XI. APPENDIX III

MATERIAL SAFETY DATA SHEET

The following items of information which are applicable to a specific product or material shall be provided in the appropriate block of the Material Safety Data Sheet (MSDS).

The product designation is inserted in the block in the upper left corner of the first page to facilitate filing and retrieval. Print in upper case letters as large as possible. It should be printed to read upright with the sheet turned sideways. The product designation is that name or code designation which appears on the label, or by which the product is sold or known by employees. The relative numerical hazard ratings and key statements are those determined by the rules in Chapter V, Part B, of the NIOSH publication, An Identification System for Occupationally Hazardous Materials. The company identification may be printed in the upper right corner if desired.

(a) Section I. Product Identification

The manufacturer's name, address, and regular and emergency telephone numbers (including area code) are inserted in the appropriate blocks of Section I. The company listed should be a source of detailed backup information on the hazards of the material(s) covered by the MSDS. The listing of suppliers or wholesale distributors is discouraged. The trade name should be the product designation or common name associated with the material. The synonyms are those commonly used for the product, especially formal chemical nomenclature. Every known chemical designation or

competitor's trade name need not be listed.

(b) Section II. Hazardous Ingredients

The "materials" listed in Section II shall be those substances which are part of the hazardous product covered by the MSDS and individually meet any of the criteria defining a hazardous material. Thus, one component of a multicomponent product might be listed because of its toxicity, another component because of its flammability, while a third component could be included both for its toxicity and its reactivity. Note that a MSDS for a single component product must have the name of the material repeated in this section to avoid giving the impression that there are no hazardous ingredients.

Chemical substances should be listed according to their complete name derived from a recognized system of nomenclature. Where possible, avoid using common names and general class names, such as "aromatic amine," "safety solvent," or "aliphatic hydrocarbon," when the specific name is known.

The "%" may be the approximate percentage by weight or volume (indicate basis) which each hazardous ingredient of the mixture bears to the whole mixture. This may be indicated as a range or maximum amount, ie, "10-40% vol" or "10% max wt" to avoid disclosure of trade secrets.

Toxic hazard data shall be stated in terms of concentration, mode of exposure or test, and animal used, ie, "100 ppm LC-rat," "25 mg/kg LD50-skin-rabbit," "75 ppm LC man," or "permissible exposure from 29 CFR 1910.1000," or if not available, from other sources of publications such as the American Conference of Governmental Industrial Hygienists or the American National Standards Institute Inc. Flashpoint, shock sensitivity

or similar descriptive data may be used to indicate flammability reactivity, or similar hazardous properties of the material.

(c) Section III. Physical Data

The data in Section III should be for the total mixture and should include the boiling point and melting point in degrees Fahrenheit (Celsius in parentheses); vapor pressure, in conventional millimeters of mercury (mmHg); vapor density of gas or vapor (air = 1); solubility in water, in parts/hundred parts of water by weight; specific gravity (water = 1); percent volatiles (indicated if by weight or volume) at 70 degrees Fahrenheit (21.1 degrees Celsius); evaporation rate for liquids or sublimable solids, relative to butyl acetate; and appearance and odor. These data are useful for the control of toxic substances. Boiling point, vapor density, percent volatiles, vapor pressure, and evaporation are useful for designing proper ventilation equipment. This information is also useful for design and deployment of adequate fire and spill containment equipment. The appearance and odor may facilitate identification of substances stored in improperly marked containers, or when spilled.

(d) Section IV. Fire and Explosion Data

Section IV should contain complete fire and explosion data for the product, including flashpoint and autoignition temperature in degrees Fahrenheit (Celsius in parentheses); flammable limits, in percent by volume in air; suitable extinguishing media or materials; special firefighting procedures; and unusual fire and explosion hazard information. If the product presents no fire hazard, insert "NO FIRE HAZARD" on the line labeled "Extinguishing Media."

