatile product tankage, and spent caustic solutions from treating operations.

Odorous compounds in steam condensates can be removed by stripping with air, flue gas, or steam and offensive gases can be burned in furnaces or boilers. Drain liquids can be collected in closed storage systems and recycled to the process.

Barometric condensers are being replaced by more modern surface condensers, and the noncondensables may be burned in process heaters or in a separate incinerator.

Spent caustic can be degasified, neutralized with flue gas, and/or stripped before disposal. Sulfides can also be removed from sour process water and spent caustic solutions by air oxidation to thiosulfates and sulfates.

Refinery waste gases that contain hydrogen sulfide are generally scrubbed with appropriate solutions for extraction of the sulfide by nonregenerative or heat-regenerative procedures. In the former method, the waste gases are scrubbed with a caustic solution, producing a solution of sodium sulfide and acid sulfide. As described above, the spent caustic may be oxidized by air blowing or sold. Vent gas from the blowing operation should be burned.

Heat-regenerative methods involve scrubbing sour gases with various types of amine, phenolate, or phosphate solutions which absorb hydrogen sulfide at moderately low temperatures and release it at higher temperatures. These methods are cyclic and consist of an absorption step, in which the hydrogen sulfide is scrubbed from the absorbing solution at approximately 38°C followed by a regeneration step in which the solution is reactivated for use by heating it to its boiling point to drive off the hydrogen sulfide. The released hydrogen sulfide is then burned or oxidized to form sulfur.

Refinery process changes may have the net effect of reducing overall emissions to the atmosphere. Examples of such process changes include substitution of hydrogen treating for chemical treatment of distillates use of harder catalysts to reduce attrition losses, and regeneration of spent chemicals for reuse.

Odor control methods for refinery are described in Appendix E.

**6.7.2 Petrochemical processes**

Petrochemical process that use air-oxidation-type reaction, lower, normally have large, continuous amounts of gas emissions to the atmosphere. The six processes considered in this section employ reactions using air oxidation.

Acrylonitrile-Carbon black-Ethylene-dichloride-Ethylene oxide-Formaldehyde-Phthalic anhydride.

**6.7.2.1 Acrylonitrile**

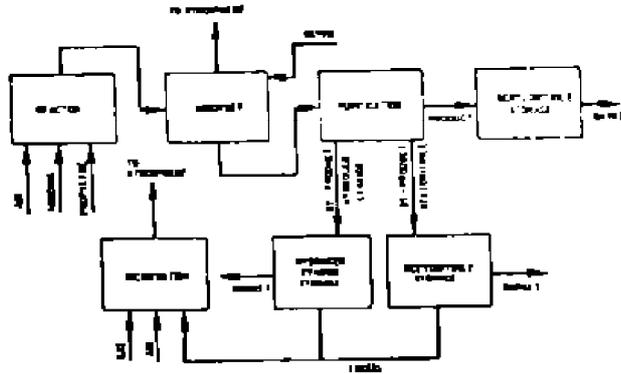
Air pollution emissions and their control. The major source of emissions from an acrylonitrile plant is the exit gas stream from the product absorber. For a typical plant producing 90 million kg a year of acrylonitrile, the gas flow rate would be 1284 scmm. The pollutants in kilograms per metric ton of acrylonitrile produced are shown in Table 7.

**TABLE 7**

<b>POLLUTANT</b>	<b>KILOGRAM PER TON OF ACRYLONITRILE PRODUCED <sup>a</sup></b>
CARBON MONOXIDE	122
PROPYLENE	38
PROPANE	61
HYDROGEN CYANIDE	0.5
ACRYLONITRILE	0.25
ACETONITRILE	6.5

**a) With no control.**

In Fig. 13 flow manufacture of acrylonitrile has been shown.



**FLOW DIAGRAM OF THE SOHIO PROCESS FOR THE MANUFACTURE OF ACRYLONITRILE, NOTING POTENTIAL AIR POLLUTION SOURCES**  
 Fig. 1

The composition of the stream will depend primarily on the selectivity of the catalyst in the reactor and the efficiency of the absorber.

A second, less important, source of emissions from this process is the by-product incinerator. About 1 to 3% of the nitrogen content of the excess hydrogen cyanide and acetonitrile is converted into nitrogen oxides in a commercial incinerator operating at 871°C. There is presently no demonstrated control device for the oxides of nitrogen. The amount of the emission depends upon the amount of by-product gas burned, the temperature of combustion, and the percent of excess air.

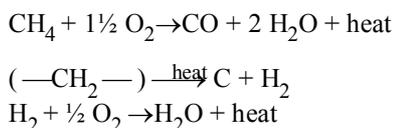
A thermal incinerator will oxidize essentially all of the contaminants from the main process vent stream. However, the gas has such a low heat content that supplemental fuel must be added to achieve stable flame control and complete combustion. Various combinations of heat exchange could be used. Because acrylonitrile plants generate more steam than they can utilize, any steam generated by the incinerator has to be exported. The most feasible air pollution control system for new plants would be a thermal incinerator with process vent gas preheat, combustion air preheat, and a waste heat boiler.

**6.7.2.2 Carbon black**

Of all carbon black produced about 84% is manufactured by the furnace process. The thermal process which produces 14% of the carbon black is a minor source of air pollution. The plants using the channel process presently account for less than 2% of production.

**6.7.2.3 Furnace process**

In the furnace process, natural gas and a high carbon aromatic oil are preheated and introduced into a furnace with a limited amount of air (Fig. 14). A combination of cracking and combustion occurs.



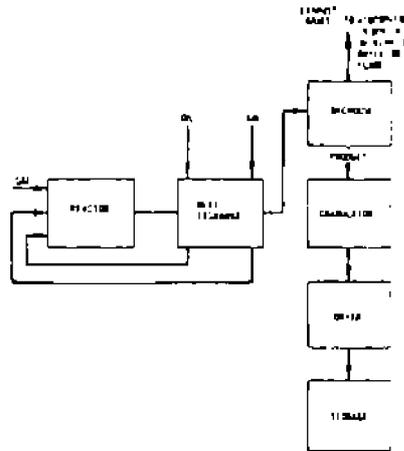


Fig. 2

**6.7.2.4 Air pollutant emissions and their control**

The major source of emissions from a furnace black plant is the exit gas stream from the bag collector. For a typical plant producing 41 million kg of black per year the gas flow rate would be 1440 scmm. The pollutants in pounds per ton of black produced are shown in Table 8. The exact composition of the stream will depend upon the grade of black produced and the composition of the aromatic oil. Grades which require a larger proportion of gas feed will have increased emissions of carbon monoxide. The amount of hydrogen sulfide formed is proportional to the sulfur content of the aromatic oil.

**TABLE 8 - POLLUTANT PRODUCTION IN THE FURNACE BLACK PROCESS**

POLLUTANT	KILOGRAM PER TON OF CARBON BLACK PRODUCED <sup>a</sup>
HYDROGEN	116.5
CARBON MONOXIDE	1270
HYDROGEN SULFIDE	27.5
SULFUR DIOXIDE	trace
METHANE AND ACETYLENE	54.5
PARTICULATE MATTER (BLACK)	2

**a) No control after baghouse.**

Any type of incineration device will oxidize most of the carbon monoxide and hydrogen sulfide in the vent stream. However, a carbon monoxide boiler or thermal incinerator would be more efficient than a flare. Because off-gas is low in heat content [about 40 BTU per scf (356,000 cal per scm)], most combustion devices require supplemental fuel (natural gas) to maintain combustion. Various combinations of heat exchange, supplemental fuel addition, and heat recovery can be used. The choice is an economic one determined by the costs of fuel and equipment and the ability to use any steam generated. The most efficient air pollution control system for new plants under most circumstances would be a

process vent gas thermal incinerator (with combustion air heat exchange) plus a waste heat boiler and steamdriven process equipment. This should oxidize all the carbon monoxide, hydrogen sulfide, and hydrocarbons.

**6.7.2.5 Ethylene dichloride**

Ethylene dichloride produced by the direct chlorination or oxychlorination of ethylene. The atmospheric pollutants from direct chlorination processes are much less than those from the oxychlorination process. Almost all ethylene dichloride used for the manufacture of vinyl chloride monomer.

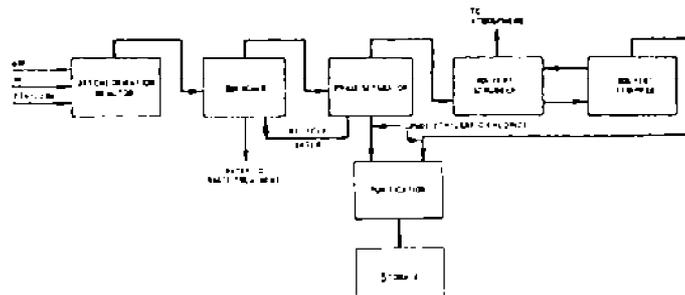
**6.7.2.6 Oxychlorination process**

Vaporized ethylene, anhydrous hydrogen chloride, and air are fed to a catalytic reactor which operates at (2.3 to 6.1 atm) and 200°C to 315°C. The reaction is



**6.7.2.7 Air pollutant emissions and their control**

The major source of emissions from an ethylene dichloride plant is the exit-gas stream from the solvent scrubber.(see Fig. 3)



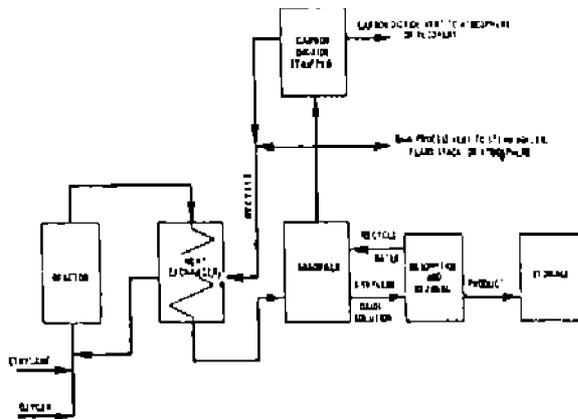
**Fig. 3**

For a typical plant of the type described producing 317 million kg per year, the gas flow rate would be 489 scmm.

The pollutants in (kilograms per metric ton) of ethylene dichloride produced are shown in Table 9. The values given are average values for several different oxychlorination processes. The composition of the stream will depend on catalyst activity, reactor operating conditions, and the solvent scrubber efficiency. All existing ethylene dichloride plants vent this stream directly to the atmosphere with no treatment. Any one of several combustion devices could be used to destroy the contaminants present. A water or caustic scrubber could be used after the combustor to remove the hydrogen chloride generated. Several different types of incineration would be feasible. The most efficient method for new plants would be a thermal incinerator followed by a waste heat boiler and a final caustic scrubber. The steam generated could be used in the plant. Because this system has not been demonstrated, it is possible that there might be significant operating problems. Careful control of temperature would be necessary to prevent condensation of hydrogen chloride and resultant corrosion of metal. Also, because of the low heating value of the gas stream 267,000 to 445,000 cal per scm, supplemental fuel would have to be added to achieve complete combustion and satisfactory flame control.

**TABLE 9 - POLLUTANT PRODUCTION IN ETHYLENE DICHLORIDE MANUFACTURE BY OXYCHLORINATION**





**FLOW DIAGRAM OF THE DIRECT OXIDATION PROCESS FOR THE MANUFACTURE OF ETHYLENE OXIDE USING OXYGEN, NOTING POTENTIAL SOURCES OF AIR POLLUTION**  
**Fig. 5**

After heat exchange with recycle gas, the reactor effluent gases pass to the main absorber where the ethylene oxide is absorbed in a water solution. Approximately two-thirds of the absorber overhead gas (which contains nitrogen, carbon dioxide, unreacted ethylene, and air) is returned as recycle to the main reactor. The remaining onethird of the main absorber overhead gas is purged from the system. Most of the ethylene in the purge stream is recovered as ethylene oxide which is formed in the purge reactor and removed in the purge absorber. The vent from the purge absorber, mostly nitrogen and carbon dioxide, contains some unreacted ethylene, a small amount of ethylene oxide, and all the ethane in the ethylene raw material. The ethylene oxide in the main absorber and purge absorber bottoms is removed by desorption, refined, and sent to storage.

Although the oxygen process is similar to the air oxidation process, there is usually no purge reactor or absorber. Also, because the conversion of ethylene per pass is lower, the recycle is larger. Product is recovered by absorption as in the air oxidation process. A carbon dioxide absorber, used on a portion of the recycle stream, controls the build-up of carbon dioxide. Other inert gases are removed by a small absorber vent gas purge. In a variation of the process, methane is added to the recycle gas to act as an inert in the reactor and yield a high calorie vent gas which burns easily in a boiler.

**TABLE 10 - POLLUTANT PRODUCTION IN ETHYLENE OXIDE MANUFACTURE BY AIR OXIDATION**

KILOGRAM PER TON OF ETHYLENE OXIDE PRODUCED- PURGE ABSORBER VENT <sup>a</sup>		
POLLUTANT	WITH NO CONTROL	WITH COMBUSTION
ETHANE	6	Nil
ETHYLENE	92	Nil
ETHYLENE OXIDE	1	Nil

a) Values are kilograms per metric ton.

**6.7.2.10 Air pollutant emissions and their control**

The only important source of emissions from ethylene oxide manufacture are the purge vents. Typical pollutants for the purge absorber vent of an ethylene oxide plant using air oxidation are shown in Table 11. For a typical (90-million-kg) per year plant the vent gas rate would be 9775 scmm. Typical main process vent pollutants for a plant using oxygen oxidation are shown in Table 11. For a 90 million kg per year plant the main process vent gas rate would be 3.4 scmm. Because the carbon dioxide vent of 164 scmm contains an insignificant amount of contaminants, it can be vented or sold as carbon dioxide.

The most efficient method to control emissions from an ethylene oxide plant is to feed the main process vent to a catalytic combustor and use the hot gases from this unit in expanders to drive the process compressors. More than 99% removal of combustible gases would be expected.

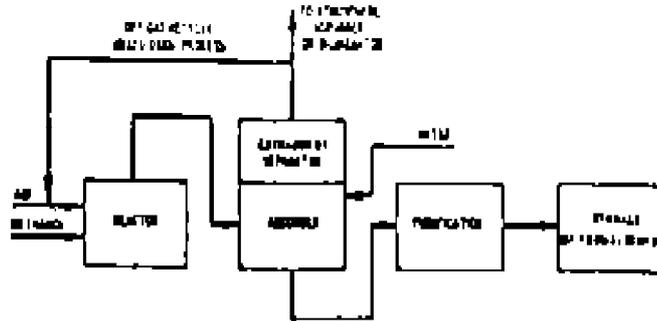
**TABLE 11 - POLLUTANT PRODUCTION IN ETHYLENE OXIDE MANUFACTURE BY OXYGEN OXIDATION**

KILOGRAM PER TON OF ETHYLENE OXIDE PRODUCED- MAIN PROCESS VENT <sup>a</sup>		
POLLUTANT	WITH NO CONTROL	WITH COMBUSTION
ETHANE	3	Nil
ETHYLENE OXIDE	2.5	Nil

a) Values are kilograms per metric ton.

**6.7.2.11 Formaldehyde**

All formaldehyde was produced by the air oxidation of methanol. About 57% was used in combination with phenol, urea, or melamine to form resins and adhesives. The largest and fastest growing use of phenol-formaldehyde resins is as an adhesive for plywood. Ureaformaldehyde resin is primarily used as an adhesive for particle board. Formaldehyde is also used to manufacture hexamethylenetetramine, pentaerythritol, and several miscellaneous resins.



**FLOW DIAGRAM OF THE METHANOL PROCESS FOR THE MANUFACTURE OF FORMALDEHYDE, NOTING POTENTIAL SOURCES OF AIR POLLUTION**  
 Fig. 6

**6.7.2.12 Air pollutant emissions and their control**

The major source of emissions from a formaldehyde plant is the exit-gas stream from the scrubber. The amount and composition of gaseous emissions and the type of control device that can be used depend upon the type of process.

For the mixed metal oxide catalyst process the pollutants in points per ton of 37% formaldehyde solution produced are shown in Table 12. The values given are for a plant operating at maximum recycle; for nonrecycle operation these values would be higher. For a typical plant producing 45 million kg per year of 37% formaldehyde, the exit-gas flow rate at maximum recycle would be 9.6 scmm. Water scrubber could be used to remove formaldehyde.

