

criteria for a recommended standard....

**OCCUPATIONAL EXPOSURE
TO
ACETYLENE**



U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

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Center for Disease Control

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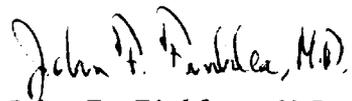
PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards at their workplace. The National Institute for Occupational Safety and Health has projected a formal system of research, with priorities determined on the basis of specified indices, to provide relevant data from which valid criteria for effective standards can be derived. Recommended standards for occupational exposure, which are the result of this work, are based on the health effects of exposure. The Secretary of Labor will weigh these recommendations along with other considerations such as feasibility and means of implementation in developing regulatory standards.

It is intended to present successive reports as research and epidemiologic studies are completed and as sampling and analytical methods are developed. Criteria and standards will be reviewed periodically to ensure continuing protection of the worker.

I am pleased to acknowledge the contributions to this report on acetylene by members of my staff and the valuable constructive comments by the Review Consultants on Acetylene, by the ad hoc committees of the American Academy of Industrial Hygiene and the American Medical Association, and by Robert B. O'Connor, M.D., NIOSH consultant in occupational medicine. The NIOSH recommendations for standards are not necessarily a consensus of all the consultants and professional societies

that reviewed this criteria document on acetylene. Lists of the NIOSH Review Committee members and of the Review Consultants appear on the following pages.

A handwritten signature in black ink that reads "John F. Finklea, M.D." The signature is written in a cursive style with a large initial 'J'.

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The Division of Criteria Documentation and Standards Development, National Institute for Occupational Safety and Health, had primary responsibility for development of the criteria and the recommended standard for acetylene. The Division review staff for this document consisted of Vernon E. Rose, M.S., and Paul Caplan, M.P.H.

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CRITERIA DOCUMENT:
RECOMMENDATIONS FOR AN OCCUPATIONAL
EXPOSURE STANDARD FOR ACETYLENE

Table of Contents

	<u>Page</u>
PREFACE	iii
NIOSH REVIEW COMMITTEE	vi
NIOSH REVIEW CONSULTANTS	vii
I. RECOMMENDATIONS FOR AN ACETYLENE STANDARD	
Section 1 - Environmental (Workplace Air)	2
Section 2 - Medical	3
Section 3 - Labeling and Posting	3
Section 4 - Personal Protective Clothing and Equipment	5
Section 5 - Informing Employees of Hazards from Acetylene	6
Section 6 - Work Practices	6
Section 7 - Sanitation Practices	10
Section 8 - Monitoring and Recordkeeping Requirements	10
II. INTRODUCTION	12
III. BIOLOGIC EFFECTS OF EXPOSURE	
Extent of Exposure	14
Historical Reports	18
Effects on Humans	19
Epidemiologic Studies	26
Animal Toxicity	26
Correlation of Exposure and Effect	31
Carcinogenicity, Mutagenicity, and Teratogenicity	32
IV. ENVIRONMENTAL DATA	
Sampling and Analysis	34
Control of Exposure and Hazards	40
V. DEVELOPMENT OF A STANDARD	
Basis for Previous Standards	43
Basis for the Recommended Standard	44
VI. WORK PRACTICES	46
VII. RESEARCH NEEDS	54

Table of Contents (Continued)

	<u>Page</u>
VIII. REFERENCES	56
IX. APPENDIX I - Sampling-Monitoring Method Using a Combustible Gas Meter and Sampling Method for Use with Gas Chromatographic Analysis	
X. APPENDIX II - Analytical Method for Acetylene	65
XI. APPENDIX III - Material Safety Data Sheet	68
XII. TABLES	78

I. RECOMMENDATIONS FOR AN ACETYLENE STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to acetylene in the workplace be controlled by compliance with the following sections. The standard is designed to protect the health and safety of workers for up to a 10-hour work shift, 40-hour workweek, over a working lifetime. Compliance with the standard should therefore prevent adverse effects produced by exposure to acetylene. The standard is measurable by techniques that are valid, reproducible, and available to industry and governmental agencies; there is sufficient technology to permit compliance with the recommended standard. The criteria and standard will be subject to review and revision as necessary.