(e) Section V. Health Hazard Information

The "Health Hazard Data" should be a combined estimate of the hazard of the total product. This can be expressed as a TWA concentration, as a permissible exposure, or by some other indication of an acceptable standard. Other data are acceptable, such as lowest LD50 if multiple components are involved.

Under "Routes of Exposure," comments in each category should reflect the potential hazard from absorption by the route in question. Comments should indicate the severity of the effect and the basis for the statement if possible. The basis might be animal studies, analogy with similar products, or human experiences. Comments such as "yes" or "possible" are not helpful. Typical comments might be:

> Skin Contact--single short contact, no adverse effects likely; prolonged or repeated contact, possibly mild irritation.
>
> Eye Contact--some pain and mild transient irritation; no corneal scarring.

"Emergency and First Aid Procedures" should be written in lay language and should primarily represent first-aid treatment that could be provided by paramedical personnel or individuals trained in first aid.

Information in the "Notes to Physician" section should include any special medical information which would be of assistance to an attending physician including required or recommended preplacement and periodic medical examinations, diagnostic procedures, and medical management of overexposed employees.

(f) Section VI. Reactivity Data

The comments in Section VI relate to safe storage and handling of hazardous, unstable substances. It is particularly important to highlight instability or incompatibility to common substances or circumstances, such as water, direct sunlight, steel or copper piping, acids, alkalies, etc. "Hazardous Decomposition Products" shall include those products released under fire conditions. It must also include dangerous products produced by aging, such as peroxides in the case of some ethers. Where applicable, shelf life should also be indicated.

(g) Section VII. Spill or Leak Procedures

Detailed procedures for cleanup and disposal should be listed with emphasis on precautions to be taken to protect employees assigned to cleanup detail. Specific neutralizing chemicals or procedures should be described in detail. Disposal methods should be explicit including proper labeling of containers holding residues and ultimate disposal methods such as "sanitary landfill," or "incineration." Warnings such as "comply with local, state, and federal antipollution ordinances" are proper but not sufficient. Specific procedures shall be identified.

(h) Section VIII. Special Protection Information

Section VIII requires specific information. Statements such as "Yes," "No," or "If necessary" are not informative. Ventilation requirements should be specific as to type and preferred methods. Respirators shall be specified as to type and NIOSH or Mining Enforcement and Safety Administration (formerly, US Bureau of Mines) approval class, ie, "Supplied air," "Organic vapor canister," etc. Protective equipment must be specified as to type and materials of construction.

(i) Section IX. Special Precautions

"Precautionary Statements" shall consist of the label statements selected for use on the container or placard. Additional information on any aspect of safety or health not covered in other sections should be inserted in Section IX. The lower block can contain references to published guides or in-house procedures for handling and storage. Department of Transportation markings and classifications and other freight, handling, or storage requirements and environmental controls can be noted.

(j) Signature and Filing

Finally, the name and address of the responsible person who completed the MSDS and the date of completion are entered. This will facilitate correction of errors and identify a source of additional information.

The MSDS shall be filed in a location readily accessible to employees exposed to the hazardous material. The MSDS can be used as a training aid and basis for discussion during safety meetings and training of new employees. It should assist management by directing attention to the need for specific control engineering, work practices, and protective measures to ensure safe handling and use of the material. It will aid the safety and health staff in planning a safe and healthful work environment and in suggesting appropriate emergency procedures and sources of help in the event of harmful exposure of employees.

MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION	
MANUFACTURER'S NAME	REGULAR TELEPHONE NO. EMERGENCY TELEPHONE NO.
ADDRESS	
TRADE NAME	
SYNONYMS	

II HAZARDOUS INGREDIENTS		
MATERIAL OR COMPONENT	%	HAZARD DATA

III PHYSICAL DATA			
BOILING POINT, 760 MM HG		MELTING POINT	
SPECIFIC GRAVITY (H_2O = 1)		VAPOR PRESSURE	
VAPOR DENSITY (AIR = 1)		SOLUBILITY IN H_2O, % BY WT	
% VOLATILES BY VOL		EVAPORATION RATE (BUTYL ACETATE = 1)	
APPEARANCE AND ODOR			

IV FIRE AND EXPLOSION DATA

FLASH POINT (TEST METHOD)		AUTOIGNITION TEMPERATURE	
FLAMMABLE LIMITS IN AIR, % BY VOL.	LOWER		UPPER
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARD			

V HEALTH HAZARD INFORMATION

HEALTH HAZARD DATA

ROUTES OF EXPOSURE

INHALATION

SKIN CONTACT

SKIN ABSORPTION

EYE CONTACT

INGESTION

EFFECTS OF OVEREXPOSURE

ACUTE OVEREXPOSURE

CHRONIC OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES

EYES

SKIN

INHALATION

INGESTION

NOTES TO PHYSICIAN

VI REACTIVITY DATA

CONDITIONS CONTRIBUTING TO INSTABILITY

INCOMPATIBILITY

HAZARDOUS DECOMPOSITION PRODUCTS

CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION

VII SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED

NEUTRALIZING CHEMICALS

WASTE DISPOSAL METHOD

VIII SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS

SPECIFIC PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY (SPECIFY IN DETAIL)

EYE

GLOVES

OTHER CLOTHING AND EQUIPMENT

IX SPECIAL PRECAUTIONS

PRECAUTIONARY
STATEMENTS

OTHER HANDLING AND
STORAGE REQUIREMENTS

PREPARED BY _____

ADDRESS _____

DATE _____

XII. APPENDIX IV

GLOSSARY*

ACIDOSIS - A disturbance of acid-base balance resulting from an increase in acidic chemical substances (proton donors) or loss of alkaline chemical substances (proton acceptors). If the accumulating substance is CO2 (which reacts with water to form carbonic acid), the condition is termed respiratory acidosis. If the accumulating acidic substance is other than CO2 or if alkaline substances are lost, the condition is termed metabolic acidosis. Homeostatic body mechanisms that attempt to correct an acidosis result in pH compensation. Such compensation may be complete (pH within normal limits) or only partial (pH remaining low). Acidosis is sometimes termed acidemia.

ALKALOSIS - A disturbance of acid-base balance resulting from an increase of alkaline chemical substances (proton acceptors) or loss of acidic chemical substances (proton donors). If the lost substance is CO2 (which reacts with water to form carbonic acid), the condition is termed respiratory alkalosis. If the lost acidic substance is other than CO2 or if alkaline substances increase, the condition is termed metabolic alkalosis. Homeostatic body mechanisms that attempt to correct an alkalosis result in pH compensation. Such compensation may be complete (pH within normal limits) or only partial (pH remaining high). Alkalosis is sometimes termed alkalemia.

ALVEOLAR GAS - The gas mixture present within the lungs reflecting the effects of respiratory gas exchange, as distinguished from dead space gas. The definition of alveolar gas composition is complicated by the discontinuous nature of lung ventilation, by lung perfusion, and by the nonuniform matching of these aspects of lung function. Alveolar gas is assumed to be saturated with water vapor at 37 C.

ALVEOLI, PULMONARY - Small outpocketings of the alveolar sacs, through the walls of which the gaseous exchange takes place.

APNEA - Cessation of breathing movements.

ATELECTASIS - Failure of the lungs to expand normally at birth, or collapse of an expanded lung as gas is absorbed following injury or obstruction of an airway.

CARBONIC ANHYDRASE - An enzyme present in various tissues, especially red blood cells and in the kidneys, which catalyzes the reaction: $CO_2 + H_2O = H_2CO_3$. Important in CO_2 transfer from tissues to systemic capillary blood and from pulmonary capillary blood to alveolar gas.

DEAD SPACE - Anatomic dead space is the total volume of all nongas-exchanging airway passages. It consists of the upper airway and bronchial tree as far as the respiratory bronchioles. Physiologic dead space is a calculated, not a topographic, volume. By comparison with the anatomic dead space, it expresses the nonuniformity of ventilatory perfusion in the lung.