**TABLE 12 - MAXIMUM ABSORBER VENT GAS RECYCLE POLLUTANTS IN FORMALDEHYDE PRODUCTION BY MIXED-OXIDE CATALYST PROCESS <sup>a</sup>**

	WITH NO CONTROL	WITH INCINERATION	WITH WATER SCRUBBING
FORMALDEHYDE	0.8	Nil	0.1
METHANOL	2	Nil	0.2
CARBON MONOXIDE	17	Nil	17
DIMETHYLE ETHER	0.8	Nil	0.8

a) Values are for kilograms per metric ton.

An incinerator is used to oxidize all contaminants from this stream but because of the very low heat content of the gas, considerable auxiliary fuel should be required.

For the silver catalyst process the pollutants in pounds per ton of 37% formaldehyde solution produced are shown in Table 13. For a typical plant producing 100 million lb (45 million kg) per year of 37% formaldehyde, the gas flow rate would be 62 scmm with a heat content of about 552,000 cal/scm. The composition of the vent gas depends again on design and operating conditions of the absorber, but the absorption is easier because of the lower gas volume. Incineration can be used to oxidize all the contaminants in this stream.

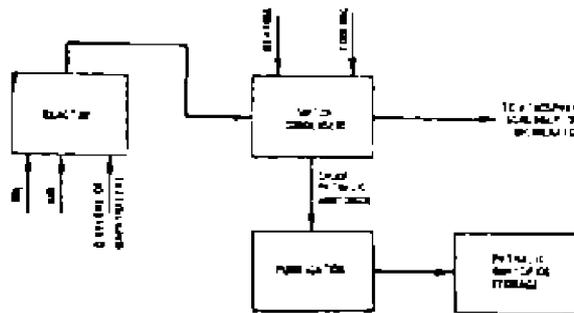
**TABLE 13 - POLLUTANT PRODUCTION IN FORMALDEHYDE MANUFACTURE BY SILVER CATALYST PROCESS**

KILOGRAM PER TON 37% FORMALDEHYDE SOLUTION PRODUCED <sup>a</sup>		
POLLUTANT	WITH NO CONTROL	WITH COMBUSTION
FORMALDEHYDE	0.6	Nil
METHANOL	2.5	Nil
CARBON MONO-OXIDE	5.2	Nil
HYDROGEN	10.0	Nil

a) Values are kilograms per metric ton.

**6.7.2.13 Phthalic anhydride**

All phthalic anhydride is produced by the vapor phase air oxidation of either o-xylene or naphthalene. About 56% goes into the production of plasticizers for vinyl resins, and phthalic-based alkyd resins, used primarily for exterior surface coatings, account for about 22% of the material produced. About 17% is used in the manufacture of polyester resins, most of which are glass reinforced.



**FLOW DIAGRAM OF THE OXIDATION O-XYLENE OR NAPHTHALENE FOR THE MANUFACTURE OF PHTHALIC ANHYDRIDE, NOTING POTENTIAL SOURCES OF AIR POLLUTION**

**Fig. 7**

The major source of emissions from phthalic anhydride manufacture is the off-gas from the switch condensers. For a typical (58 million kg per year) plant this stream has a flow rate of 3680 scmm). The composition of this stream is shown in Table 15 for plants using oxylene feedstock. The organic acids and anhydrides are malodorous lachrymators.

The most common type of emission control is water scrubbing. A typical combination for this application is a venturi scrubber followed by a cyclone separator and a packed countercurrent scrubber. The absorption efficiencies of the various scrubbers will vary considerably, but typical emission are given in Table 14. The scrubbing liquid must be incinerated in a small natural gas incinerator.

**TABLE 14 - POLLUTANT PRODUCTION IN PHTHALIC ANHYDRIDE MANUFACTURE**

KILOGRAM PER TON PHTHALIC ANHYDRIDE PRODUCED <sup>a</sup>			
POLLUTANT	WITH NO CONTROL	WITH INCINERATION	WITH WATER SCRUBBING
ORGANIC ACIDS AND ANHYDRIDES	65	2.5	3
SULFUR DIOXIDE	5	5	5
CARBON MONOXIDE	140	0.1	140
PARTICULATE MATTER	Trace	-	Trace

a) Values are kilograms per metric ton.

**6.7.2.14 Emission reduction during air pollution episodes**

Atmospheric emissions from the petrochemical processes described in this section can be reduced significantly or stopped completely within a period of 1-3 hours. Petrochemical plants usually have several independent trains of processing equipment, and these trains may be shutdown as required to reduce emissions. Most operators also have the option of reducing production by leaving all trains on line and reducing the throughput per train. In either case the emissions from the process would be approximately proportional to operating level.

**6.7.3 Fertilizer industries**

Pollutant Consider	Process of Operation	Control System
dust	Phosphate fertilizers: crushing, grinding, and calcining	Exhaust system, scrubber, cyclone, baghouse
PH <sub>3</sub> , P <sub>2</sub> O <sub>5</sub> , PO <sub>4</sub> mist	Hydrolysis of P <sub>2</sub> O <sub>5</sub>	Scrubbers, flare
HF, SiF <sub>4</sub>	Acidulation and curing	Scrubbers
Particulates	Granulation	Exhaust system, scrubber,
NH <sub>3</sub> , NH <sub>4</sub> Cl, HF, SiF <sub>4</sub>	Ammoniation	Cyclone, electrostatic precipitator, baghouse, high-energy scrubber
NO <sub>2</sub> gases	Nitric acid acidulation	Scrubber, addition of urea
Particulates	Superphosphate storage and shipping	Exhaust system, cyclone, or baghouse
NH <sub>3</sub> , NO <sub>2</sub>	Ammonium nitrate reactor	Scrubber
NH <sub>4</sub> , NO <sub>3</sub>	Prilling tower	Proper operation control, scrubbers

**6.7.4 Crude oil terminals:**

**Operations and environment controls**

The discussion in this section is limited to those crude oil terminal operations which are separate from refineries.

Several types of crude terminals are encountered throughout the industry based upon the sources and final destinations of the crude oil. The types of terminals to be considered in the following discussion are: inland pipeline terminals, marine shipping terminals, onshore marine receiving terminals, offshore marine receiving terminals, barge shipping terminals and barge receiving terminals.

A large amount of storage capacity is required at crude oil terminals, not only to enable the crude to be brought into the terminal from numerous producing regions (which may include several different quality crudes), but also to provide the tankage for segregation, batching, blending and inventorying necessary for continuous pipeline operations before the crude oil can be moved to refineries. Similar operations are necessary for marine terminals both for shipping and receiving of crude oil.

The sources of pollutants are based on the type of operation (receiving or shipping) and the type of transportation used (pipeline, tanker, or barge).

#### **6.7.4.1 Air pollution control**

The most significant of the air pollutants emitted by a terminal operation are hydrocarbon, which occur at all types of crude facilities. Other air pollutants include odors,  $\text{SO}_x$ ,  $\text{NO}_x$ , CO, and particulates are also concerned.

#### **6.7.4.2 Hydrocarbons**

Emission sources include storage tanks (normally onshore), transportation vessel tanks, tanker refueling, tank cleaning (both storage and vessels), tank degassing (preparation for inspection and maintenance), ballasting and fugitive emissions. In the case of onshore or permanent facilities, the mechanisms for limiting hydrocarbon emissions or collecting the vapors for incineration are similar to those discussed for refineries. The emissions from operations such as tanker refueling and tank degassing may incorporate vapor recovery or vapor collection/disposal (flaring) systems depending on whether an on-shore or off-shore facility is involved. Several operational control techniques have been considered as alternatives to the use of vapor control systems. These approaches include segregated ballasting, tank cleaning, slow loading, short loading, and the routing of vapors into tanks that are being emptied. The hydrocarbon emissions from ballasting on the other hand are normally uncontrolled. Hydrocarbon vapors can also be created by crude oil washing of cargo tanks during unloading.

##### **6.7.4.2 (a) Emissions from tankers ballasted tanks**

The emission of hydrocarbon gas from ballasted tanks can be avoided in one of three ways or any combination thereof;

By the use of permanent ballast tanks of sufficient capacity to provide the minimum departure draught (International Marine Organization standards should be used). For more information please refer to environmental management practices in oil refineries and terminals United Nation environment programme 1987.

#### **6.7.4.3 Sulphur oxides ( $\text{SO}_x$ )**

Emissions result from the flaring of  $\text{H}_2\text{S}$  containing gases, space heating with fuel oil, fuel combustion and tankers. The flaring emissions are uncontrolled while the fuel combustion emissions may be "controlled" by using the low-sulphur fuel oil.

#### **6.7.4.4 Nitrogen oxides ( $\text{NO}_x$ )**

Sources include space heating, the flare and tankers. Emission controls are normally not employed due to the small quantities emitted.

#### 6.7.4.5 Particulates

Emissions at the terminal should be limited to fugitive emissions such as dust which can be controlled by methods such as paving or vegetation cover.

#### 6.7.4.6 Odors

Odors from a crude terminal are usually caused by H<sub>2</sub>S, mercaptans and hydrocarbon emissions. The most effective means of controlling odorcausing emissions, especially those containing H<sub>2</sub>S, is vapor collection and incineration.

### 6.8 Threshold Limit Values

#### Introduction to the Chemical Substances

Threshold Limit Values (TLVs) 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 health effects.

These limits are intended for use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and for no other use, e.g., in the evaluation or control of community air pollution nuisances; in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods; as proof or dis-proof of an existing disease or physical condition; or,

#### Definitions

Three categories of Threshold Limit Values (TLVs) are specified herein, as follows:

- a) Threshold Limit Value-Time-Weighted Average (TLV-TWA)-the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.
- b) Threshold Limit Value-Short-Term Exposure Limit (TLV-STEL)- the concentration to which workers can be exposed continuously for a short period of time without suffering from:
  - 1) irritation,
  - 2) chronic or irreversible tissue damage, or,
  - 3) narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded. It is not a separate independent exposure limit; rather, it supplements the timeweighted average (TWA) limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

A STEL is defined as a 15-minute TWA exposure which should not be exceeded at any time during a workday even if the 8-hour TWA is within the TLV-TWA. Exposures above the TLV-TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There should be at least 60 minutes between successive exposures in this range. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

- c) Threshold Limit Value-Ceiling(TLV-C)the concentration that should not be exceeded during any part of the working exposure.

In conventional industrial hygienic practice if instantaneous monitoring is not feasible, then the TLV-C can be assessed by sampling over a 15-minute period except for those substances that may cause immediate irritation when exposures are short.

For some substances, e.g., irritant gases, only one category, the TLV-Ceiling, may be relevant. For other substances, one or two categories may be relevant, depending upon their physiologic action. It is important to observe that if any one of these types of TLVs is exceeded, a potential hazard from that substance is presumed to exist.

The Chemical Substances TLV Committee holds to the opinion that TLVs 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.

**Time-Weighted Average (TWA) vs Ceiling (C) Limits.** TWAs permit excursions above the TLV provided they are compensated by equivalent excursions below the TLV-TWA during the workday. In some instances, it may be permissible to calculate the average concentration for a workweek rather than for a workday. The relationship between the TLV and permissible excursion is a rule of thumb and in certain cases may not apply. The amount by which the TLVs 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 a decision as to whether a hazardous condition exists.

Although the TWA concentration provides the most satisfactory, practical way of monitoring airborne agents for compliance with the TLVs, there are certain substances for which it is inappropriate. In the latter group are substances which are predominantly fast acting and whose TLV is more appropriately based on this particular response. Substances with this type of response are best controlled by a ceiling limit that should not be exceeded.

It is implicit in these definitions that the manner of sampling to determine noncompliance with the limits for each group must differ; a single, brief sample, that is applicable to a ceiling limit, is not appropriate to the TWA; here, a sufficient number of samples are needed to permit a TWA concentration throughout a complete cycle of operations or throughout the workshift.

Whereas the ceiling limit places a definite boundary that concentrations should not be permitted to exceed, the TWA requires an explicit limit to the excursions that are permissible above the listed TLVs. It should be noted that the same factors are used by the Chemical Substances TLV Committee in determining the magnitude of the value of the STELs, or whether to include or exclude a substance for a ceiling listing.

## **Mixtures**

Special consideration should be given also to the application of the TLVs in assessing the health hazards that may be associated with exposure to mixtures of two or more substances. A brief discussion of basic considerations involved in developing TLVs for mixtures and methods for their development, amplified by specific examples, are given in Appendix 2 C.

## **Respirable and Total Dust**

For solid substances and liquified mists, TLVs are expressed in terms of total dust, except where the term "respirable dust" is used. See Appendix D, Particle Size-Selective Sampling Criteria for Airborne Particulate Matter, for the definition of respirable dust.

## **Particulates Not Otherwise Classified (PNOC)**

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. Such dusts have also been called (biologi-

cally " 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 PNOCs has the following characteristics:

- 1) The architecture of the air spaces remains intact;
- 2) collagen (scar tissue) is not formed to a significant extent; and
- 3) the tissue reaction is potentially reversible.

Excessive concentrations of PNOCs in the workroom air may seriously reduce visibility; may cause unpleasant deposits in the eyes, ears, and nasal passages (e.g., Portland cement dust); or cause injury to the skin or mucous membranes by chemical or mechanical action or by the rigorous skin cleansing procedures necessary for their removal.

A TLV-TWA of 10 mg/m<sup>3</sup> of total dust containing no asbestos and < 1% crystalline silica is recommended for substances in these categories and for which no specific TLVs have been assigned.

### **Conversion of TLVs in ppm to mg/m<sup>3</sup>**

TLVs for gases and vapors are usually established in terms of parts per million of substance in air by volume (ppm). For convenience to the user, these TLVs are also listed here in terms of milligrams of substance per cubic meter of air (mg/m<sup>3</sup>). The conversion is based on 760 torr barometric pressure and 25°C, giving a conversion equation of:

$$\text{TLV in mg/m}^3 = \frac{(\text{TLV in ppm}) (\text{gram molecular weight of the substance})}{24,45}$$

Resulting values are rounded to two significant figures below 100 and to three significant figures above 100. This is not done to give any converted value a greater precision than that of the original TLV, but to avoid increasing or decreasing the TLV significantly merely by the conversion of units.

**In the Appendix G you will find the exposure levels that are allowed in your work place you must not exceed these levels.**

## APPENDICES

### APPENDIX A CARCINOGENS

The Chemical Substances Threshold Limit Values Committee classifies certain substances found in the occupational environment as either confirmed or suspected human carcinogens. The present listing of substances that have been identified as carcinogens takes two forms: those for which a TLV has been assigned and those for which environmental and exposure conditions have not been sufficiently defined to assign a TLV. Where a TLV has been assigned, it does not necessarily imply the existence of a biological threshold; however, if exposures are controlled to this level, we would not expect to see a measurable increase in cancer incidence or mortality.

The TLV Committee considers information from the following kinds of studies to be indicators of a substance's potential to be a carcinogen in humans: epidemiology studies, toxicology studies, and, to a lesser extent, case histories. Scientific debate over the existence of biological thresholds for carcinogens is unlikely to be resolved in the near future. Because of the long latent period for many carcinogens, and for ethical reasons, it is often impossible to base timely risk-management decisions on results from human studies.

In order to recognize the qualitative differences in research results, two categories of carcinogens are designated in this booklet:

#### **A1 - Confirmed Human Carcinogens**

Substances, or substances associated with industrial processes, recognized to have carcinogenic potential.

#### **A2 - Suspected Human Carcinogens**

Chemical substances, or substances associated with industrial processes, which are suspect of inducing cancer, based on either limited epidemiological evidence or demonstration of carcinogenesis in one or more animal species by appropriate methods.

Exposures to carcinogens must be kept to a minimum. Workers exposed to A1 carcinogens without a TLV should be properly equipped to eliminate to the fullest extent possible all exposure to the carcinogen. For A1 carcinogens with a TLV and for A2 carcinogens, worker exposure by all routes should be carefully controlled to levels as low as reasonably achievable (ALARA) below the TLV. Please see the Documentation of the Threshold Limit Values, Appendix A, "Identification and Classification of Carcinogens," for a more complete description and derivation of these designations.