Arsine, an inorganic compound of arsenic, in variable small amounts is often present in commercially available acetylene as a contaminant. Because arsenic and its inorganic compounds have been implicated in the production of malignancies of the lung, NIOSH recommends that certain precautions be taken to assure that exposure of employees to arsenic is minimized. In order that employees are informed of the hazards of the contaminants in commercially available acetylene, which may be, in addition to arsine, phosphine, hydrogen sulfide, methylacetylene, and others, it is recommended that commercially available acetylene be chemically analyzed qualitatively and quantitatively to the extent necessary to allow an evaluation of the total toxic hazard due to the presence of acetylene in

the workplace. It is imperative that employees be informed of the results of this analysis and be provided with an interpretation of these results with respect to possible adverse effects on their health. The Material Safety Data Sheet (MSDS) must contain the results of the aforementioned analysis and provide an indication of the total hazard to health caused by commercially available acetylene.

These criteria and recommended standard apply to exposure of workers to acetylene (C₂H₂), also known as ethine, ethyne, and Narcylene. "Occupational exposure to acetylene" is defined as exposure to airborne acetylene at concentrations greater than the environmental limit. Exposure at lower environmental concentrations will not require adherence to the following sections of Chapter I with the exception of Sections 3, 4(a), 5, 6, 7, and 8. If exposure to other chemicals also occurs, as would be the case with various commercial grades of acetylene (which, depending on the source, may contain phosphine, arsine, hydrogen sulfide, methyl acetylene, or other contaminants), provisions of any applicable standard for these chemicals shall also be followed.

Section 1 - Environmental (Workplace Air)

(a) Concentration

Occupational exposure to airborne acetylene shall be controlled so that no employees will be exposed to acetylene at a concentration in excess of 2,500 ppm (2,662 mg/cu m of air).

(b) Sampling, Collection, and Analysis

Procedures for collection and analysis of environmental samples shall be as provided in Appendices I and II, or by any methods shown to be at

least equivalent in accuracy, precision, and sensitivity to the methods specified.

Section 2 - Medical

(a) Proper medical care shall be available to all employees affected by exposure to acetylene in emergency situations.

(b) Based on the principles of good occupational health practice, the employer should provide a preplacement medical examination, including medical history, and periodic physical examinations to employees who may be occupationally exposed to acetylene.

Section 3 - Labeling and Posting

(a) Labeling

Containers of acetylene shall be marked as required by the US Department of Transportation. These markings shall be kept in a readable condition. In addition, the following label shall be affixed to all containers:

ACETYLENE

DANGER!

FLAMMABLE AND EXPLOSIVE

Keep away from heat, flame, and sparks.
Close valve when not in use.

Either this label shall include a statement of qualitative and quantitative

analyses of the contents of the container (including, as a minimum, the relative amounts of phosphine, arsine, and hydrogen sulfide), must use other effective means to convey to employees the results of these analyses and an appropriate interpretation of these results with respect to the possible adverse effects on their health.

Labels for portable compressed-gas containers shall include a statement requiring their use in an upright position only. Wherever possible, these labels shall be located at the valve end and not on the cylindrical part of the container body. Lettering on each container label should be of sufficient size to be readily visible.

(b) Posting

Areas where acetylene is present shall be posted with the following sign:

ACETYLENE
DANGER! NO SMOKING
FLAMMABLE AND EXPLOSIVE GAS

In areas where calcium carbide is stored or used for acetylene generation, the following sign shall be posted:

CALCIUM CARBIDE
DANGER! NO SMOKING
DO NOT USE WATER OR FOAM ON FIRES

This warning sign shall be printed both in English and in the predominant language of non-English-reading workers. Employees unable to read posted warnings and labels and those unfamiliar with English or with the predominant non-English language shall receive periodic training sufficient to ensure their understanding of the contents of the label and poster specified in this section and to provide a continuing reminder of these contents.