DIFFUSING CAPACITY - The rate of gas transfer through a unit area of a permeable membrane in relation to the gas pressure difference across it. Pulmonary diffusing capacity is usually measured with O2 or CO and is expressed as ml of gas transferred/mmHg pressure difference/minute.

DYSPNEA - The uncomfortable awareness or consciousness of the need for increased breathing. It may be referred to as air hunger or labored breathing. Dyspnea is subjective by definition; it is a symptom, not a sign, usually related to decreased ventilatory capacity and increased work of breathing.

ECTOPIC FOCUS - The point at which an abnormal impulse is generated between normal impulses resulting in a premature contraction of the heart.

EOSINOPHIL - A granulocyte of the peripheral blood and bone marrow having a staining characteristic or an affinity for the red dye, eosin. Generally, eosinophils comprise only 2-4% of the total number of white cells. They are active in detoxification and in the disintegration and removal of protein from the body. Eosinophils have bilobed nuclei.

ERYTHROCYTE - A red blood cell. Human erythrocytes are biconcave, hemoglobin-containing disks about 1 μ thick and about 7.7 μ in diameter. There are normally about 5 million in each cubic millimeter of blood. The average lifespan is about 120 days. Erythrocytes are important in both O2 and CO2 transport. Circulating erythrocytes of mammals have no nuclei.

HYPERCAPNIA - A greater than normal amount of carbon dioxide in the blood.

HYPERPNEA - Increased rate or depth (or both) of breathing. Example: hyperpnea of exercise.

HYPERVENTILATION - Generally, an increased pulmonary ventilation rate beyond the actual requirement for adequate respiratory gas exchange. It may result from increased rate or depth of breathing, or a combination of these. Usually, hyperventilation is best expressed in terms of alveolar ventilation rate. It results in increased alveolar and arterial blood O2 tension and in decreased alveolar and arterial blood CO2 tension. Hyperventilation may produce dizziness, numbness, tingling, and significant psychomotor impairment if continued and is a cause of respiratory alkalosis.

HYPOVENTILATION - Generally, a reduced pulmonary ventilation rate below that actually required for adequate respiratory gas exchange. It may result from decreased rate or depth of breathing, or a combination of these. Usually, hypoventilation is best expressed in terms of alveolar ventilation rate. It results in decreased alveolar and arterial blood O2 tension, and increased alveolar and arterial blood CO2 tension. If continued, hypoventilation produces hypoxemia, hypercapnia, CO2 retention, and respiratory acidosis. Chronic alveolar hypoventilation is an important clinical syndrome. The combination of hypoxemia with respiratory acidosis constricts the pulmonary vascular bed to produce pulmonary arterial hypertension.

HYPOXEMIA - Low blood O2 tension or oxyhemoglobin saturation.

HYPOXIA - Low or reduced O2 concentration or tension at any specified point in the transfer system from inspired gas to the metabolizing tissues. Also, insufficient O2 tension or insufficient concentration of free O2 molecules to meet the requirements of aerobic metabolism. Histohypoxia: reduced or insufficient PO2 at the tissue or cellular level. Hypoxidation: a state or condition of reduced aerobic metabolism in association with the reduced energy requirements of hypothermia hibernation, hypothyroidism, or the effect of certain drugs. Hypoxidosis: a state or condition of impaired aerobic metabolism in hypoxia, enzyme deficiency or dysfunction, substrate lack, or excessive accumulation of metabolites. Paradoxically, hypoxidosis may result from hyperbaric oxygenation.

MINUTE VOLUME OF BREATHING - The volume of gas inspired or expired/minute under any given conditions. Usually, expiratory minute volume is expressed as expired gas vol/min. Note that expired gas usually differs from inspired gas with regard to temperature and to water vapor, CO2, and O2 contents.