## APPENDIX B SUBSTANCES OF VARIABLE COMPOSITION

### B1 - Polytetrafluoroethylene\* decomposition products

Thermal decomposition of the fluorocarbon chain in air leads to the formation of oxidized products containing carbon, fluorine, and oxygen. Because these products decompose in part by hydrolysis in alkaline solution, they can be quantitatively determined in air as fluoride to provide an index of exposure. No TLV is recommended pending determination of the toxicity of the products, but air concentration should be minimal. (\* Trade names: Algoflon, Fluon, Teflon, Tetran)

### B2 - Welding Fumes-Total Particulate (NOC) TLV-TWA, 5 mg/m<sup>3</sup>

Welding fumes cannot be classified simply. The composition and quantity of both are dependent on the alloy being welded and the process and electrodes used. Reliable analysis of fumes cannot be made without considering the nature of the welding process and system being examined; reactive metals and alloys such as aluminum and titanium are arc-welded in protective, inert atmosphere such as argon. These arcs create relatively little fume, but they do create an intense radiation which can produce ozone. Similar processes are used to arc-weld steels, also creating a relatively low level of fumes. Ferrous alloy also are arc-welded in oxidizing environments that generate considerable fume and can produce carbon monoxide instead of ozone. Such fumes generally are composed of discrete particles of amorphous slags containing iron, manganese, silicon, and other metallic constituents depending on the alloy system involved. Chromium and nickel compounds are found in fumes when stainless steels are arc-welded. Some coated and flux-cored electrodes are formulated with fluorides and the fumes associated with them can contain significantly more fluorides than oxides. Because of the above factors, arc-welding fumes frequently must be tested for individual constituents that are likely to be present to determine whether specific TLVs are exceeded. Conclusions based on total fume concentration are generally adequate if no toxic elements are present in welding rod, metal, or metal coating and conditions are not conducive to the formation of toxic gases.

Most welding, even with primitive ventilation, does not produce exposures inside the welding helmet above 5 mg/m<sup>3</sup>. That which does, should be controlled.

**APPENDIX C  
THRESHOLD LIMIT VALUES FOR MIXTURES**

When two or more hazardous substances which act upon the same organ system are present, their combined effect, rather than that of either individually, should be given primary consideration. In the absence of information to the contrary, the effects of the different hazards should be considered as additive. That is, if the sum of the following fractions,

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

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 A.1 and B.1).

Exceptions to the above rule may be made when there is a 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 ( $C_1/T_1 + C_2/T_2$ , etc.) itself has a value exceeding unity (see Example B.1).

Synergistic action or potentiation may occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or synergistic agents are not necessarily harmful by themselves. Potentiating effects of exposure to such agents by routes other than that of inhalation are 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 that are typically associated with two or more harmful atmospheric contaminants are welding, automobile repair, blasting, painting, lacquering, certain foundry operations, diesel exhausts, etc.

**Examples of TLVs for Mixtures**

**A. Additive effects**

The following formula apply only when the components in a mixture have similar toxicologic effects; they should not be used for mixtures with widely differing reactivities, e.g. hydrogen cyanide and sulfur dioxide. In such case, the formula for Independent Effects (see para B) should be used.

- 1) General case, where air is analyzed for each component, the TLV of mixture=

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

**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.**

(to be continued)

**APPENDIX C (continued)**

**Example A.1:** Air contains 400 ppm of acetone (TLV, 750 ppm), 150 ppm of sec-butyl acetate (TLV, 200 ppm) and 100 ppm of methyl ethyl ketone (TLV, 200 ppm).

Atmospheric concentration of mixture = 400 + 150 + 100 = 650 ppm of mixture.

$$\frac{400}{750} + \frac{150}{200} + \frac{100}{200} = 0.53 + 0.75 + 0.5 = 1.78$$

Threshold Limit is exceeded.

2) 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. When the percent composition (by weight) of the liquid mixture is known, the TLV<sub>s</sub> of the constituents must be listed in mg/m<sup>3</sup>. TLV of mixture=

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

**Note:**

In order 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 × the TLV; 10 × the TLV; etc.)

**Example A.2:** Liquid contains (by weight):

50% heptane: TLV = 400 ppm or 1600 mg/m<sup>3</sup>

$$1 \text{ mg/m}^3 \equiv 0.25 \text{ ppm}$$

30% methyl chloroform: TLV = 350 ppm or 1900 mg/m<sup>3</sup>

$$1 \text{ mg/m}^3 \equiv 0.18 \text{ ppm}$$

20% perchloroethylene: TLV = 50 ppm or 335 mg/m<sup>3</sup>

$$1 \text{ mg/m}^3 \equiv 0.15 \text{ ppm}$$

$$\text{TLV of Mixture} = \frac{1}{\frac{0.5}{1600} + \frac{0.3}{1900} + \frac{0.2}{335}} = \frac{1}{0.00031 + 0.00016 + 0.0006} = \frac{1}{0.00107} = 935 \text{ mg} = \text{m}^3$$

of this mixture

50% or (935)(0.5) = 468 mg/m<sup>3</sup> is heptane

30% or (935)(0.3) = 281 mg/m<sup>3</sup> is methyl chloroform

20% or (935)(0.2) = 187 mg/m<sup>3</sup> is perchloroethylene

(to be continued)

**APPENDIX C (continued)**

These values can be converted to ppm as follows:

heptane:  $468 \text{ mg/m}^3 \times 0.25 = 117 \text{ ppm}$

methyl chloroform:  $281 \text{ mg/m}^3 \times 0.18 = 51 \text{ ppm}$

perchloroethylene:  $187 \text{ mg/m}^3 \times 0.15 = 29 \text{ ppm}$

TLV of mixture =  $117 + 51 + 29 = 197 \text{ ppm}$ , or  $935 \text{ mg/m}^3$

**B. Independent effects**

TLV for mixture =

$$\frac{C_1}{T_1} = 1 ; \quad \frac{C_2}{T_2} = 1 \quad \frac{C_3}{T_3} = 1 ; \text{ etc}$$

**Example B.1:** Air contains  $0.15 \text{ mg/m}^3$  of lead (TLV, 0.15) and  $0.7 \text{ mg/m}^3$  of sulfuric acid (TLV, 1).

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

Threshold limit is not exceeded.

**C. TLV for mixtures of mineral dusts**

For mixtures of biologically active mineral dusts, the general formula for mixtures given in A.2 may be used.

## APPENDIX D

### PARTICLE SIZE-SELECTIVE SAMPLING CRITERIA FOR AIRBORNE PARTICULATE MATTER

For chemical substances present in inhaled air as suspensions of solid particles or droplets, the potential hazard depends on particle size as well as mass concentration because of:

- 1) effects of particle size on deposition site within the respiratory tract, and
- 2) the tendency for many occupational diseases to be associated with material deposited in particular regions of the respiratory tract.

ACGIH has recommended particle size-selective TLVs for crystalline silica for many years in recognition of the well established association between silicosis and respirable mass concentrations. It now has embarked on a re-examination of other chemical substances encountered in particulate form in occupational environments with the objective of defining:

- 1) the size-fraction most closely associated for each substance with the health effect of concern, and
- 2) the mass concentration within that size fraction which should represent the TLV.

The Particle Size-Selective TLVs (PSS-TLV<sub>s</sub>) will be expressed in three forms, e.g.,

- a) Inspirable Particulate Mass TLV<sub>s</sub> (IPM-TLV<sub>s</sub>) for those materials that are hazardous when deposited anywhere in the respiratory tract.
- b) Thoracic Particulate Mass TLV<sub>s</sub> (TPM-TLV<sub>s</sub>) for those materials that are hazardous when deposited anywhere within the lung airways and the gas-exchange region.
- c) Respirable Particulate Mass TLV<sub>s</sub> (RPM-TLV<sub>s</sub>) for those materials that are hazardous when deposited in the gas-exchange region.

The three particulate mass fractions described above are defined in quantitative terms as follows:

- a) Inspirable Particulate Mass consists of those particles that are captured according to the following collection efficiency regardless of sampler orientation with respect to wind direction:

$$E = 50 (1 + \exp[-0.06 d_a]) \pm 10;$$

for  $0 < d_a \leq 100 \mu\text{m}$

Collection characteristics for  $d_a > 100 \mu\text{m}$  are presently unknown. E is collection efficiency in percent and  $d_a$  is aerodynamic diameter in  $\mu\text{m}$ .

- b) Thoracic Particulate Mass consists of those particles that penetrate a separator whose size collection efficiency is described by a cumulative lognormal function with a median aerodynamic diameter of  $10 \mu\text{m} \pm 1.0 \mu\text{m}$  and with a geometric standard deviation of 1.5 ( $\pm 0.1$ ).
- c) Respirable Particulate Mass consists of those particles that penetrate a separator whose size collection efficiency is described by a cumulative lognormal function with a median aerodynamic diameter of  $3.5 \mu\text{m} \pm 0.3 \mu\text{m}$  and with a geometric standard deviation of 1.5 ( $\pm 0.1$ ). This incorporates and clarifies the previous ACGIH Respirable Dust Sampling Criteria.

These definitions provide a range of acceptable performance for each type of size-selective sampler. Further information is available on the background and performance criteria for these particle size-selective sampling recommendations.

## APPENDIX E

## ODOR CONTROL METHODS FOR REFINERY PURPOSES

### 1. ALKYLATION UNITS AND ASPHALT OXIDIZERS

Odor emissions are effectively prevented by afterburners or the collection and feeding the off-gases to process heaters.

### 2. BAROMETRIC CONDENSERS AND VACUUM TOWERS

Odor prevention has been achieved by venting all off-gases, including vacuum jet gases, to process heaters or where necessary, flares. If the off-gases contain high concentrations of sulphur compounds, further improvement may be obtained by pretreating the off-gases prior to burning. Condensing the vacuum jet stream and adding the condensate to the foul-water stripper has also been effective. In many refineries, the barometric condensers are being replaced with closed units which effectively eliminate this source.

### 3. BIO-OXIDATION UNITS

Odor emissions have been controlled by separating and pretreating particularly odorous streams. Proper maintenance of pH levels and mechanical aeration have also decreased odor emissions. In addition, proper handling of the bio-oxidation unit sludge improves odor prevention.

### 4. CATALYTIC CRACKING UNITS

Many odor problems have essentially been eliminated by the replacement of older moving bed units with new fluid catalytic cracking units. In addition, desulphurizing the feedstock has been effective.

### 5. CAUSTIC TREATMENT

Odor problems have been diminished by condensing the off-gases, recovering spent caustic by air blowing and burning the off-gases, or converting the thiols and extracting the resulting disulphides.

### 6. COKERS

Odor emissions are controlled by extracting the off-gas with gas-oil streams or condensing the off-gases and feeding the non-condensables to a process heater unit. The water quench is also a source of odors which can be eliminated by feeding the quench vapors to a flare or condensing it and adding the condensate to the foul-water stripper. The use of an amine scrubber on the off-gases with the scrubbed stream added to the fuel gas line is also effective.

### 7. DESALTER

Odors have been prevented by feeding the desalter water to a sourwater stripper, or in some circumstances by disposal in deep wells.

### 8. INCINERATOR

Odor emissions can be controlled by increasing the combustion temperature.

(to be continued)

APPENDIX E (continued)

## 9. LUBE OIL

Odors can be significantly reduced through the use of solvent extraction in place of acid treatment. Further improvement has been obtained by adding vapor control systems to the solvent storage tanks, installing blower-scrubber systems to the vents from blending and canning areas, and the use of hydrotreating instead of  $H_2SO_4$  in the production of white oil.

## 10. PROPANE LOADING

Odor problems are commonly produced during the addition of an odorant. The use of a totally enclosed odorant system and a flush of the piping with the propane after odorant addition eliminates the major source of odor.

## 11. PUMPS AND COMPRESSORS

Odors are controlled by the replacement of packed seals with mechanical seals. Where mechanical seals cannot be used, the pump seals can be enclosed and vented to flare system with flare gas recovery and led to the refinery fuel system.

## 12. SAFETY FLARES

Flares should only be used for upset conditions to minimize odor problems.

## 13. SEWER SYSTEMS

Odor problems may be prevented by adding oil separators to each process unit, pretreating the effluent before discharge to the sewer and flashing the desalter water before it discharged to the sewer. Where possible, all hot spent process water should be cooled before dumping in the sewer.

## 14. SOUR-WATER STRIPPING

Odors created can be prevented by collecting the off-gases and sending them to a sulphur recovery unit, or by incineration.

## 15. SPILLS AND LEAKS

Odor problems may be minimized by collecting the spill in vacuum trucks for quick disposal.

## 16. STEAMING OF TOWERS AND VESSELS

Odor emissions can be reduced by conducting a more complete pumpout and through the use of a water or gasoline wash prior to steaming. Improvement can also be obtained by containing the first steam and venting it to a flare and treating the waste water.

(to be continued)

APPENDIX E (continued)

**17. STORAGE TANKS FOR VOLATILE MATERIALS**

Storage tank odors prevention has been improved by the use of floating roofs and not pumping below the level where a proper seal is maintained. Odor prevention from asphalt tanks or during cleaning may be improved by venting through a charcoal cannister.

**18. SULPHUR RECOVERY UNIT**

Odor prevention may be obtained by maintaining adequate temperatures in the process unit and storing the sulphur in molten form in a closed system.

**19. VAPOR COLLECTION SYSTEM**

Odors are reduced by recovery of all off-gases and vapor emissions in a completely closed system for use as fuel gas, recycle for reprocessing, or to be sent to a combustion device for incineration.

**20. HYDROGEN TREATING**

Odors compounds are treated with hydrogen to produce desirable products and H<sub>2</sub>S.

## APPENDIX F MEASUREMENT OF AIR POLLUTION

Air samples often require detection and measurement in the ppmv to ppbv (parts by volume) range; source concentrations range from tenths of a percent to a few hundred ppmv. In areas of high population density, extensive community sampling networks have been established using continuous monitors installed at strategic locations with the data telemetered to a central data-processing center. Less complex sampling techniques are used in remote areas, in metropolitan areas with limited budgets, or in determining sites for fixed monitors. Special problems may be investigated with portable, vehicle-carried, or airborne sampling equipment. Air sampling may fulfill one or more of the following objectives :

- 1) Establishing and operating a pollution alert network;
- 2) monitoring the effect of an emission source;
- 3) predicting the effect of a proposed installation,
- 4) establishing seasonal or yearly trends,
- 5) locating the source of an undesirable pollutant,
- 6) obtaining permanent sampling records for legal action, and,
- 7) correlating pollutant dispersion with Environmental Protection Organization of Iran (EPOI).

Source sampling has problems which are distinct and different from ambient sampling. Source gas temperature may be high and contain high concentrations of water vapor or entrained mist, dust, or other interfering substances; and particulates and gases may be deposited on or absorbed in extractive probes before reaching the measuring instrument. Typical objectives in source sampling are:

- 1) Demonstrating compliance with regulations;
- 2) providing emission data;
- 3) measuring product loss or optimizing process variables;
- 4) obtaining engineering data for design;
- 5) acceptance testing of control equipment, and;
- 6) determining need for maintenance of process or control equipment. Depending on the objective, source sampling may be infrequent, occasional, intermittent, or continuous.

### Source sampling

Source test methods for air pollutants fall into two broad categories, based on the physical state of the target pollutant, solid or fluid.

Details are given in IPS-C-SF-860.

Methods for the measurement of the concentration of particulate matter in ducts carrying gases is also in IPS-C-SF-860.

### Equipment

List of equipment for measurement of particulate content are given in IPS-C-SF-860.

### Principle of isokinetic sampling

In order to have a representative measurement of the dust content in the duct, an isokinetic sample has to be taken at each measuring point. Details are given in IPS-C-SF-860.

(to be continued)

## APPENDIX F (continued)

## Gaseous pollutants

Modern source-test methods for sampling gaseous pollutants from stacks involve two basic approaches: Continuous emissions monitoring, or CEM, and wet chemistry. In CEM, the pollutant is monitored in real-time using analyzers to detect the chemical in situ (in the stack) or in a sample of the gas that has been extracted from the stack and conditioned.

CEM analyzers are available for monitoring carbon monoxide, NO<sub>x</sub>, SO<sub>2</sub>, total hydrocarbons, hydrogen sulfide and hydrochloric acid. Many contractors who perform source tests have mobile vans outfitted with CEM systems for short-term monitoring programs.