Section 4 - Personal Protective Clothing and Equipment

(a) Protective Clothing

Individuals handling acetylene cylinders shall wear leather-type gloves and safety shoes. For welding or cutting operations, leather vests and welding sleeves are recommended, together with fiber-frame instead of metal-frame spectacles. Metal belt buckles and metal buttons that could become heated and cause burns should be avoided. Proper protective clothing shall be worn when dealing with any acetylene fire.

(b) Respiratory Protection

The use of respirators is not indicated because engineering controls or work practices, including those designed for welding or cutting operations, shall be used to maintain acetylene concentrations below the prescribed limits. This control equipment shall be sparkproof, explosion-proof, and electrically grounded. However, where the potential exists for the occurrence of a life-threatening emergency situation, emergency respiratory equipment shall be available.

Section 5 - Informing Employees of Hazards from Acetylene

(a) All employees shall be informed, at the beginning of their employment or assignment to an area where acetylene is used, stored, produced, or handled, of the hazards, appropriate emergency procedures, and proper conditions for safe use of acetylene and precautions to minimize exposure. All employees shall be informed, in addition, of the results of the chemical analyses of contaminants in acetylene to which they may be exposed, in accordance with Section 3(a) of this recommended standard. Each employee shall be instructed as to the availability of such information, which shall be kept on file. Information kept on file shall include that prescribed in paragraph (b) below and shall be accessible to the worker at each place of employment where acetylene is involved in unit processes and operations.

(b) Information as specified in Appendix III shall be recorded on the US Department of Labor Form OSHA-20, "Material Safety Data Sheet" (MSDS), or on a similar form approved by the Occupational Safety and Health Administration, US Department of Labor. In addition to the information specified in Appendix III, the MSDS must include the results of chemical analyses, both qualitative and quantitative, performed on commercially available acetylene, as well as an indication of the total toxic hazard of the material.

Section 6 - Work Practices

(a) Emergency Procedures

For all work areas in which there is a reasonable potential for emergencies, procedures as specified below, as well as any other procedures

appropriate for a specific operation or process, shall be formulated in advance, and employees shall be instructed in their implementation.

(1) Procedures shall include prearranged plans for obtaining emergency medical care and for necessary transportation of injured workers.

(2) Firefighting procedures shall be established and implemented. These shall include procedures for emergencies arising from acetylene production, the use of acetylene in cylinders, or the transmission of acetylene by hose or pipeline. Fire protection equipment shall be conspicuously identified and located so as to be readily visible and accessible in an emergency.

(A) Acetylene fires arising from wet calcium carbide inside a building shall be extinguished by using dry-powder extinguishers or carbon dioxide. No water or water-based foams shall be used in such situations. Care must be taken to ensure that extinguishing the fire will not increase the hazard of explosion or lack of oxygen by allowing acetylene to accumulate in an unventilated area.

(B) The handling of acetylene cylinders in fire situations shall be in accordance with the Compressed Gas Association Safety Bulletin SB-4.

(3) Employees not essential to emergency operations shall be evacuated from exposure areas during emergencies.

(4) Personnel properly trained in the procedures and adequately protected against the attendant hazards shall shut off, isolate, and immediately repair the leaking sources of acetylene.

(b) Suitable engineering controls designed to limit exposure to acetylene to that prescribed in subsection (a) of Section 1 shall be utilized where appropriate and feasible. In addition, such controls shall be designed to limit fire and explosion hazards associated with acetylene.

Procedures for the handling, use, and storage of acetylene cylinders shall be in compliance with the present federal standard 29 CFR 1910.102(a) which is Compressed Gas Association pamphlet G-1. It is recommended that Compressed Gas Association pamphlet P-1 also be used for such procedures since additional information is contained in this publication. The use of acetylene cylinders in welding or cutting processes shall be in compliance with 29 CFR 1910.252. In addition, only acetylene cylinders which are suitably protected from any contact with hot metal slag or sparks shall be used in any welding or cutting operations.

Ventilation systems shall be designed to prevent the accumulation or recirculation of acetylene in the workplace. Exhaust ventilation systems discharging to outside air must conform with applicable local, state, and federal pollution regulations. To ensure maximum effectiveness, ventilation systems should be subject to regular preventive maintenance and cleaning and to periodic measurement of airflow.