PARTIAL PRESSURE - The pressure or tension exerted by any constituent gas in a mixture; the most significant measurement with respect to the physicochemical and physiologic behavior of a gas. As described by Dalton's law, the total pressure of a gas mixture is the arithmetic sum of all the individual partial pressures of the constituent gases.

PULMONARY EDEMA - A clinical term referring to a transudate of body fluids within the alveolar spaces of the lung. Usually, it is the result of increased pulmonary intravascular pressure, or it may be due to chemical

injury to the alveolar membrane. Such fluid may interfere greatly with respiratory gas exchange. Compare: pulmonary interstitial edema, which usually occurs earlier and is an accumulation of transudate fluid within the pulmonary tissues.

SURFACE TENSION - A property of liquids that is due to intermolecular attractive forces, or cohesion, and to the specific orientation of molecules at the boundary of a liquid. A force exerted in the plane of the interface that acts to preserve the integrity of the surface of separation and to resist rupture of the surface film. The tension upon the surface of a liquid in contact with another fluid with which it does not mix. An exposed liquid surface tends to contract to the smallest possible area, forming spheroidal drops (one surface) or bubbles (two surfaces). Laplace's law relates surface tension and radius to pressure. Surface tension is expressed as dynes/cm or as ergs/sq cm.

TIDAL VOLUME - The volume of gas added to, and then removed from, functional residual capacity with each breath; it is usually about 500 ml. Tidal volume comprises the volume entering the alveoli (300 to 400 ml) plus the volume remaining in the airway (150 to 200 ml) for each breath. It increases with metabolic rate (O2 consumption and CO2 production) as, for example, in exercise. Tidal volume multiplied by respiratory frequency gives the rate of total pulmonary ventilation, a value that is usually expressed in liters/min. During mild-to-moderate exercise, tidal volume increases largely by increase of the volume of gas in the lungs at the end of inspiration (at the expense of inspiratory reserve volume). During heavy exercise, tidal volume increases proportionately more by decrease of

the volume of gas in the lungs at the end of expiration (at the expense of expiratory reserve volume).

*Adapted from Slonim and Hamilton [150]

XIII. APPENDIX V

CALCULATION OF pH USING THE HENDERSON-HASSELBALCH EQUATION*

The dissociation constant of carbonic acid is expressed as

$$KA = \frac{[H]\ [HCO3]}{[H2CO3]}$$

The Henderson-Hasselbalch equation shows the relationship of this dissociation in terms of pH. It substitutes the concentration of carbon dioxide for carbonic acid in the denominator because the equilibrium is such that only minimal amounts of the acid exist relative to the amount of dissolved gas. At equilibrium, dissolved carbon dioxide exceeds carbonic acid by 809 times. [26] The equation also illustrates that the relationship between bicarbonate and carbon dioxide determines the blood pH. It also illustrates that, as long as this ratio remains constant, the pH will not change. In normal individuals, the ratio is 20:1 and the blood pH is normally 7.40 as shown by the following calculations:

$$pH = pK + \log \frac{[HCO3]}{[CO2]}$$

where, in arterial blood of healthy persons,

$[HCO3] = 56.8$ vol% $CO2$

$[CO2] = 2.84$ vol% $CO2$

$pK = 6.10$

therefore

$$\begin{aligned} pH &= 6.1 + \log 20 \\ &= 6.1 + 1.30 \\ &= 7.40 \end{aligned}$$

The sequence of bicarbonate and carbon dioxide concentration changes during respiratory acidosis and the subsequent compensation for this acidosis may be calculated as follows:

Condition	$\frac{[HCO3]}{[CO2]}$	$pH = 6.1 + \log \frac{[HCO3]}{[CO2]}$
Control	$\frac{24.0}{1.2} = 20$	7.40
Respiratory acidosis	$\frac{27.2}{1.6} = 17$	7.34
Partial compensation	$\frac{28.8}{1.6} = 18$	7.36
Chronic acidosis, compensated	$\frac{32.0}{1.6} = 20$	7.40