The second approach, wet chemistry, involves collecting the sample in a container, solid adsorbent or liquid-impinger train that must be manipulated manually in the field and then removed to a laboratory for analysis. All the gases that can be measured with CEM also have their respective "wet chemistry" method.

In addition, there are wet-chemistry methods for the class of gaseous pollutants that includes benzene, vinyl chloride, and formaldehyde. EPA method 106 for vinylchloride. The EPA volatile organic. Sampling Train (VOST) for organics, and California Air Resources Board (CARB) Method 430 for formaldehyde is accepted.

## Whole-air sampling

EPA Method 106 is an example of "whole air" sampling, in which a sample of the stack gas is extracted from the stack into a container called a Tedlar bag. The whole air sample is then transported to the laboratory for gas chromatography (GC) analysis.

Although Tedlar bags are used to collect several types of compounds, their use requires care. Different compounds behave differently in the bags, thus influencing the reproducibility of the analytical results.

EPA's gas-chromatographic technique specifies flame ionization detection (FID) for analyzing vinyl chloride. However, the GC-FID analyzer can sometimes give erroneous results because it may actually be detecting compounds other than vinyl chloride.

To increase the level of confidence of an analysis, the laboratory technician should perform a second-column confirmation (by running the sample on another GC column). Otherwise, by the time the error is discovered, the sample's "holding time" can have expired and it may no longer be representative of the emissions stream.

The mass spectrophotometer (MS) detector is a better alternative for gas analysis. Although a GC-FID analysis is generally less expensive than one using GC-MS, the mass spectrometer provides the actual proof (or disproof)

- without second-column confirmation
- that a peak on the gas chromatograph is the target compound.

However, compared with FID and other GC detectors, the mass spectroscopy suffers from low detection limits. This limitation is being overcome with cryogenic concentration techniques, which are now being incorporated into modern GC-MS systems for the analysis of air.

**(to be continued)**

## APPENDIX F (continued)

### Volatile-organics sampling

EPA's Volatile Organics Sampling Train (VOST) can sample vinyl chloride and a much-larger host of volatile organic gases than can be handled by Tedlar bags. In VOST, stack gas is extracted from the source, cooled, and passed through

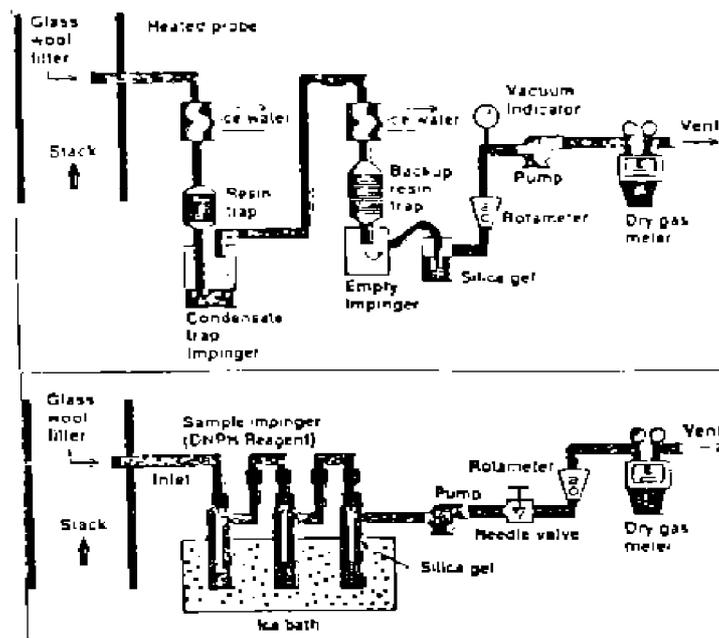
a pair of adsorbent traps (Fig. 6, top). The first trap is of Tenax; the second, Tenax and charcoal. The traps are then taken to the laboratory, where they are thermally desorbed onto the cryogenic trap of the GC-MS system.

This method allows for longer sample-holding times. Further, the traps can be spiked with isotopically labeled target compounds—the ultimate in quality assurance because it provides for a high degree of confidence in the test result if the spike is present. Good spike-recovery means that the target compound survived the rigors of sampling and was thermally desorbed from the sample tube without degradation.

Another sampling train for gases is CARB's Method 430 for formaldehyde (Fig. F-1, bottom). This is an example of "wet impingement" and is particularly interesting in that part of the analytical chemistry is accomplished in the impinger during sampling.

The emissions gas is extracted from the stack and bubbled through impingers containing an acidic solution of 2,4-dinitrophenylhydrazine (DNPH); formaldehyde (and other aldehydes) reacts with the DNPH to form a stable derivative. The sample is recovered from the sampling train and transported for analysis.

In the laboratory, the derivative is extracted with an organic solvent and analyzed by high-pressure liquid chromatography (HPLC) fitted with an ultraviolet detector. It should be noted that contamination is a real problem with this method. Rigorous steps must be taken to ensure that the impinger solutions are clean and protected from exposure to ambient air during the entire course of use.



**SAMPLING TRAINS FOR VOLATILE ORGANICS (PHOTO AND TOP SCHEMATIC) AND A "WET IMPINGEMENT" METHOD FOR FORMALDEHYDE**

**Fig. F-1**

(to be continued)

**APPENDIX F (continued)**

## Determination in work place air

### Determination of vinyl chloride-charcoal tube/gas chromatographic method

It is said that even 1 ppm of monomer in vinyl chloride is carcinogenic. The method is for determination of the vinyl chloride monomer concentration in work place air in the range from  $250 \text{ Mg/m}^3 (= 100 \text{ ml/m}^3)$  to  $25 \text{ Mg/m}^3 (= 10 \text{ ml/m}^3)$  when sampling of 30 lit of air is taken.

#### Principle

A known volume of air sample is passed through a glass or metal tube packed with activated charcoal. The vinyl chloride is adsorbed onto the charcoal. The collected vinyl chloride is desorbed using carbon disulfide and analysed with a gas chromatograph equipped with a flame ionization detector.

#### Reagents

During the analysis, use only reagents of recognized analytical grade and only distilled water or water of equivalent quality.

- a) Vinyl chloride liquid in a small gas cylinder.

##### Warning

Vinyl chloride is recognized as a human carcinogen. Avoid any exposure by inhalation or skin contact. Personal protection (e.g. an effective respirator shall be available in all cases where exposure to vinyl chloride is possible.

Vinyl chloride vapor is highly flammable. Usage shall be restricted to a well-ventilated fume cupboard. An effective fire extinguisher shall be permanently available.

- b) Carbon disulfide ( $\text{CS}_2$ ), chromatographic quality, previously checked for compounds coincident with the vinyl chloride peak. The  $\text{CS}_2$  shall not contain impurities that coelute with vinyl chloride giving a response greater than 0,06 ng of vinyl chloride at an injection volume of 1  $\mu\text{l}$ . This requirement shall be checked for each batch of  $\text{CS}_2$ .

##### Warning

Carbon disulfide vapor is toxic. Avoid any exposure by inhalation or skin contact. Carbon disulfide is highly flammable. Usage shall be restricted to a well ventilated fume cupboard. An effective fire extinguisher shall be permanently available.

Small waste quantities of carbon disulfide shall be disposed of only in accordance with local regulations and accepted practices.

- c) Activated coconut shell charcoal, particle size 0,35 mm to 0,85 mm. Before packing the tubes, the charcoal shall be heated in an inert atmosphere, e.g. high-purity nitrogen, at approximately  $600^\circ\text{C}$  for 1 h. To prevent recontamination of the charcoal, it shall be kept in a clean atmosphere during cooling to room temperature, storage and loading into the tubes.

(to be continued)

## APPENDIX F (continued)

#### Note:

Suitable tubes containing pretreated coconut charcoal are commercially available (see 6.1).

d) Vinyl chloride standard solutions for the preparation of the calibration graph.

1) Vinyl chloride standard solution, containing 260 mg of  $C_2H_3Cl$  per liter.

Pipette 10.0 ml of the carbon disulfide (b) into a vial, cap the vial and cool in dry ice. Obtain pure vinyl chloride vapor at atmospheric pressure by partially filling a previously evacuated gas bag with pure gas from the small gas cylinder (a).

Fill a syringe (5.8) with 1.0 ml of the vinyl chloride vapor from the gas bag and close the valve of the syringe. Insert the tip of the needle through the septum cap into the carbon disulfide. Open the valve and withdraw the plunger slightly to allow the carbon disulfide to enter the syringe. The action of the vinyl chloride dissolving in the carbon disulfide creates a vacuum and the syringe becomes filled with the solvent. Return the solution to the vial. Flush the syringe twice with the solution and return the flushings to the vial.

1 ml of this standard solution contains 260  $\mu g$  of  $C_2H_3Cl$ .

**Note:**

**The vinyl chloride concentrations are given for the case in which the vinyl chloride vapor is injected at 20°C and 101.3 kPa.**

2) Vinyl chloride standard solution containing 52 mg of  $C_2H_3Cl$  per liter.

Add approximately 5 ml of the carbon disulfide to a 10 ml one-mark volumetric flask. Pipette 2 ml of the standard solution into this flask, dilute to the mark with the carbon disulfide and mix well.

1 ml of this Standard solution contains 52  $\mu g$  of  $C_2H_3Cl$ .

3) Vinyl chloride standard solution containing 5.2 mg of  $C_2H_3Cl$  per liter.

Add approximately 5 ml of the carbon disulfide to a 10 ml one-mark volumetric flask.

Pipette 1 ml of the standard solution into this flask, dilute to the mark with the carbon disulfide and mix well.

1 ml of this standard solution contains 5.2  $\mu g$  of  $C_2H_3Cl$ .

4) Vinyl chloride standard solution containing 0.52 mg of  $C_2H_3Cl$  per liter.

Add approximately 5 ml of the carbon disulfide to a 10 ml one-mark volumetric flask. Pipette 1 ml of the standard solution into this flask, dilute to the mark with the carbon disulfide and mix well.

1 ml of this standard solution contains 0.52  $\mu g$  of  $C_2H_3Cl$ .

5) Vinyl chloride standard solution containing 0,052 mg of  $C_2H_3Cl$  per liter.

Add approximately 5 ml of the carbon disulfide to a 10 ml one-mark volumetric flask. Pipette 1 ml of the standard solution item 3 into this flask, dilute to the mark with the carbon disulfide and mix well.

1 ml of this standard solution contains 0.52  $\mu g$  of  $C_2H_3Cl$ .

**(to be continued)**

**APPENDIX F (continued)**

e) Vinyl chloride control solutions for checking the calibration graph.

1) Vinyl chloride control solution, containing 130 mg of  $C_2H_3Cl$  per liter.

Prepare this solution as described in d.1, but inject 0.5 ml instead of 1,0 ml of the vinyl chloride vapor.

1 ml of this control solution contains 130  $\mu g$  of  $C_2H_3Cl$ .

2) Vinyl chloride control solution, containing 52 mg of  $C_2H_3Cl$  per liter.

Use the solution prepared as described in e.I.

1 ml of this control solution contains 0.52  $\mu g$  of  $C_2H_3Cl$ .

### **Apparatus**

Standard for:

Ordinary laboratory apparatus are given in IPS-C-SF-860.

### **Expression of results**

Standard for calculation, precision and test report are given in IPS-C-SF-860.

**APPENDIX G  
EXPOSURE LEVEL ALLOWED IN WORK PLACE**

Substance	[CAS #]	ADOPTED VALUES	
		TWA ppm <sup>a)</sup> mg/m <sup>3b)</sup>	STEL ppm <sup>a)</sup> mg/m <sup>3b)</sup>
[ Acetaldehyde [75-07-0] (1976).....	100	180	150    270
Acetic acid [64-19-7] (1976).....	10	25	15    37
Acetic anhydride [108-24-7] (1976).....		C 5 C 21	—    —
•Acetone [67-64-1] (1982).....	750	1780	1000    2380
•Acetonitrile [75-06-8] (1976).....	40	67	60    101
Acetylene [74-86-2] (1981).....	— <sup>(c)</sup>	—	—    —
Acetylene dichloride, see 1,2-Dichloroethylene			
cetylene tetrabromide [79-27-6] (1986).....	1	14	—    —
Acetylsalicylic acid (Aspirin)			
[50-78-2] (1980).....	—	5	—    —
Acrolein [107-02-8] (1976).....	0.1	0.23	0.3    0.69
[ Acrylamide [79-06-1]-Skin (1987).....		—    0.03,A2	—    —
• Acrylic acid [79-10-7]-Skin (1990).....	2	5.9	—    —
•[ Acrylonitrile [107-13-1]-Skin (1984).....	2,A2	4.3,A2	—    —
•[ Aldrin [309-00-2]-Skin (1986).....	—	0.25	—    —
Allyl alcohol [107-18-6]-Skin (1976).....	2	4.8	4    9.5
[ Allyl chloride [107-06-1] (1976).....		1    3.0	2    6.0
Allyl glycidyl ether (AGE) [106-92-3] (1976).....	5	23	10    47
Allyl propyl disulfide [2179-59-1] (1976).....		2    12	3    18
a-Alumina, see Aluminum oxide			
Aluminum [7429-90-5], as Al			
Metal dust (1986).....	—	10	—    —
Pyro powders (1979).....	—	5	—    —
Welding fumes (1979).....	—	5	—    —
Soluble salts (1979).....	—	2	—    —
Alkyls (NOC <sup>(d)</sup> ) (1979).....	—	2	—    —
Aluminum oxide [1344-28-1] as Al (1986)..	—	10 <sup>(e)</sup>	—    —
[ 4-Aminodiphenyl [92-67-1]-Skin (1972).....	—	A1	—    —
2-Aminoethanol, see Ethanolamine			
2-Aminopyridine [504-29-0] (1986).....	0.5	2.0	—    —
3-Amino-1,2,4-triazole, see Amitrole			
[ Amitrole [61-82-5] (1986).....	—	0.2	—    —
Ammonia [7664-41-7] (1976).....	25	17	35    24
Ammonium chloride fume			
[12125-02-9] (1976).....	—	10	—    20
Ammonium perfluorooctanoate			
[3825-26-1] (1988) <sup>a</sup> .....	—	0.1	—    —
Ammonium, sulfamate			
[7773-06-0] (1986).....	—	10	—    —
Amosite, see Asbestos			
n-Amyl acetate [628-63-7] (1987)	100	532	—    —
sec-Amyl acetate [626-38-0] (1987).....	125	665	—    —
LL L [ Aniline [62-53-3] and homologues-Skin (1986)	2	7.6	—    —
[ Anisidine [29191-52-4] (0-, p- isomers)			
-Skin (1977).....	0.1	0.50	—    —
Antimony [7440-36-0] and compounds,			
as Sb (1980)	—	0.5	—    —
[ Antimony trioxide [1309-64-4]			
Handling and use, as Sb (1978).....	—	0.5	—    —
Production (1980).....	—	A2	—    —

(to be continued)

**APPENDIX G (continued)****ADOPTED VALUES**

Substance	[CAS #]	TWA		STEL	
		ppm <sup>a)</sup>	mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	mg/m <sup>3b)</sup>