(c) Acetylene containers shall have the valve closed and any regulator purged when not in use. All such containers shall be made from suitable materials and shall be protected from heat, corrosion, mechanical damage, and sources of ignition. Portable acetylene containers shall be used only while in a vertical position. These containers should also be stored in a vertical position. Containers that are not stored vertically shall be placed in a vertical position for at least 30 minutes before use.

(d) Because of the hazards associated with the combination of acetylene with certain other chemicals, unintentional contact between acetylene and the following substances shall be strictly prohibited: fluorine, chlorine, bromine, iodine, potassium, or cobalt; copper, silver, mercury, or any salts of these metals; or hydrides of sodium, cesium, or rubidium.

(e) All major equipment and piping employed in acetylene operations shall be electrically continuous and bonded to a grounding electrode in accordance with 29 CFR 1910.308 and 29 CFR 1910.309.

(f) Vessel Entry

(1) Entry into confined spaces, such as tanks, hoppers, and process vessels which have contained acetylene, or in which acetylene is used or combusted, shall be controlled by a permit system. Permits shall be signed by an authorized representative of the employer, certifying that preparation of the confined space, precautionary measures, and personal protective equipment are adequate, and that prescribed procedures will be followed.

(2) Confined spaces which have contained acetylene or in which acetylene combustion has occurred shall be inspected and tested for oxygen deficiency, as well as for the concentration of acetylene or other contaminants, especially phosphine, arsine, and hydrogen sulfide. Other standards have been developed for these contaminants and are listed in CFR 1910.1000. The space shall be thoroughly ventilated, cleaned, neutralized, and washed, as necessary, prior to entry.

(3) Inadvertent entry of acetylene into the confined space while work is in progress shall be prevented. Acetylene supply lines shall

be disconnected and blocked off.

(4) Confined spaces shall be ventilated while work is in progress to keep the acetylene concentration and concentrations of combustible byproducts below acceptable limits and to prevent oxygen deficiency.

(5) Individuals entering confined spaces where they may be exposed to acetylene shall be equipped with a lifeline tended by another worker outside the space.

Section 7 - Sanitation Practices

Smoking, introducing any source of ignition, or causing any form of ignition shall be prohibited in areas where acetylene is produced, stored, handled, or used. This prohibition shall not apply to deliberate introduction of ignition sources used in routine procedures, such as the lighting of a torch for welding or the burning of acetylene for illumination purposes.

Section 8 - Monitoring and Recordkeeping Requirements

Where workers may be occupationally exposed to acetylene, industrial hygiene surveys to evaluate exposure conditions shall be conducted within 6 months of the promulgation of this recommended standard, or within 30 days after installation of a new process or process change. Records of these surveys shall be maintained.

(a) If it is determined that acetylene concentrations are greater than the recommended environmental limit, then a program of personal

monitoring shall be instituted to identify and measure, or permit calculation of, the exposure.

(1) In all monitoring, samples representative of the environmental exposure shall be collected. An adequate number of samples shall be collected to permit the calculation of an environmental exposure for every operation or process.

(2) Environmental monitoring for an operation or process shall be repeated at 30-day intervals where the acetylene concentration has been found to exceed the recommended environmental limit. Monitoring shall continue until two consecutive determinations indicate that exposure to acetylene no longer exceeds the environmental limit.

(b) The employer shall keep records on all industrial hygiene surveys and all determinations of environmental concentrations. Records of the latter shall include the determined concentration of exposure and a description of the monitoring, sampling, and analytical methods. In addition, records shall be maintained on the types of respirators and personal protective equipment, if any, worn by employees. The monitoring records shall identify the employees for whom air samples were collected, and the employer shall make such records available to representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, and of the employee or former employee.

(c) The employer shall keep the records of all environmental monitoring of airborne acetylene for each employee for whom air samples are collected for at least 5 years after the employee's employment is terminated.

II. INTRODUCTION

This report presents the criteria and the recommended standard based thereon which were prepared to meet the need for preventing occupational hazards arising from exposure to acetylene. The criteria document fulfills the responsibility of the Secretary of Health, Education, and Welfare under Section 20(a)(3) of the Occupational Safety and Health Act of 1970 to "...develop criteria dealing with toxic materials and harmful physical agents and substances which will describe...exposure levels at which no employee will suffer impaired health or functional capacities or diminished life expectancy as a result of his work experience."