*Adapted from Comroe et al [151] and Comroe [26]

XIV. TABLES

TABLE XIV-1

PHYSICAL CONSTANTS OF CARBON DIOXIDE

Molecular formula	CO2
Molecular weight	44.01
Triple point	-69.9 F (-56.6 C) and 60.4 psig* (416.5 kPa**)
Sublimation temperature at 1 atm***	-109.3 F (-78.5 C)
Critical temperature	87.9 F (31.1 C)
Critical pressure	1,055.9 psig (7,281 kPa)
Latent heat of sublimation at -109.3 F (-78.5 C) and 1 atm	246.3 BTU/lb (590.3 kJ/kg)
Latent heat of vaporization at 2 F (-16.7 C) and 302 psig (2,080 kPa)	119.0 BTU/lb (276.8 kJ/kg)
Specific gravity of gas at 32 F (0 C) and 1 atm (air = 1)	1.5240
Vapor density at 32 F (0 C) and 1 atm	0.12341 lb/cu ft (1.977 kg/cu m)
Liquid density at 2 F (-16.7 C)	63.3 lb/cu ft (1,010 kg/cu m)
Liquid density at 70 F (21.1 C)	47.5 lb/cu ft (761 kg/cu m)
Conversion factors (760 mmHg and 25 C)	1 ppm = 1.8 mg/cu m 1 mg/cu m = 0.556 ppm 7.6 mmHg = 1 torr

*pounds per square inch gage
**0.0101971 kg/sq cm
***760 mmHg = 14.70 pounds per square inch

Adapted from [2]

TABLE XIV-2

OCCUPATIONS WITH POTENTIAL EXPOSURES TO CARBON DIOXIDE

Aerosol packagers	Furnace workers
Alkali salt makers	Gluemakers
Bakers	Grain alcohol workers
Baking powder makers	Grain elevator workers
Beverage carbonators	Ice cream makers
Blast furnace workers	Insecticide makers
Boiler room workers	Lime kiln workers
Brass founders	Linseed oil boilers
Brewers	Mineral water bottlers
Brick burners	Miners
Bronze founders	Natural carbon dioxide workers
Caisson workers	Pottery workers
Canners	Refrigerating car workers
Carbonated water makers	Refrigerating plant workers
Carbon dioxide makers	Salicylic acid makers
Carbon dioxide workers	Sewer workers
Carbonic acid makers	Ships' hold workers
Cave explorers	Silo workers
Charcoal burners	Soda makers
Cupola workers	Starch makers
Dairy farmers	Submariners
Disinfectant makers	Sugar refiners
Distillers	Tannery pit workers
Divers	Tobacco moisteners, storehouse
Dockworkers	Tunnel workers
Drug makers	Urea makers
Dry ice workers	Vat workers
Drying room workers	Vault workers
Dyemakers	Vinegar makers
Ensilage diggers	Vintners
Explosive makers	Vulcanizers
Fertilizer workers	Welders, inert atmosphere
Fire extinguisher makers	Well cleaners
Firefighters	White lead makers
Foundry workers	Yeast makers

Adapted from Gafafer [12]

Table XIV-3

SIGNS AND SYMPTOMS OBSERVED IN 42 PERSONS
EXPOSED TO CARBON DIOXIDE AT 7.5%

Signs & Symptoms	Number of Persons Affected
Dyspnea	24
Headache	15
Increased motor activity	10
Restlessness	10
Visual, color distortions	8
Loss of balance	7
Vertigo	6
Sweating	6
Numbness	5
Loss of limb control	4
Irritation	4
Mental disorientation	2

Modified from Schaefer [30]

☆ U.S. GOVERNMENT PRINTING OFFICE: 1977—757-057/5746

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
ROBERT A. TAFT LABORATORIES
4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

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U.S. DEPARTMENT OF H.E.W.
HEW 399

DHEW (NIOSH) Publication No. 76-194