Z

ANTU [86-88-4] (1986).....	—	0.3	—	—
Argon [7440-37-1] (1981).....	—	— <sup>(d)</sup>	—	—
<hr/>				
•[ Arsenic [7440-38-2] and soluble compounds, as As (1980).....	—	0.2	—	—
Arsenic trioxide production [1327-53-3] (1980).....	—	A2	—	—
• Arsine [7784-42-1] (1977).....	0.05	0.16	—	—
•[ Asbestos <sup>(f)</sup>				
• Amosite [12172-73-5] (1980)		0.5 fiber/cc, A1		
• Chrysotile [12001-29-5] (1980)		2 fibers/cc, A1		
• Crocidolite [12001-28-4] (1980)		0.2 fiber/cc, A1		
• Other forms (1980).....		2 fibers/cc, A1		
Asphalt (petroleum) fumes [8052-42-4] (1987).....	—	5	—	—
Atrazine [1912-24-9] (1983).....	—	5	—	—
L Azinphos-methyl [86-50-0] - Skin (1986).....	—	0.2	—	—
Barium [7440-39-3], soluble Compounds, as Ba (1977)	—	0.5	—	—
Barium sulfate [7727-43-7] (1986).....	—	—	10 <sup>(a)</sup>	—
<hr/>				
Benomyl [17804-35-2] (1986).....	0.84	10	—	—
L • Benzene [71-43-2] (1987).....	(10,A2)	(32,A2)	—	—
[ Benzidine [92.87.5]-Skin (1982).....	—	—	A1	—
<hr/>				
p-Benzoquinone, see Quinone				
Benzoyl peroxide [94-36-0] (1977).....	—	5	—	—
[ Benzo(a)pyrene [50-32-8] (1976)	—	A2	—	—
[ Benzyl chloride [100-44-7] (1977)	1	5.2	—	—
•[ Beryllium [7440-41-7] and compounds, as Be (1979)	—	0.002,A2	—	—
Biphenyl [92-52-4] (1987).....	0.2	1.3	—	—
Bismuth telluride [1304-82-1] (1986).....	—	10	—	—
Se-doped (1986).....	—	5	—	—
Borates, tetra, sodium salts [1303-96-4] Anhydrous (1977).....	—	—	1	—
<hr/>				
Decahydrate (1977).....	—	5	—	—
Pentahydrate (1977).....	—	1	—	—
Boron oxide [1303-86-2] (1986)	—	10	—	—
Boron tribromide [10294-33-4] (1986).....	C 1	C 10	—	—
Boron trifluoride [7637-07-2] (1977).....	C 1	C 2.8	—	—
Bromacil [314-40-9] (1986).....	1	11	—	—
Bromine [7726-95-6] (1976).....	0.1	0.66	0.3	2.0
Bromine pentafluoride [7789-30-2] (1986).....	0.1	0.72	—	—
Bromochloromethane, see Chlorobromomethane				
Bromoform [75-25-2]-Skin (1977).....	0.5	5.2	—	—
[ 1,3-Butadiene [106-99-0] (1986)	10,A2	22,A2	—	—
Butane [106-97-8] (1981).....	—	800 1900	—	—
Butanethiol, see Butyl mercaptan				
2-Butanone, see Methyl ethyl ketone. (MEK)				
2-Butoxyethanol (EGBE) [111-76-2]-Skin (1987)	25	121	—	—
n-Butyl acetate [123-86-4] (1976)	150	713	200	950
sec-Butyl acetate [106-46-4] (1987).....	200	950	—	—
tert-Butyl acetate [540-88-5] (1987).....	200	950	—	—
Butyl acrylate [141-32-2] (1978)	10	52	—	—

(to be continued)

**APPENDIX G (continued)**

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm <sup>a)</sup>	mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	mg/m <sup>3b)</sup>
Z					
Z					
Z					
Z					
Z					
Z					
Z					

n-Butyl alcohol [71-36-3]- kin (1977).....	C 50	C 152	—	—
§ sec-Butyl alcohol [78-92-2] (1990).....	100	303	—	—
tert-Butyl alcohol [75-65-0] (1976).....	100	303	150	455
Butylamine [109-73-9]-Skin (1976) .....	C 5	C 15	—	—
• tert-Butyl chromate, as CrO <sub>3</sub> [1189-85-1]-Skin (1977).....	—	C 0.1	—	—
• n-Butyl glycidyl ether (BGE) [2426-08-6] (1981).....	25	133	—	—
n-Butyl lactate [138-22-7] (1977)	5	30	—	—
Butyl mercaptan [109-79-5] (1977).....	0.5	1.8	—	—
o-sec-Butylphenol {89-72-5} - Skin (1980).....	5	31	—	—
p-tert-Butyltoluene [98-51-1] (1976).....	10	61	20	121
L [ Cadmium [7440-43-9] dusts and salts, as Cd (1976).....	—	(0.05)	—	—
Cadmium oxide [1306-19-0 Fume, as Cd (1974).....	—	(C 0.05)	—	—
Production (1983).....	—	(0.05)	—	—
Calcium carbonate [1317-65-3] (1986).....	—	10 <sup>(e)</sup>	—	—
Calcium cyanamide [156-62-7] (1986).....	—	0.5	—	—
Calcium hydroxide [1306-62-0] (1978).....	—	5	—	—
Calcium oxide [1306-78-8] (1978).....	—	2	—	—
Calcium silicate [1344-95-2] (1974).....	—	10 <sup>(a)</sup>	—	—
Calcium sulfate [7778-18-9] (1986).....	—	10 <sup>(e)</sup>	—	—
Camphor, synthetic [76-22-2] (1976).....	2	12	3	19
Caprolactam [105-60-2] Dust (1974).....	—	(1)	—	(3)
Vapor (1974).....	(4.3)	(20)	(8.6)	(40)
Captafol [2425-06-1]-Skin (1977).....	—	0.1	—	—
Captan [133-06-2] (1986).....	—	5	—	—
Carbaryl [63-25-2] (1986).....	—	5	—	—
Carbofuran [1563-66-2] (1977).....	—	0.1	—	—
[ Carbon black [1333-86-4] (1986).....	—	3.5	—	—
Carbon dioxide [124-38-9] (1986).....	5000	9000	30,000	54,000
L • Carbon disulfide [75-15-0]-Skin (1986).....	—	10	31	—
L • Carbon monoxide [630-08-0] (1976).....	—	50	57	400
458				
Carbon tetrabromide [558-13-4] (1976).....	0.1	1.4	0.3	4.1
•[ Carbon tetrachloride [56-23-5]-Skin (1986).....	5,A2	31,A2	—	—
Carbonyl chloride, see phosgene				
Carbonyl fluoride [353-50-4] (1981).....	2	5.4	5	13
Catechol [120-80-9] (1977).....	5	23	—	—
Cellulose (paper fiber) [9004-34-6] (1986).....	—	10	—	—
Cesium hydroxide [21351-79-1] (1977).....	—	2	—	—
§[ Chlordane [57-74-9]-Skin (1990).....	—	0.5	—	—
[ Chlorinated camphene [8001-35-2]-Skin (1976).....	—	0.5	—	1
§ Chlorinated diphenyl oxide [31242-93-0] (1990).....	—	0.5	—	—
Chlorine [7782-50-5] (1989).....	0.5	1.5	1	2.9
Chlorine dioxide [10049-04-4] (1976).....	0.1	0.28	0.3	0.83
Chlorine trifluoride [7790-91-2] (1977).....	C 0.1	C 0.38	—	—
Chloroacetaldehyde [107-20-0] (1977).....	C 1	C 3.2	—	—
Chloroacetone [78-95-5]-Skin (1989).....	C 1	C 3.8	—	—
a-Chloroacetophenone [532-27-4] (1977).....	0.05	0.32	—	—
Chloroacetyl chloride [79-04-9] (1980).....	(0.05)	(0.23)	—	—
Chlorobenzene [108-90-7] (1950).....	(75)	(345)	—	—

(to be continued)

APPENDIX G (continued)

**ADOPTED VALUES**

Substance	[CAS #]	TWA		STEL	
		ppm <sup>a)</sup>	mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	mg/m <sup>3b)</sup>

	o-Chlorobenzylidene malononitrile [2698-41-1] -Skin (1983).....	C 0.05	C 0.39	—	—
	§ Chlorobromomethane [74-97-5] (1990).....	200	1060	—	—
	2-Chloro-1.3-butadiene, see β-Chloroprene				
	§ Chlorodifluoromethane [75-45-6] (1990).....	1000	3540	—	—
	§• Chlorodiphenyl (42% chlorine) [53469-21-9]-Skin (1990).....	—	1	—	—
	§•[ Chlorodiphenyl (54% chlorine) [11097-69-1]-Skin (1990).....	—	0.5	—	—
	1-Chloro-2.3-epoxy propane, see Epichlorohydrin				
	2-Chloroethanol, see Ethylene chlorohydrin				
	Chloroethylene, see Vinyl chloride				
	•[ Chloroform [67-66-3] (1986).....	10,A2	49,A2	—	—
	[ bis (Chloromethyl) ether [542-88-1] (1981).....		0.001,A1	0.0047,A1	—
	[ Chloromethyl methyl ether [107-30-2] (1983)...		A2	A2	—
	1-Chloro-1-nitropropane [600-25-9] (1981).....	2	10	—	—
	Chloropentafluoroethane [76-15-3] (1981).....		1000	6320	—
	§ Chloropicrin [76-06-2] (1990).....	0.1	0.67	—	—
	•[ β-Chloroprene [126-99-8]-Skin (1980).....	10	36	—	—
	o-Chlorostyrene [2039-87-4] (1976).....	50	283	75	425
	§ o-Chlorotoluene [96-49-8] (1990).....	50	259	—	—
	2-Chloro-6-(trichloromethyl) pyridine, see Nitrapyrin				
	§ Chlorpyrifos [2921-88-2]-Skin (1990).....	—	0.2	—	—
	• Chromite ore processing (Chromate), as Cr (1978).....	—	0.05,A1	—	—
	Chromium [7440-47-3] Metal (1981).....	—	0.5	—	—
	Chromium (II) compounds, as Cr (1981).....	—	0.5	—	—
	Chromium (III) compounds, as Cr (1981).....	—	0.5	—	—
	L•[ Chromium (VI) compounds, as Cr				
	L• Water soluble (1981).....	—	0.05	—	—
	• Certain water insoluble (1981).....	—	0.05,A1	—	—
	Z•[ Chromyl chloride [14977-61-8] (1982).....	0.025	0.16	—	—
	[ Chrysene [218-01-9] (1981).....		A2	A2	—
	Chrysotile, see Asbestos				
	§ Clopidol [2971-90-6] (1990).....	—	10	—	—
	Coal dust (1987).....	—	2. <sup>(g)</sup> Respirable fraction	—	—
	•[ Coal tar pitch volatiles [65996-93-2], as benzene solubles (1981).....	—	0.2,A1	—	—
	[ Cobalt [7440-48-4], as Co Metal dust & fume (1987).....	—	0.05	—	—
	Cobalt carbonyl [10210-68-1], as Co (1983)....	—	0.1	—	—
	Cobalt hydrocarbonyl [16842-03-8], as Co (1983).....	—	—	0.1	—
	Copper [7440-50-8] Fume (1977).....	—	—	0.2	—
	Dusts & mists, as Cu (1986).....	—	1	—	—
	Cotton dust, raw (1986).....	—	0.2 <sup>(h)</sup>	—	—
	• Cresol [1319-77-3], all isomers-Skin ((1977)....	5	22	—	—
	Cristobalite, see Silica-Crystalline				
	Crocidolite, see Asbestos				
	[ Crotonaldehyde [4170-30-3] (1987).....		2	5.7	—
	§ Crufomate [299-86-5] (1990).....	—	5	—	—
	Cumene [98-82-8]-Skin (1987).....	—	50	246	—
	Cyanamide [420-04-2] (1977).....	—	2	—	—

(to be continued)

ADOPTED VALUES

Substance	[CAS #]	TWA		STEL	
		ppm <sup>a)</sup>	mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	mg/m <sup>3b)</sup>
Cyanides [151-50-8; 143-33-9], as CN-Skin (1977).....	—	—	5	—	—
Cyanogen [460-19-5] (1977).....	10	—	21	—	—
Cyanogen chloride [506-77-4] (1980).....	C 0.3	—	C 0.75	—	—
Cyclohexane [110-82-7] (1987).....	300	—	1030	—	—
Cyclohexanol [108-93-0]-Skin (1977).....	50	—	206	—	—
Cyclohexanone [108-94-1]-Skin (1987).....	25	—	100	—	—
Cyclohexene [110-83-8] (1977).....	300	—	1010	—	—
Cyclohexylamine [108-91-8] (1977).....	10	—	41	—	—
§ Cyclonite [121-82-4]-Skin (1990).....	—	—	1.5	—	—
Cyclopentadiene [542-92-7] (1987).....	75	—	203	—	—
Cyclopentane [287-92-3] (1987).....	600	—	1720	—	—
Cyhexatin [13121-70-5] (1986).....	—	—	5	—	—
2,4-D [94-75-7] (1986).....	—	—	10	—	—
• [ DDT (Dichlorodiphenyl-trichloroethane) [50-29-3] (1986).....	—	—	1	—	—
Decaborane [17702-41-9]-Skin (1976).....	0.05	—	0.25	0.15	0.75
L Demeton [8065-48-3]-Skin (1966).....	0.01	—	0.11	—	—
Diacetone alcohol [123-42-2] (1987).....	50	—	238	—	—
1,2-Diaminoethane, see Ethylenediamine					
Diatomaceous earth, see Silica-Amorphous					
L Diazinon [333-41-5]-Skin (1986).....	—	—	0.1	—	—
[ Diazomethane [334-88-3] (1977).....	0.2	—	0.34	—	—
Diborane [19287-45-7] (1977).....	0.1	—	0.11	—	—
1,2-Dibromoethane, see Ethylene dibromide					
2-N-Dibutylaminoethanol [102-81-8]-Skin (1986).....	2	—	14	—	—
[ Dibutyl phenyl phosphate [2528-78-7]-Skin (1990).....	0.3	—	3.5	—	—
Dibutyl phosphate [107-66-4] (1976).....	1	—	8.6	2	17
Dibutyl phthalate [84-74-2] (1987).....	—	—	5	—	—
[ Dichloroacetylene [7572-29-4] (1977).....	C 0.1	—	C 0.39	—	—
o-Dichlorobenzene [96-50-1]-Skin (1977)...	C 50	—	C 301	—	—
p-Dichlorobenzene [106-46-7] (1977).....	75	—	451	110	661
[ 3,3'-Dichlorobenzidine [91-94-1]-Skin (1976).....	—	—	A2	—	—
Dichlorodifluoromethane [75-71-8] (1986)..	1000	—	4950	—	—
1,3-Dichloro-5,5-dimethyl hydantion [118-52-5] (1976).....	—	—	0.2	—	0.4
• 1,1-Dichloroethane [75-34-3] (1976).....	200	—	810	250	1010
1,2-Dichloroethane, see Ethylene dichloride					
1,1-Dichloroethylene, see Vinylidene chloride					
1,2-Dichloroethylene [540-59-0] (1987).....	200	—	793	—	—
Dichloroethyl ether [111-44-4]-Skin (1976)....	5	—	29	10	58
Dichlorofluoromethane [75-43-4] (1980).....	10	—	42	—	—
Dichloromethane, see Methylene chloride					
1,1-Dichloro-1-nitroethane [594-72-9] (1986)..	2	—	12	—	—
1,2-Dichloropropane, see Propylene dichloride					
[ Dichloropropene [542-75-6]-Skin (1986).....	1	—	4.5	—	—
2,2-Dichloropropionic acid [75-99-0] (1980)...	1	—	5.8	—	—
Dichlorotetrafluoroethane [76-14-2] (1986)....	1000	—	6990	—	—
L Dichlorvos [62-73-7]-Skin (1986).....	0.1	—	0.90	—	—
Dicrotophos [141-66-2]-Skin (1977).....	—	—	0.25	—	—