The National Institute for Occupational Safety and Health (NIOSH), after a review of data and consultation with others, formalized a system for the development of criteria upon which standards can be established to protect the health of workers from exposure to hazardous chemical and physical agents. It should be pointed out that any criteria and recommended standard should enable management and labor to develop better engineering controls resulting in more healthful work practices and should not be used as a final goal.

These criteria for a standard for acetylene are part of a continuing series of criteria developed by NIOSH. The proposed standard applies only to the processing, manufacture, and use of acetylene, and to other occupational exposure to acetylene as applicable under the Occupational Safety and Health Act of 1970. It is intended to (1) protect workers

against fire and explosion hazards, (2) be measurable by techniques that are valid, reproducible, and available to industry and government agencies, and (3) be attainable with existing technology.

It appears from the information available at present that no toxic hazards to employees exist when acetylene is present at concentrations near or up to four times the established lower explosive limit (LEL) of 25,000 ppm. Therefore, the major problem to employees and management is the control of potential fire and explosion hazards from acetylene. However, some commercial grades of acetylene may contain concentrations of impurities (such as phosphine, arsine, and hydrogen sulfide) which could pose a toxic threat to any employee working in operations that involve the production or use of such gases.

The development of the recommended standard for occupational exposure to acetylene has revealed deficiencies of information in chronic inhalation studies at low levels in both humans and animals, in biotransformation studies to determine if acetylene is metabolized, in epidemiologic studies of employees exposed to acetylene for extended periods, in determination of the impurities present in commercial acetylene and of its products of combustion, and in chronic inhalation studies on these impurities and combustion products.

III. BIOLOGIC EFFECTS OF EXPOSURE

Extent of Exposure

Pure acetylene, C_2H_2 (molecular weight 26.04), is a colorless and odorless gas. The characteristic garliclike odor of technical grade acetylene is attributable to contamination by impurities. Impurities which may be present include: divinyl sulfide, ammonia, oxygen, nitrogen, phosphine, arsine, methane, carbon dioxide, carbon monoxide, hydrogen sulfide, vinyl acetylene, divinyl acetylene, diacetylene, propadiene, hexadiene, butadienyl acetylene, and methyl acetylene. [1] Pertinent physical properties of acetylene are listed in Table XII-1. [2-4]

The oldest and most widely used method for producing acetylene is the reaction of water with calcium carbide. The other major method of acetylene production is by thermal cracking of hydrocarbons. [1]

Acetylene produced on a large scale for commercial purposes was first reported by Willson and Suckert [5] in 1895. In their process, calcium carbide was produced from lime and coke in an electric furnace. The use of acetylene produced from calcium carbide spread quickly and, before the end of the 19th century, it was manufactured in 10 countries. [6]

Calcium carbide served as the sole raw material source for acetylene manufactured in the US until 1951, when production of acetylene from hydrocarbon sources began. [7] Initially, hydrocarbon-produced acetylene was recovered as a byproduct of ethylene production. Ethylene recovered from refinery gases or manufactured by cracking other hydrocarbons contained 0.2-2.0% acetylene by weight.

The three general methods for commercial production of acetylene from

hydrocarbons are the thermal (Wulff) process, [8] the partial oxidation processes, [7] and the electric arc process. [7] The Wulff process uses a feed gas (methane, ethane, propane, or any C2 to C15 hydrocarbon stream) which is passed through a heated furnace. Partial oxidation processes depend on the partial oxidation of a hydrocarbon from which acetylene is isolated and produced. In the US, methane is used as a feed gas, yielding a gas mixture containing 8-10% acetylene. [7] The electric arc process uses an electric arc to produce the heat necessary for hydrocarbon conversion to acetylene. [7]

In 1972, Japanese researchers introduced the use of a high-temperature gas (plasma) jet to produce acetylene from higher aliphatic hydrocarbons. [9] In this process, propane and isobutane were found to be the most suitable starting materials. The advantage of this system is that the cost of plant construction is reduced because a large quantity of acetylene can be produced from a small unit. Since oxygen is not present in the plasma jet, acetylene is easily separated and refined. [10]

In 1973, a new process for producing acetylene from coal was reported by the US Bureau of Mines' Office of Coal Research. [11] This process may allow acetylene to be economically competitive with ethylene as a starting material for vinyl chloride production.