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm <sup>a)</sup>	mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	mg/m <sup>3b)</sup>
Dicyclopentadiene [77-73-6] (1977).....		5	27	—	—
Dicyclopentadienyl iron [102-54-5] (1986).....		—	10	—	—
•[ Dieldrin [60-57-1]-Skin (1986).....		—	0.25	—	—
Diethanolamine [111-42-2] (1980).....		3	13	—	—
Diethylamine [109-89-7] (1981).....		10	30	25	75
2-Diethylaminoethanol [100-37-8]-Skin (1977)..		10	48	—	—
Diethylene triamine [111-40-0]-Skin (1977).....		1	4.2	—	—
Diethyl ether, see Ethyl ether					
Di(2-ethylhexyl) phthalate, see Di-sec-octyl phthalate					
Diethyl ketone [96-22-0] (1981).....		200	705	—	—
Diethyl phthalate [84-66-2] (1987).....		—	5	—	—
Difluorodibromomethane [75-61-6] (1986).....		100	858	—	—
[ Diglycidyl ether (DGE) [2238-07-5] (1981).....		0.1	0.53	—	—
Dihydroxybenzene, see Hydroquinone					
Diisobutyl ketone [108-83-8] (1977).....		25	145	—	—
Diisopropylamine [108-18-9]-Skin (1977).....		5	21	—	—
Dimethoxymethane, see Methylal					
Dimethyl acetamide [127-19-5]-Skin (1986).....		10	36	—	—
Dimethylamine [124-40-3] (1977).....		10	18	—	—
Dimethylaminobenzene, see Xylidene					
L Dimethylaniline [121-69-7]					
(N,N-Dimethylaniline)-Skin (1976).....		5	25	10	50
Dimethylbenzene, see Xylene					
[ Dimethyl carbamoyl chloride [79-44-7] (1978)...		A2	A2	—	—
Dimethyl-1,2-dibromo-2,2-dichloroethyl phosphate, see Naled					
L Dimethylformamide [68-12-2]-Skin (1986).....		10	30	—	—
2,6-Dimethyl-4-heptanone, see Diisobutyl ketone					
•[ 1,1-Dimethylhydrazine [57-14-7]-Skin (1976).....		(0.5,A2)	(12,A2)	—	—
Dimethylnitrosoamine, see N-Nitrosodimethylamine					
Dimethylphthalate [131-11-3] (1986).....		—	5	—	—
[ Dimethyl sulfate [77-78-1]-Skin (1977).....		0.1,A2	0.52,A2	—	—
Dinitolmide [148-01-6] (1976).....		—	5	—	—
L Dinitrobenzene [528-29-0; 99-65-0; 100-25-4]					
(all isomers)-Skin (1986).....		0.15	1.0	—	—
Dinitro-o-cresol [534-52-1]-Skin (1986).....		—	0.2	—	—
3,5-Dinitro-o-toluamide, see Dinitolmide					
L •[ Dinitrotoluene [25321-14-6]-Skin (1986).....		—	1.5	—	—
•[ Dioxane [123-91-1]-Skin (1986).....		25	90	—	—
L Dioxathion [78-34-2]-Skin (1977).....		—	0.2	—	—
Diphenyl, see Biphenyl					
Diphenylamine [122-39-4] (1986).....		—	10	—	—
Diphenylmethane diisocyanate, see Methylene bisphenyl isocyanate					
Dipropylene glycol methyl ether					
[34590-94-8]-Skin (1976).....		100	606	150	909
Dipropyl ketone [123-19-3] (1981).....		50	233	—	—
Diquat [85-00-7] (1986).....		—	0.5	—	—
•[ Di-sec-octyl phthalate [117-81-7] (1976).....		—	5	—	10
Disulfiram [97-77-8] (1986).....		—	2	—	—
Disulfoton [298-04-4] (1986).....		—	0.1	—	—
2,6-Di-tert-butyl-p-cresol [128-37-0] (1987).....		—	10	—	—
Diuron [330-54-1] (1977).....		—	10	—	—
Divinyl benzene [1321-74-0] (1980).....		10	53	—	—
Emery [1302-74-5] (1986).....		—	10 <sup>(e)</sup>	—	—

(to be continued)

APPENDIX G (continued)

ADOPTED VALUES					
Substance	[CAS #]	TWA		STEL	
		ppm <sup>a)</sup>	mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	mg/m <sup>3b)</sup>
Endosulfan [115-29-7]-Skin (1986).....	—	—	0.1	—	—
Endrin [72-20-8]-Skin (1988).....	—	—	0.1	—	—
Enflurane [13838-16-9] (1988).....	75	—	566	—	—
Enzymes, see Subtilisins					
Z • [ Epichlorohydrin [106-89-8]-Skin (1986).....	(2)	—	(7.6)	—	—
L EPN [2104-64-5]-Skin (1986).....	—	—	0.5	—	—
1.2-Epoxypropane, see propylene oxide					
2.3-Epoxt-1-propanol, see Glycidol					
Ethane [74-84-0] (1981).....	—(c)	—	—	—	—
Ethanethiol, see Ethyl mercaptan					
Ethanol, see Ethyl alcohol					
Ethanolamine [141-43-5] (1978).....	3	—	7.5	6	15
L Ethion [563-12-2]-Skin (1977).....	—	—	0.4	—	—
• 2-Ethoxyethanol (EGEE) [110-80-5]-Skin (1984)	5	—	18	—	—
2-Ethoxyethyl acetate (EGEEA)					
[111-15-9]-Skin (1984).....	5	—	27	—	—
Ethyl acetate [141-78-6] (1977).....	400	—	1440	—	—
• [ Ethyl acrylate [140-88-5] (1990).....	5,A2	—	20,A2	15,A2	61,A2
Ethyl alcohol [64-17-5] (1977).....	1000	—	1880	—	—
Ethylamine [75-04-7] (1977).....	10	—	18	—	—
Ethyl amyl ketone [541-85-5] (1977).....	25	—	131	—	—
L Ethyl benzene [100-41-4] (1976).....	100	—	434	125	543
Z Ethyl bromide [74-96-4] (1976).....	(200)	—	(891)	(250)	(1110)
Ethyl butyl ketone [106-35-4] (1987).....	50	—	234	—	—
Ethyl chloride [75-00-3] (1986).....	1000	—	2640	—	—
Ethylene [74-85-1] (1981).....	—(c)	—	—	—	—
Ethylene chlorohydrin					
[107-07-3]-Skin (1977).....	C 1	—	C 3.3	—	—
Ethylenediamine [107-15-3] (1977).....	10	—	25	—	—
[ Ethylene dibromide [106-93-4]-Skin (1982).....	A2	—	A2	—	—
• [ Ethylene dichloride [107-06-2] (1986).....	10	—	40	—	—
Ethylene glycol [107-21-1]					
Vapor and mist (1981).....	C 50	—	C 127	—	—
• Ethylene glycol dinitrate					
[628-96-6]-Skin (1985).....	0.05	—	0.31	—	—
Ethylene glycol methyl ether acetate, see 2-Methoxyethyl acetate					
[ Ethylene oxide [75-21-8] (1984).....	1,A2	—	1.8,A2	—	—
• [ Ethylenimine [151-56-4]-Skin (1977).....	0.5	—	0.88	—	—
Ethyl ether [60-29-7] (1976).....	400	—	1210	500	1520
Ethyl formate [109-94-4] (1987).....	100	—	303	—	—
Ethylidene chloride, see 1.1-Dichloroethane					
Ethylidene norbornene [16219-75-3] (1977)..	C 5	—	C 25	—	—
Ethyl mercaptan [75-08-1] (1986).....	0.5	—	1.3	—	—
N-Ethylmorpholine [100-74-3]-Skin (1986)..	5	—	24	—	—
Ethyl silicate [78-10-4] (1986).....	10	—	85	—	—
L Fenamiphos [22224-92-6]-Skin (1984).....	—	—	0.1	—	—
L Fensulfothion [115-90-2] (1977).....	—	—	0.1	—	—
L Fenthion [55-38-9]-Skin (1983).....	—	—	0.2	—	—
Ferbam [14484-64-1] (1986).....	—	—	10	—	—
Ferrovandium dust [12604-58-9] (1983).....	—	—	1	—	3
• Fibrous glass dust (1978).....	—	—	10	—	—
L Fluorides, as F (1977).....	—	—	2.5	—	—

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		TWA ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	STEL ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
• Fluorine [7782-41-4] (1976).....		1	1.6	2	3.1
Fluorotrichloromethane, see Trichlorofluoromethane					
L Fonofos [944-22-9-Skin (1977).....		—	0.1	—	—
Z •[ Formaldehyde [50-00-0] (1985).....		(1,A2)	(1.2,A2)	(2,A2)	(2.5,A2)
Formamide [75-12-7]-Skin (1988).....		10	18	—	—
Z Formic acid [64-18-6] (1967).....		5	9.4	(—)	(—)
L Furfural [98-01-1]-Skin (1987).....		2	7.9	—	—
Furfuryl alcohol [98-00-0]-Skin (1982).....		10	40	15	60
• Gasoline [8006-61-9] (1982).....		300	890	500	1480
Germanium tetrahydride [7782-65-2] (1986)		0.2	0.63	—	—
Glass, fibrous or dust, see Fibrous glass dust					
Glutaraldehyde [111-30-8] (1979).....		C 0.2	C 0.82	—	—
Glycerin mist [56-81-5] (1981).....		—	10 <sup>(i)</sup>	—	—
Glycidol [556-52-5] (1987).....		25	76	—	—
Glycol monoethyl ether, see 2-Ethoxyethanol					
Grain dust (oat, wheat, barley) (1986).....		—	4 <sup>(i)</sup>	—	—
Z Graphite (natural) [7782-42-5] (1987).....		—	(2.5 <sup>(i)</sup> , Respirable dust)	—	—
Z Graphite (synthetic) [7782-42-5] (1971).....		—	(10 <sup>(e)</sup> )	—	—
Gypsum, see Calcium sulfate					
Hafnium [7440-58-6] (1986).....		—	0.5	—	—
Halothane [151-67-7] (1988).....		50	404	—	—
Helium [7440-59-7] (1981).....		— <sup>(c)</sup>	—	—	—
Z [ Heptachloe [76-44-8]-Skin (1986).....		—	(0.5)	—	—
Heptane [142-82-5] (n-Heptane) (1976).....		400	1640	500	2050
2-Heptanone, see Methyl n-amyl ketone					
3-Heptanone, see Ethyl butyl ketone					
[ Hexachlorobutadiene					
[87-68-3]-Skin (1982).....		0.02,A2	0.21,A2	—	—
Hexachlorocyclopentadiene [77-47-4] (1986)		0.01	0.11	—	—
Z Hexachloroethane [67-72-1] (1989).....		(1)	(9.7)	—	—
Hexachloronaphthalene					
[1335-87-1]-Skin (1986).....		—	0.2	—	—
Hexafluoroacetone [684-16-2]-Skin (1986)...		0.1	0.68	—	—
Hexamethylene diisocyanate					
[822-06-0] (1988).....		0.005	0.034	—	—
[ Hexamethyl phosphoramidate					
[680-31-9]-Skin (1978).....		A2	A2	—	—
L Hexane (n-Hexane) [110-54-3] (1982).....		50	176	—	—
• Other isomers (1982).....		500	1760	1000	3500
2-Hexanone, see Methyl n-butyl ketone					
Hexone, see Methyl isobutyl ketone					
sec-Hexyl acetate [108-84-9] (1977).....		50	295	—	—
Hexylene glycol [107-41-5] (1977).....		C 25	C 121	—	—
Z •[ Hydrazine [302-01-2]-Skin (1977).....		(0.1,A2)	(0.13,A2)	—	—
Hydrogen [1333-74-0] (1981).....		— <sup>(c)</sup>	—	—	—
Hydrogenated terphenyls [37275-59-5] (1977)		0.5	4.9	—	—
Hydrogen bromide [10035-10-6] (1986).....		C 3	C 9.9	—	—
Hydrogen chloride [7647-01-0] (1977).....		C 5	C 7.5	—	—
• Hydrogen cyanide [74-90-8]-Skin (1980).....		C 10	C 11	—	—
Hydrogen fluoride [7664-39-3], as F (1986)..		C 3	C 2.6	—	—
Hydrogen peroxide [7722-84-1] (1986).....		1	1.4	—	—
Hydrogen selenide [7783-07-5], as Se (1977)		0.05	0.16	—	—
• Hydrogen sulfide [7783-06-4] (1976).....		10	14	15	21

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
Hydroquinone [123-31-9] (1987).....	—	—	2	—	—
4-Hydroxy-4-methyl-2-pentanone, see Diacetone alcohol					
2-Hydroxypropyl acrylate [999-61-1]-Skin (1980).....		0.5	2.8	—	—
Indene [95-13-6] (1987).....		10	48	—	—
Indium [7440-74-6] & compounds, as in (1986).....	—	—	0.1	—	—
Iodine [7553-56-2] (1977).....		C 0.1	C 1.0	—	—
Iodoform [75-47-8] (1986).....		0.6	10	—	—
Iron oxide fume (Fe <sub>2</sub> O <sub>3</sub> ) [1309-37-1], as Fe (1986).....		B2	5	—	—
Iron pentacarbonyl [13463-40-6], as Fe (1982).....		0.1	0.23	0.2	0.45
Iron salts, soluble, as Fe (1986).....	—	—	1	—	—
Isoamyl acetate [123-92-2] (1987).....		100	532	—	—
Isoamyl alcohol [123-51-3] (1976).....		100	361	125	452
§ Isobutyl acetate [110-19-0] (1990).....		150	713	—	—
Isobutyl alcohol [78-83-1] (1987).....		50	152	—	—
Isooctyl alcohol [26952-21-6]-Skin (1982).		50	266	—	—
Isophorone [78-59-1] (1977).....		C 5	C 28	—	—
Isophorone diisocyanate [4098-71-9]-Skin (1988).....		0.005	0.045	—	—
Isopropoxyethanol [109-59-1] (1987).....		25	106	—	—
Isopropyl acetate [108-21-4] (1976).....		250	1040	310	1290
Isopropyl alcohol [67-63-0] (1976).....		400	983	500	1230
Isopropylamine [75-31-0] (1976).....		5	12	10	24
N-Isopropylaniline [768-52-5]-Skin (1986).		2	11	—	—
Isopropyl ether [108-20-3] (1976).....		250	1040	310	1300
• Isopropyl glycidyl ether (IGE) [4016-14-2] (1976).....		50	238	75	356
Kaolin [1332-58-7] (1986).....	—	—	10 <sup>(e)</sup>	—	—
Ketene [463-51-4] (1976).....		0.5	0.86	1.5	2.6
L•[ Lead [7439-92-1], inorg dusts & fumes, as Pb (1986).....	—	—	0.15	—	—
Lead arsenate [7784-40-9], as PbHAsO <sub>4</sub> (1985).....	—	—	0.15	—	—
Z •[ Lead chromate [7758-97-6], (as Cr) (1977).	—	—	(0.05,A2)	—	—
Limestone, see Calcium carbonate					
[ Lindane [58-89-9]-Skin (1986).....	—	—	0.5	—	—
Lithium hydride [7580-67-8] (1977).....	—	—	0.025	—	—
L.P.G. (Liquified petroleum gas) [68476-85-7] (1987).....		1000	1800	—	—
Magnesite [546-93-0] (1986).....	—	—	10 <sup>(e)</sup>	—	—
Magnesium oxid fume [1309-48-4] (1977)	—	—	10	—	—
L Malathion [121-75-5]-Skin (1977).....	—	—	10	—	—
Maleic anhydride [108-31-6] (1977).....		0.25	1.0	—	—
Manganese [7439-96-5], as Mn					
• Dust & compounds (1988).....	—	—	5	—	—
Fume (1979).....	—	—	1	—	3
Manganese cyclopentadienyl tricarbonyl. [12079-65-1], as Mn-Skin (1986).....	—	—	0.1	—	—

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
Marble, see Calcium carbonate					
Mercury [7439-97-6], as Hg-Skin					
Alkyl compounds (1980).....	—		0.01	—	0.03
All forms except alkyl Vapor (1982).....	—		0.05	—	—
• Aryl & inorganic compounds (1982).....	—		0.1	—	—
• Mesityl oxide [141-79-7] (1981).....	15		60	25	100
Methacrylic acid [79-41-4] (1981).....	20		70	—	—
Methane [74-82-8] (1981).....	— <sup>(d)</sup>		—	—	—
Methanethiol, see Methyl mercaptan					
Methanol, see Methyl alcohol					
L Methomyl [16752-77-5] (1977).....	—		2.5	—	—
Methoxychlor [72-43-5] (1977).....	—		10	—	—
• 2-Methoxyethanol (EGME)					
[109-86-4]-Skin (1984).....	5		16	—	—
2-Methoxyethyl acetate (EGMEA)					
[110-49-6]-Skin (1984).....	5		24	—	—
4-Methoxyphenol [150-76-5] (1982).....	—		5	—	—
Methyl acetate [79-20-9] (1976)	200		606	250	757
§ Methyl acetylene [74-99-7] (1990).....	1000		1640	—	—
Methyl acetylene-propadiene					
mixture (MAPP) (1976).....	1000		1640	1250	2050
Methyl acrylate [96-33-3]-Skin (1977).....	10		35	—	—
Methylacrylonitrile [126-98-7]-Skin (1986)	1		2.7	—	—
Methylal [109-87-5] (1987).....	1000		3110	—	—
Methyl alcohol [67-56-1]-Skin (1976).....	200		262	250	328
Methylamine [74-89-5] (1977).....	10		13	—	—
Methyl amyl alcohol, see Methyl isobutyl carbinol					
Methyl n-amyl ketone [110-43-0] (1987).....	50		233	—	—
L N-Methyl aniline [100-61-8]-Skin (1986).....	0.5		2.2	—	—
• [Methyl bromide [74-83-9]-Skin (1986).....	5		19	—	—
• Methyl n-butyl ketone [591-78-6]-Skin (1981)	5		20	—	—
• [Methyl chloride [74-87-3]-Skin (1981).....	50		103	100	207
• L Methyl chloroform [71-55-6] (1976).....	350		1910	450	2460
Methyl 2-cyanoacrylate [137-05-3] (1976)....	2		9.1	4	18
Methylcyclohexane [108-87-2] (1987).....	400		1610	—	—
Methylcyclohexanol [25639-42-3] (1987).....	50		234	—	—
o-Methylcyclohexanone [583-60-8]-Skin (1976)	50		229	75	344
2-Methylcyclopentadienyl					
manganese tricarbonyl [12108-13-3], as					
Mn-Skin (1986).....	—		0.2	—	—
L Methyl demeton [8022-00-2]-Skin (1986).....	—		0.5	—	—
Methylene bisphenyl isocyanate (MDI)					
[101-68-8] (1988).....	0.005		0.051	—	—
• [Methylene chloride [75-09-2] (1988).....	50,A2		174,A2	—	—
ZL • [4.4-Methylene bis(2-chloroaniline)					
[101-14-4]-Skin (1974).....	(0.02,A2)		(0.22,A2)	—	—
Methylene bis (4-cyclohexylisocyanate)					
[5124-30-1] (1988).....	0.005		0.054	—	—
[ 4.4-Methylene dianiline [101-77-9]-Skin (1986)	0.1,A2		0.81,A2	—	—
L Methyl ethyl ketone (MEK) [78-93-3] (1976)..	200		590	300	885

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		TWA		STEL	
		ppm <sup>a)</sup>	mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	mg/m <sup>3b)</sup>
Methyl ethyl ketone peroxide [1338-23-4] (1977)		C 0.2	C 1.5	—	—
Methyl formate [107-31-3] (1976).....		100	246	150	368
5-Methyl-3-heptanone, see Ethyl amyl ketone..					
Z •[ Methyl hydrazine [60-34-4]-Skin (1976).....		(C 0.2,A2)	(C 0.38,A2)	—	—
•[ Methyl iodide [74-88-4]-Skin (1986).....		2,A2	12,A2	—	—
Methyl isoamyl ketone [110-12-3] (1982).....		50	234	—	—
Methyl isobutyl carbinol [108-11-2]-Skin (1976)		25	104	40	167
Methyl isobutyl ketone [108-10-1] (1981).....		50	205	75	307
Methyl isocyanate [624-83-9]-Skin (1977).....		0.02	0.047	—	—
Methyl isopropyl ketone [563-80-4] (1981).....		200	705	—	—
• Methyl mercaptan [74-93-1] (1977).....		0.5	0.98	—	—
Methyl methacrylate [80-62-6] (1987).....		100	410	—	—
L Methyl parathion [298-00-0]-Skin (1986).....		—	0.2	—	—
• Methyl propyl ketone [107-87-9] (1976).....		200	705	250	881
Methyl silicate [681-84-5] (1986).....		1	6	—	—
a-Methyl styrene [98-83-9] (1981).....		50	242	100	483
Metribuzin [21087-64-9] (1984).....		—	5	—	—
L Mevinphos [7786-34-7]-Skin (1976).....		0.01	0.092	0.03	0.27
Mica [12001-26-2] (1986).....		—	3 <sup>(i)</sup> Respirable dust	—	—
Mineral wool fiber (1974).....		—	10 <sup>(e)</sup>	—	—
Molybdenum [7439-98-7], as Mo					
Soluble compounds (1986)		—	5	—	—
Insoluble compounds (1986).....		—	10	—	—
Monochlorobenzene, see Chlorobenzene					
Monocrotophos [6923-22-4] (1977).....		—	0.25	—	—
Z Morpholine [110-9-8]-Skin (1966).....		20	71	(30)	(107)
L Naled [300-76-5]-Skin (1986).....		—	3	—	—
Naphthalene [91-20-3] (1976).....		10	52	15	79
[ β-Naphthylamine [91-59-8] (1972).....		—	A1	—	—
Neon [7440-01-9] (1981).....		— <sup>(c)</sup>	—	—	—
[ Nickel [7440-02-0]					
Z Metal (1966).....		—	(1)	—	—
Z Insoluble compounds, as Ni (1974).....		—	(1)	—	—
Z •[ Soluble compounds, as Ni (1976).....		—	(0.1)	—	—
Z •[ Nickel carbonyl [13463-39-3], as Ni (1977)..		(0.05)	(0.12)	—	—
Z •[ Nickel sulfide roasting,					
fume & dust, as Ni (1978).....		—	(1,A1)	—	—
Nicotine [54-11-5]-Skin (1986).....		—	0.5	—	—
Nitrapyrin [1929-82-4] (1982).....		—	10	—	20
Nitric acid [7697-37-2] (1976).....		2	5.2	4	10
L Nitric oxide [10102-43-9] (1986).....		25	31	—	—
L p-Nitroaniline [100-01-6]-Skin (1982).....		—	3	—	—
L Nitrobenzene [98-95-3]-Skin (1986).....		1	5	—	—
L p-Netrochlorobenzene [100-00-5]-Skin (1988)		0.1	0.64	—	—
[ 4-Netrodiphenyl [92-93-3] (1976).....		—	A1	—	—
Nitroethane [79-24-3] (1986).....		100	307	—	—
Nitrogen [7727-37-9] (1989).....		— <sup>(c)</sup>	—	—	—
• Nitrogen dioxide [10102-44-0] (1981).....		3	5.6	5	9.4
L Nitrogen trifluoride [7783-54-2] (1986).....		10	29	—	—
• Nitroglycerin (NG) [55-63-0]-Skin (1985).....		0.05	0.46	—	—

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
Z Nitromethane [75-52-5] (1986).....		(100)	(250)	—	—
1-Nitropropane [108-03-2] (1986).....		25	91	—	—
[ 2-Nitropropane [79-46-9] (1987).....		10,A2	36,A2	—	—
[ N-Nitrosodimethylamine [62-75-9]-Skin (1972).		—	A2	—	—
L Nitrotoluene [88-72; 99-08-1; 99-99-0]-Skin (1982).....		2	11	—	—
Nitrotrichloromethane, see Chloropicrin					
Nitrous oxide [10024-97-2] (1989).....		50	90	—	—
Nonane [111-84-2] (1976).....		200	1050	—	—
Nuisance particulates, see Particulates Not Otherwise Classified (PNOC)					
Octachloronaphthalene [2234-13-1]-Skin (1976)		—	0.1	—	0.3
Octane [111-65-9] (1976).....		300	1400	375	1750
Oil mist, mineral (1976).....		—	5 <sup>(k)</sup>	—	10
Osmium tetroxide [20816-12-01], as Os (1976).		0.0002	0.0016	0.0006	0.0047
Oxalic acid [144-62-7] (1976).....		—	1	—	2
Oxygen difluoride [7783-41-7] (1986).....		C 0.05	C 0.11	—	—
Ozone [10028-15-6] (1989).....		C 0.1	C 0.20	—	—
Paraffin wax fume [8002-74-2] (1987).....		—	2	—	—
paraquat [4685-14-7], respirable sizes (1978)....		—	0.1	—	—
• [ Parathion [56-38-2]-Skin (1986).....		—	0.1	—	—
Particulate polycyclic aromatic hydrocarbons (PPAH), see Coal tar pitch volatiles					
Particulates Not Otherwise Classified (PNOC) (1986).....		—	10	—	—
Pentaborane [19624-22-7] (1976).....		0.005	0.013	0.015	0.039
Pentachloronaphthalene [1321-64-8] (1986).....		—	0.5	—	—
L Pentachlorophenol [87-86-5]-Skin (1986).....		—	0.5	—	—
Pentaerythritol [115-77-5] (1986).....		—	10	—	—
• Pentane [109-66-0] (1976).....		600	1770	750	2210
2-Pentanone, see Methyl propyl ketone					
L• [ Perchloroethylene [127-18-4] (1984).....		50	339	200	1370
Perchloromethyl mercaptan [594-42-3] (1977)....		0.1	0.76	—	—
Perchloryl fluoride [7616-94-6] (1976).....		3	13	6	25
Precipitated silica, see Silica-Amorphous					
Perlite [93763-70-3] (1986).....		—	10 <sup>(e)</sup>	—	—
Petroleum distillates, see Gasoline; Stoddard solvent; VM&P naphtha					
Phenacyl chloride, see a-Chloroacetophenone					
L Phenol [108-95-2]-Skin (1987).....		5	19	—	—
Phenothiazine [92-84-2]-Skin (1986).....		—	5	—	—
[ N-Phenyl-beta-naphthylamine [135-88-6] (1979)		A2	A2	—	—
Z p-Phenylenediamine [106-50-3]-Skin (1966)....		—	0.1	—	—
Phenyl ether [101-84-8], vapor (1976).....		1	7	2	14
Phenylethylene, see Styrene, monomer					
Z• [ Phenyl glycidyl ether (PGE) [122-60-1] (1982)...		1	6.1	—	—
• [ Phenylhydrazine [100-63-0]-Skin (1985).....		(5,A2)	(22,A2)	(10,A2)	(44,A2)
• Phenyl mercaptan [108-98-5] (1978).....		0.5	2.3	—	—
Phenylphosphine [638-21-1] (1977).....		C 0.05	C 0.23	—	—
Phorate [298-02-2]-Skin (1976).....		—	0.05	—	0.2
Phosdrin, see Mevinphos					
Phosgene [75-44-5] (1978).....		0.1	0.40	—	—
Phosphine [7803-51-2] (1976).....		0.3	0.42	1	1.4
Phosphoric acid [7664-38-2] (1976).....		—	1	—	3
Phosphorus (yellow) [7723-14-0] (1986).....		—	0.1	—	—

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
§ Phosphorus oxychloride [10025-87-3] (1990).....		0.1	0.63	—	—
Phosphorus pentachloride [10026-13-8] (1980)...		0.1	0.85	—	—
Phosphorus pentasulfide [1314-80-3] (1976).....		—	1	—	3
Phosphorus trichloride [7719-12-2] (1982).....		0.2	1.1	0.5	2.8
Phthalic anhydride [85-44-9] (1987).....		1	6.1	—	—
m-Phthalodinitrile [626-17-5] (1977).....		—	5	—	—
§ Picloram [1918-02-1] (1990).....		—	10	—	—
• Picric acid [88-89-1] (1990).....		—	0.1	—	—
Pindone [83-26-1] (1987).....		—	0.1	—	—
Piperazine dihydrochloride [142-64-3] (1982).....		—	5	—	—
2-Pivalyl-1.3-indandione, see Pindone					
Plaster of Paris, see Calcium sulfate					
Platinum [7440-06-4] Metal (1981).....		—	1	—	—
Soluble salts, as Pt (1981)		—	0.002	—	—
Polychlorobiphenyls, see Chlorodiphenyls					
Polytetrafluoroethylene decomposition products (1972).....		—	B1	—	—
Portland cement [65997-15-1] (1986).....		—	10 <sup>(e)</sup>	—	—
Potassium hydroxide [1310-58-3] (1977).....		—	C 2	—	—
• Propane [74-98-6] (1981).....		— <sup>(c)</sup>	—	—	—
[ Propane sultone [1120-71-4] (1977).....		A2	A2	—	—
Propargyl alcohol [107-19-7]-Skin (1987).....		1	2.3	—	—
[ β-Propiolactone [57-57-8] (1987).....		0.5,A2	1.5,A2	—	—
§ Propionic acid [79-09-4] (1990).....		10	30	—	—
Propoxur [114-26-1] (1987).....		—	0.5	—	—
n-Propyl acetate [109-60-4] (1976).....		200	835	250	1040
n-Propyl alcohol [71-23-8]-Skin (1976).....		200	492	250	614
Propylene [115-07-1] (1976).....		— <sup>(d)</sup>	—	—	—
Propylene dichloride [78-87-5] (1976).....		75	347	110	508
L Propylene glycol dinitrate [6423-43-4]-Skin (1985)		—	0.05	0.34	—
Propylene glycol monomethyl ether [107-98-2] (1976).....		100	369	150	553
[ Propylene imine [75-55-8]-Skin (1983).....		2,A2	4.7,A2	—	—
[ Propylene oxide [75-56-9] (1981).....		20	48	—	—
L n-Propyl nitrate [627-13-4] (1978).....		—	25	107	40
172 Propyne, see Methyl acetylene .					
Pyrethrum [8003-34-7] (1981).....		—	5	—	—
Pyridine [110-86-1] (1987).....		5	16	—	—
Pyrocatechol, see Catechol Quartz, see Silica-					
Crystalline Quinone [106-51-4] (1987).....		0.1	0.44	—	—
RDX, see Cyclonite					
Resorcinol [108-46-3] (1976).....		10	45	20	90
• Rhodium [7440-16-6]					
•Metal (1982).....		—	\1	—	—
•Insoluble compounds, as Rh (1984).....		—	1	—	—
•Soluble compounds, as Rh (1984).....		—	0.01	—	—
Ronnel [299-84-3] (1977).....		—	10	—	—
Rosin core solder pyrolysis products, as formaldehyde (1987).....		—	0.1	—	—
Rotenone (commercial) [83-79-4] (1987).....		—	5	—	—
Rouge (1986).....		—	10 <sup>(e)</sup>	—	—
• Rubber solvent (Naphtha) (1977).....		400	1590	—	—

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
Selenium [7782-49-2] and compounds, as Se (1977).....	—	—	0.2	—	—
Selenium hexafluoride [7783-79-1], as Se (1979).....	—	0.05	0.16	—	—
Sesone [136-78-7] (1986).....	—	—	10	—	—
Silane, see Silicon tetrahydride					
Silica-Amorphous					
•Diatomaceous earth (uncalcined) [61790-53-2] (1986).....	—	—	10 <sup>(n)</sup>	—	—
•Precipitated silica [112926-00-8] (1987).....	—	—	10 <sup>(e)</sup>	—	—
•Silica gel [112926-00-8] (1987).....	—	—	10 <sup>(e)</sup>	—	—
[ Silica-Crystalline Cristobalite [14464-46-1] (1986).....	—	—	0.05 <sup>(i)</sup>	Respirable dust	—
• Quartz [14808-60-7] (1986).....	—	—	0.1 <sup>(i)</sup>	Respirable dust.	—
Z • Silica fused [60676-86-0] (1985).....	—	—	0.1 <sup>(i)</sup>	Respirable dust.	—
Tridymite [15468-32-3] (1986).....	—	—	0.05 <sup>(i)</sup>	Respirable dust.	—
• Tripoli [1317-95-9] (1985).....	—	—	0.1 <sup>(i)</sup>	Of contained respirable quartz	—
Silicon [7440-21-3] (1986).....	—	—	10 <sup>(e)</sup>	—	—
Silicon carbide [409-21-2] (1986).....	—	—	10 <sup>(e)</sup>	—	—
Silicon tetrahydride [7803-62-5] (1983).....	—	5	6.6	—	—
Silver [7440-22-4]					
•Metal (1981).....	—	—	0.1	—	—
Soluble compounds, as Ag (1981).....	—	—	0.01	—	—
Soapstone					
Respirable dust (1985).....	—	—	3 <sup>(i)</sup>	—	—
Total dust (1985).....	—	—	6 <sup>(e)</sup>	—	—
Sodium azide [26628-22-8] (1977).....	—	C 0.11	C 0.29	—	—
Sodium bisulfite [7631-90-5] (1980).....	—	—	5	—	—
Sodium 2,4-dichloro-phenoxyethyl sulfate, see Sesone					
Sodium fluoroacetate [62-74-8]-Skin (1976)...	—	—	0.05	—	0.15
Sodium hydroxide [1310-73-2] (1977).....	—	—	C 2	—	—
Sodium metabisulfite [7681-57-4] (1980).....	—	—	5	—	—
Starch [9005-25-8] (1986).....	—	—	10	—	—
Stearates <sup>(l)</sup> (1988).....	—	—	10	—	—
Stibine [7803-52-3] (1986).....	—	0.1	0.51	—	—
• Stoddard solvent [8052-41-3] (1987).....	—	100	525	—	—
Strychnine [57-24-9] (1986).....	—	—	0.15	—	—
•[ Styrene, monomer [100-42-5]-Skin (1981).....	—	50	213	100	426
Subtilisins [1395-21-7] (Proteolytic enzymes as 100% pure crystalline enzyme) (1977).....	—	—	C 0.00006 <sup>(m)</sup>	—	—
Sucrose [57-50-1] (1986).....	—	—	10	—	—
L Sulfotep [3689-24-5]-Skin (1986).....	—	—	0.2	—	—
• Sulfur dioxide [7446-09-5] (1986).....	—	2	5.2	5	13
Sulfur hexafluoride [2551-62-4] (1986).....	—	1000	5970	—	—
Sulfuric acid [7664-93-9] (1989).....	—	—	1	—	3
Sulfur monochloride [10025-67-9] (1986)....	—	C 1	C 5.5	—	—
Sulfur pentafluoride [5714-22-7] (1986).....	—	C 0.01	C 0.10	—	—
Sulfur tetrafluoride [7783-60-0] (1986).....	—	C 0.1	C 0.44	—	—
Sulfuryl fluoride [2699-79-8] (1976).....	—	5	21	10	42
Sulprofos [35400-43-2] (1984).....	—	—	1	—	—