The production method used determines the nature and amount of the impurities which will be present. Acetylene manufactured from hydrocarbon feedstock is inherently free of phosphine, arsine, and hydrogen sulfide, but all of these impurities may be present in acetylene mixtures produced from calcium carbide. [12] Production of crude acetylene from calcium carbide in acetylene generators results in a number of other impurities.

Calcium sulfide, calcium phosphide, and calcium cyanamide, which are present in some industrial grades of calcium carbide, produce hydrogen sulfide, phosphine, and ammonia, respectively. These substances are present in varying but small proportions in crude acetylene gas. Both arsine and silane reaction products may be produced from trace amounts of other contaminants present in the calcium carbide. [13]

In 1958, worldwide production of acetylene amounted to 2.1 million tons, of which 83% was generated from calcium carbide. [14] In the US, 0.4 million tons of acetylene were produced, 60% of which was generated from calcium carbide. In 1966, US acetylene production amounted to 0.5 million tons, 23% of which was generated from calcium carbide. In 1974, seven companies in the US were responsible for the production of 0.2 million tons of acetylene from hydrocarbons and from ethylene byproduct processes. [15] No information is available on the percentage produced by the carbide process in 1975.

The first major commercial use of acetylene was as an illuminant and heat source. [1] Concomitant with the advancement of oxyacetylene technology in the first decade of the 20th century, the use of acetylene was expanded to the welding and cutting industries. [6] This development was enhanced by the discovery that hazards due to the explosibility of compressed acetylene could be overcome by dissolving acetylene in acetone disseminated on a porous mass inside a steel container. [16]

The current uses of acetylene may be categorized as nonchemical or chemical. Nonchemical uses of acetylene are as a fuel gas, eg, in the welding and cutting industries, and other miscellaneous uses, eg, as a temporary or emergency illuminant. Chemically, acetylene is used as a

starting material for a number of products such as vinyl chloride, vinyl acetylene, acrylonitrile, vinyl acetate, tetrachloroethane, acrylic acid, methyl and ethyl acrylates, propargyl alcohol, vinyl ethers, acetylene black, 2-butyne-1,4-diol, 3-methyl-1-butyne-3-ol, 3-methyl-1-pentyne-3-ol, bicycloheptadiene, and ethylidene fluoride. [7] In addition, there are miscellaneous chemical uses of acetylene, eg, as a ripening agent for fruit. The use of acetylene as a raw material for chemical synthesis during the years 1935-1966 is summarized in Table XII-2. [7] In 1973, 0.2 million tons of acetylene produced from hydrocarbons were used in the US, most of it in the synthesis of other chemicals: vinyl chloride monomer, 33%; acrylates, 26%; acetylenic chemicals, 20%; vinyl acetate, 17%; and chlorinated solvents, 4%. [15]

The industrial importance of acetylene has been eclipsed by the introduction of less expensive raw materials, such as ethylene and propylene. [15] Acetylene has been competing with butadiene as a starting material in the manufacture of neoprene, which, prior to 1968, was produced entirely from acetylene. [7]

An increase in the use of Reppe chemicals (chemicals synthesized from acetylene at pressures greater than atmospheric), such as propargyl alcohol, may increase the demand for acetylene, thus checking to some extent its present production decline. [7] In addition, use of acetylene for the production of tetrahydrofuran is increasing. [15] In 1966, approximately 110 million pounds of acetylene were used for nonchemical purposes, principally in welding and metal-cutting. Other gases such as liquid petroleum gas and physical agents such as electric-arc procedures have also been used in welding and cutting operations. [7]

A commodity specification for acetylene was developed by the Compressed Gas Association in 1972. [12] It attempted to set specification requirements for all grades of acetylene which were available commercially and for which an end use had been established through industrial experience. This information is presented in Table XII-3. [12]

A number of occupations that involve potential exposure to acetylene are listed in Table XII-4. [17] Since acetylene is used in a wide variety of industrial operations, NIOSH estimates that approximately 1,700,000 workers are potentially exposed to acetylene in the US.

Historical Reports

Miller [18] reported that Edmund Davy first produced acetylene in 1836 by the reaction of potassium carbide with water. The first report of exposure to acetylene described its use at high concentrations as a general anesthetic. [19] These reports involved exposure to partially purified acetylene produced by the action of water on crude calcium carbide. This acetylene probably contained impurities such as phosphine, arsine, hydrogen sulfide, ammonia, and carbon monoxide. Biologic or adverse effects attributed to acetylene were probably caused in part by one or more of these impurities. [20,21]

Von Oettingen [20] reported that, in 1883, Lewin produced anesthesia by administering acetylene in air at a concentration of 1% (10,000 ppm). Experimental results reported by Lewin and others before 1900 were probably obtained using unpurified acetylene of unknown composition generated from carbide, and thus the exact anesthetic concentration cannot be related to

later work. [21]

The first extensive laboratory and clinical investigations on the use of acetylene as an inhalation anesthetic reportedly were conducted in the early 1920's by Wieland and Gauss, as reported by Reisch. [22] Following their work, acetylene was used as an inhalation anesthetic in central Europe, and the majority of published reports, both experimental and clinical, appeared in the German literature. At that time, purified acetylene for anesthetic use was being marketed under the name of Narcylene. [23] By 1924, Goldman and Goldman [24] reported that Gauss had successfully used acetylene as an anesthetic in over 2,000 human operative procedures lasting from 3 to 180 minutes. Acetylene never became popular as an anesthetic because of its disagreeable odor. [25] Another drawback noted by Adriani [26] was its undesirable effect on the circulation.

No reports of acute or chronic toxic effects were found in early clinical or laboratory investigations of acetylene as an anesthetic.

Effects on Humans

Acetylene is toxic in the sense that it will produce varying degrees of temporary and reversible narcosis when administered with oxygen in concentrations of 100,000 ppm or greater. [27,28] Acetylene has been described as a safe anesthetic exhibiting in humans the advantages of an almost total lack of immediate aftereffects and no evidence of any residual or permanent toxicity. [24,29,30] In any event, the results of the anesthetic studies found in the literature cannot be directly related to most workplace environments because of the high acetylene and varying

oxygen concentrations used in these anesthetic studies.

Only one report has been found on industrial exposure to acetylene prior to 1940. In 1934, Eichler [31] reported the case of a worker exhibiting a variety of symptoms including bronchitis and a stomach ulcer after having been exposed to acetylene in an industrial environment. The employee had worked for an unspecified period of time in a welding plant where acetylene was produced from calcium carbide. No mention was made of any attempt to measure concentrations of acetylene or acetylene impurities present in the workplace. The opinion of the examining physician was that the worker's symptoms could have originated from chronic phosphine poisoning. In recent years, a number of case studies have appeared on the incidence of various health effects associated with the manufacture and use of acetylene. [32-38] In 1958, Harger and Spolyar [32] reported the case of a 16-year-old boy described as an inexperienced operator of a carbide-acetylene generator who was found dead, lying prone, with his face very near or partly over an open carbide hopper. The cause of death established at autopsy was acute pulmonary edema of undetermined cause. The authors concluded that the responsible toxic agent was probably phosphine. The presence of an 8-ppm average phosphine concentration was established by subsequent analyses performed on the air near the operator's breathing level during the hopper-filling period. Phosphine concentrations in the hopper ranged from 75 to 95 ppm. The raw acetylene produced in this plant was found to contain less than 3 ppm of arsine (no estimations of breathing zone concentrations were reported), and the "highest concentration of hydrogen sulfide breathed" was estimated at less than 10 ppm, and this for "only a short period." It is of interest

that, about 2 weeks before his death, the youth had begun to complain of periods of dizziness while filling the generator hopper with calcium carbide, and that, on two such occasions, he had reported losing consciousness. Ten days before his death, he had blacked out while driving home from work.