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
Systox, see Demeton 2.4.5-T [93-76-5] (1986)..	—		10	—	—
Talc (containing no asbestos fibers)					
[14807-96-6] (1983).....	—		2 <sup>(i)</sup> Respirable dust		
[ Talc (containing asbestos fibers) (1985).....			Use asbestos TLV-TWA. <sup>(n)</sup>		
Tantalum [7440-25-7], metal					
and oxide [1314-61-0] dusts (1988).....	—		5	—	—
TEDP, see Sulfotep					
Tellurium [13494-80-9] and compounds, as Te (1977)					
Tellurium hexafluoride [7783-80-4], as Te (1977)	0.02		0.10	—	—
L Temephos [3383-96-8] (1986).....	—		10	—	—
L TEPP [107-49-3]-Skin (1986).....	0.004		0.047	—	—
Terphenyls [26140-60-3] (1980).....	C 0.5		C 4.7	—	—
1.1.1.2-Tetrachloro-2,2-difluoroethane					
[76-12-0] (1986).....	500		4170	—	—
1.1.2.2-Tetrachloro-1.2-difluoroethane					
[76-12-0] (1986).....	500		4170	—	—
[ 1,1,2,2-Tetrachloroethane [79-34-5]-Skin (1986)	1		6.9	—	—
Tetrachloroethylene, see Perchloroethylene					
Tetrachloromethane, see Carbon tetrachloride					
Tetrachloronaphthalene [1335-88-2] (1986)....	—		2	—	—
• Tetraethyl lead [78-00-2], as Pb-Skin (1986)....	—		0.1 <sup>(o)</sup>	—	—
Tetrahydrofuran [109-99-9] (1976).....	200		590	250	737
• Tetramethyl lead [75-74-1], as Pb-Skin (1986).	—		0.15 <sup>(o)</sup>	—	—
Tetramethyl succinonitrile					
[3333-52-6]-Skin (1986).....	0.5		2.8	—	—
Tetranitromethane [509-14-8] (1977).....	1		8	—	—
Tetrasodium pyrophosphate [7722-88-5] (1980)	—		5	—	—
• Tetryl [479-45-8] (1986).....	—		1.5	—	—
Thallium [7440-28-0] Soluble compounds,					
as Tl-Skin (1977).....	—		0.1	—	—
4,4-Thiobis (6-tert-butylm-cresol .					
[96-69-5] (1986).....	—		10	—	—
Thioglycolic acid [68-11-1]-Skin (1978).....	1		3.8	—	—
Thionyl chloride [7719-09-7] (1986).....	C 1		C 4.9	—	—
Thiram [137-26-8] (1990).....	—		1	—	—
Tin [7440-31-5]					
Metal (1982).....	—		2	—	—
Oxide & inorganic compounds, except					
SnH <sub>4</sub> as Sn (1982).....	—		2	—	—
Z Organic compounds, as Sn-Skin (1965).....	—		0.1	—	(—)
Titanium dioxide [13463-67-7] (1986).....	—		10 <sup>(e)</sup>	—	—
[ o-Tolidine [119-93-7]-Skin (1982).....	A2		A2	150	565
L Toluene [108-88-3] (1976).....	100		377	150	565
[ Toluene-2,4-diisocyanate					
(TDI) [584-84-9] (1983).....	0.005		0.036	0.02	0.14
L [ 0-Toluidine [95-53-4]-Skin (1984).....	2,A2		8.8,A2	—	—
L m-Toluidine [108-44-1]-Skin (1986).....	2		8.8	—	—
L p-Toluidine [106-49-0]-Skin (1986).....	2,A2		8.8,A2	—	—
Toluol, see Toluene					
Toxaphene, see Chlorinated camphene					
Tributyl phosphate [126-73-8] (1986).....	0.2		2.2	—	—
Trichloroacetic acid [76-03-9] (1980).....	1		6.7	—	—

(to be continued)

APPENDIX G (continued)

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
1,2,4-Trichlorobenzene [120-82-1] (1978).....		C 5	C 37	—	—
1,1,1-Trichloroethane, see Methyl chloroform					
•[ 1,1,2-Trichloroethane [79-00-5]-Skin (1986)....		10	55	—	—
L•[ Trichloroethylene [79-01-6] (1984).....		50	269	200	1070
Trichlorofluoromethane [75-69-4] (1982).....		C 1000	C 5620	—	—
Trichloromethane, see Chloroform					
Trichloronaphthalene [1321-65-9]-Skin (1986)		—	5	—	—
Trichloronitromethane, see Chloropicrin					
1,2,3-Trichloropropane [96-18-4]-Skin (1987)..		10	60	—	—
1,1,2-Trichloro-1,2,2-trifluoroethane [76-13-1] (1976).....		1000	7670	1250	9590
Tricyclohexyltin hydroxide, see Cyhexatin					
Tridymite, see Silica-Crystalline					
Triethylamine [121-44-8] (1983).....		10	41	15	62
Trifluorobromomethane [75-63-8] (1986).....		1000	6090	—	—
Trimellitic anhydride [552-30-7] (1981).....		0.005	0.039	—	—
Trimethylamine [75-50-3] (1983).....		10	24	15	36
Trimethyl benzene [[25551-13-7] (1987).....		25	123	—	—
Trimethyl phosphite [121-45-9] (1986).....		2	10	—	—
2,4,6-Trinitrophenol, see Picric acid					
2,4,6-Trinitrophenylmethylnitramine, see Tetryl					
L[ 2,4,6-Trinitrotoluene (TNT) [118-96-7]-Skin (1986).....		—	0.5	—	—
Triorthocresyl phosphate [78-30-8]-Skin (1986)		—	0.1	—	—
Triphenyl amine [603-34-9] (1980).....		—	5	—	—
Triphenyl phosphate [115-86-6] (1986).....		—	3	—	—
Tripoli, see Silica-Crystalline					
Tungsten [7440-33-7], as W					
Insoluble compounds (1976) .....		—	5	—	10
Soluble compounds (1976)		—	1	—	3
Turpentine [8006-64-2] (1987)		100	556	—	—
• Uranium (natural) [7440-61-1]					
Soluble & insoluble compounds, as U (1976).....		—	0.2	—	0.6
n-Valeraldehyde [110-62-3] (1978).....		50	176	—	—
Vanadium, as V <sub>2</sub> O <sub>5</sub> [1314-62-1]					
Respirable dust & fume (1982).....		—	0.05	—	—
Vegetable oil mists <sup>(p)</sup> (1972).....		—	10	—	—
• Vinyl acetate [108-05-4] (1976).....		10	35	20	70
Vinyl benzene, see Styrene					
• [ Vinyl bromide [593-60-2] (1980).....		5,A2	22,A2	—	—
• [ Vinyl chloride [75-01-4] (1980).....		5,A1	13,A1	—	—
Vinyl cyanide, see Acrylonitrile					
[ Vinyl cyclohexene dioxide [106-87-6]-Skin (1977).....		10,A2	57,A2	—	—
• [ Vinylidene chloride [75-35-4] (1984).....		5	20	20	79
Vinyl toluene [25013-15-4] (1981).....		50	242	100	483
• VM & P Naphtha [8032-32-4] (1987).....		300	1370	—	—
Warfarin [81-81-2] (1987).....		—	0.1	—	—
Welding fumes (NOC <sup>(d)</sup> ) (1977).....		—	5,B2	—	—
[ Wood dust (certain hard woods as beech & oak) (1981).....		—	1	—	—

(to be continued)

**APPENDIX G (continued)**

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
[ Soft wood (1981).....	—	—	5	—	10
L Xylene [1330-20-7; 95-47-6; 108-38-3; 106-42-3] (o-, m-p-isomers) (1976).....	100	100	434	150	651
m-Xylene a,a'-diamine [1477-55-0]-Skin (1977)	—	—	C 0.1	—	—
L • Xylidine (mixed isomers) [1300-73-8]-Skin (1990).....	—	0.5,A2	2.5,A2	—	—
Yttrium [7440-65-5] metal & compounds, as Y (1988).....	—	—	1	—	—
Zinc chloride fume [7646-85-7] (1976).....	—	—	1	—	2
•[ Zinc chromates [13530-65-9; 1103-86-9; 37300-23-5], as Cr (1988).....	—	—	0.01,A1	—	—
Zinc oxide [1314-13-2] Fume (1976).....	—	—	5	—	10
Dust (1976).....	—	—	10 <sup>(e)</sup>	—	—
Zirconium [7440-67-7] and compounds, as Zr (1976).....	—	—	5	—	10

(to be continued)

**APPENDIX G (continued)  
NOTICE OF INTENDED CHANGES  
(for 1990-91)**

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

Substance	[CAS #]	ADOPTED VALUES			
		ppm <sup>a)</sup>	TWA mg/m <sup>3b)</sup>	ppm <sup>a)</sup>	STEL mg/m <sup>3b)</sup>
y Benzene [71-43-2]-Skin.....		0.1,A2	0.3,A2	—	—
L y L L L Cadmium [7440-43-9] and compounds, as Cd			—	0.01,A2, Total dust	
				0.002,A2, Respirable fraction <sup>(i)</sup>	
Calcium chromate [13765-19-0], as Cr.....	—	—	0.001,A2	—	—
Calcium silicate (synthetic) [1344-95-2].....	—	—	10 <sup>(e)</sup>	—	—
y Caprolactam [105-60-2] Dust.....	—	—	1	—	3
Vapor.....	5	23	10	46	
Chloroacetyl chloride [79-04-9]-Skin.....	0.05	0.23	0.15	0.69	
Chlorobenzene [108-90-7].....	10	46	—	—	
2-Chloropropionic acid [598-78-7]-Skin.....	0.1	0.44	—	—	
1,1-Dimethylhydrazine [57-14-7]-Skin.....	0.01,A2	0.025,A2	—	—	
y Epichlorohydrin [106-89-8]-Skin.....	0.1,A2	0.38,A2	—	—	
y Ethyl bromide [74-96-4]-Skin.....	5,A2	22,A2	—	—	
Formaldehyde [50-00-0].....	C 0.3,A2	C 0.37,A2	—	—	
Formic acid [64-18-6].....	5	9.4	10	19	
Graphite (all forms except graphite fibers) [7782-42-5].....	—	2, <sup>(i)</sup> Respirable dust	—	—	
y Heptachlor and heptachlor epoxide [76-44-8]- Skin.....	—	0.05,A2	—	—	
Hexachloroethane [67-72-1].....	1,A2	9.7,A2	—	—	
Hydrazine [302-01-2]-Skin.....	0.01,A2	0.013,A2	—	—	
Lead chromate [7758-97-6] as Pb.....	—	0.05,A2	—	—	
as Cr.....	—	0.012,A2	—	—	
y 4,4-Methylene bis (2-chloroaniline) [101-14-4]-Skin.....	A1	A1	—	—	
Methyl hydrazine [60-34-4]-Skin.....	0.01,A2	0.019,A2	—	—	
Morpholine [110-91-8]-Skin.....	20	71	—	—	
Nickel [7440-02-0] Metal.....	—	0.05,A1	—	—	
Insoluble compounds, as Ni.....	—	0.05,A1	—	—	
Soluble compounds, as Ni.....	—	0.05,A1	—	—	
Nickel carbonyl [13463-39-3], as Ni.....		Delete listing; nickel listing above applies.			
Nickel sulfide roasting, fume & dust, as Ni...		Delete listing; nickel listing above applies.			
y Nitromethane [75-52-5].....	20	50	—	—	
y Pentachloronitrobenzene [82-68-8].....	—	0.5	—	—	
Perfluoroisobutylene [382-21-8].....	C 0.01	C 0.082	—	—	
m-Phenylenediamine [108-45-2].....	—	0.1	—	—	
o-Phenylenediamine [95-54-5].....	—	0.1,A2	—	—	
p-Phenylenediamine [106-50-3].....	—	0.1	—	—	
Phenylhydrazine [100-63-0]-Skin.....	0.1,A2	0.44,A2	—	—	
Silica fume (amorphous) [69012-64-2].....	—	0.2 <sup>(i)</sup> Respirable dust	—	1 <sup>(i)</sup>	
y Silica, fused (amorphous) [60676-86-0].....	—	0.1 <sup>(i)</sup> Respirable dust	—	—	
Strontium chromate [7789-06-2], as Cr.....	—	0.001,A2	—	—	
Tin, organic compounds, as Sn-Skin.....	—	0.1	—	0.2	
y Triethanolamine [102-71-6].....	0.5,A2	3.1,A2	—	—	

**(to be continued)**

**APPENDIX G (continued)  
UNITS**

<b>No.</b>	<b>Quantity</b>	<b>Unit</b>	<b>Symbol</b>
2.1 Units for substances			
2.1.1 Gases and vapors			
2.1.1.1	Volume fraction of main constituents of air (for example nitrogen, oxygen, carbon dioxide)	Per cent (by volume)	%
2.1.1.2	Mass concentration of gaseous pollutants <sup>1)</sup>	milligram per cubic metre microgram per cubic metre	mg/m <sup>3</sup> µg/m <sup>3</sup>
2.1.2 Particles			
2.1.2.1	Mass concentration of suspended matter	milligram per cubic metre microgram per cubic metre nanogram per cubic metre	mg/m <sup>3</sup> µg/m <sup>3</sup> ng/m <sup>3</sup>
2.1.2.2	Size of particles	micrometre	µm
2.1.2.3	Atmospheric dustfall <sup>2)</sup> (deposit gauges)	gram per square metre thirty days milligram per square metre thirty days	g/ (m <sup>2</sup> .30 d) mg/ (m <sup>2</sup> .30 d)
2.1.2.4	Biological, microbiological and other suspended matter (for example pollen, spores, micro-organisms)	reciprocal cubic metre reciprocal cubic decimetre	m <sup>-3</sup> dm <sup>-3</sup>
2.2 Units for specifying the state of a gas			
2.2.1	Celsius temperature	degree Celsius	°C
2.2.2	Pressure	pascal kilopascal	Pa kPa
2.2.3	Relative humidity	per cent	%
2.3 Meteorological quantities			
2.3.1	Wind speed	metre per second	m/s
2.3.2	Wind direction <sup>3)</sup>	degree	°
2.3.3	Precipitation intensity	millimetre per day	mm/d
2.3.4	Irradiance	watt per square metre	W/m <sup>2</sup>
2.4 Time			
	Time	second minute hour day	s min h d
2.5 Miscellaneous			
2.5.1	Geographical location [Northern (N) or Southern (S) latitude] [Eastern (E) or Western (W) longitude]	degree	°
2.5.2	Altitude	metre	m

1) The units milligram per cubic metre and microgram per cubic metre express concentrations in mass per volume and because the mass of a voute of gas depends on temperature and pressure, the cubic metre can only be transformed to mass accurately, if ambient temperature and pessure are known.

Gaseous pollutants have often been expressed on a milligram per litre (mg/l) basis.

2) When deposit gages are used, no account is taken of the volume of air from which the atmospheric dustfall is deposited, the duration of collection of the atmospheric dustfall should also be reported.

3) Wind direction is conventionally reported as degrees measured clockwise from North as 0° to the North as 360°