In 1960, Jones [33] reported a somewhat similar fatal incident in Australia. A carbide-acetylene generator operator was found either unconscious or already dead, lying across the top of a calcium carbide feed hopper, his head inside the filler hole. He was pronounced dead on arrival at a nearby hospital. The only significant autopsy findings reported were the presence of 8% carboxyhemoglobin in the blood (he was not a known smoker) and intense congestion of the lungs with widespread edema and areas of recent hemorrhage. A verdict of "death due to the effects of accidental poisoning by an irritant gas incurred in the course of his employment" was returned at the subsequent inquest. The author concluded from the circumstantial evidence that the victim might have been exposed to an atmosphere containing up to 80% acetylene with corresponding oxygen depletion, with resulting loss of consciousness. The presence of phosphine and hydrogen sulfide in the raw acetylene, and consequently in the air of the carbide hopper, was postulated but not established by analysis. It was suggested that carboxyhemoglobinemia was produced from carbon monoxide "trapped" in the calcium carbide and released on its reaction with water, but that the carbon monoxide did not contribute to the death of the victim.

In 1963, there appeared an isolated report [34] of urticaria and dyspnea associated with the use of an oxyacetylene torch in preheat welding. These signs occurred in one subject within 15 minutes of starting

a welding operation. The dyspnea disappeared within 1 hour after cessation of use of the torch, and the urticaria subsided within 6 hours. An experimental reexposure was performed 1.5 weeks later in the presence of several physicians. The precise working circumstances of the original incident were recreated and, 10 minutes after the test started, the subject had to discontinue welding because of marked dyspnea. At the same time, 10 extensive erythematous wheals appeared scattered over his chest, abdomen, arms, and back. These areas were pruritic; also, there was evidence of dermatographism which had not been present before the test. Kaplan and Zeligman [34] concluded that the urticaria and "asthma" resulted from inhalation of "gases or particulate matters which originated from the contents of the acetylene tank, the combustion products of the commercial acetylene gas, and/or the combustion products of preheat welding with the railroad rod."

In the 1969 edition of their textbook, Deichmann and Gerarde [35] reported the case of a worker who inhaled acetylene gas from a leaking torch and was hospitalized 18 hours later because of severe dyspnea and chest pain. There was clinical and radiologic evidence of extensive pulmonary edema, bronchopneumonia, and bilateral pleural effusion. These authors believed that an unidentified impurity in the acetylene was probably responsible for the pulmonary irritation. They observed that acetylene previously had been used as an anesthetic with no reports of pulmonary changes of the type described in this case.

In 1970, Ross [36] reported loss of consciousness in a worker using an oxyacetylene flame in a confined space. Ross did not attribute the loss of consciousness to the effects of acetylene, but concluded that the

probable causal factors were oxygen depletion of the atmosphere linked with a high carbon dioxide concentration and the heat of the job. All these were aggravated by the small, confined working space. Here, the worker was using the torch inside a very small reheater boiler.

In 1971, de Hamel [37] reported what he described as "the first case of acute acetylene anesthesia which I have ever come across." An oxyacetylene torch was used under water to cut some steel reinforcing rods sticking out of a riverbed. The operator sat on the riverbed with his head just above the water. Bubbles of gas from the underwater torch-cutting process rose to the surface close to the worker's face. After an unstated period of time, the worker complained of feeling very weak, "like having an anesthetic." He turned off his torch and rested for a while. Shortly after resuming his work, he collapsed and was incapable of movement. After a third attempt, he collapsed and could not move for 15 minutes. He recovered completely by the following day. The author did not estimate exposure levels or give any patient history. It is unlikely that this worker was exposed to any appreciable concentration of uncombusted acetylene in his breathing zone; therefore, it is doubtful that this was a case of acute acetylene anesthesia.

In 1973, Ross [38] reported two additional cases of loss of consciousness, one fatal; both were associated with the use of oxyacetylene torches in a confined space. In this incident, the oxyacetylene torch was being used to "metallize" aluminum onto steel inside a tank where ventilation was inadequate, and it was concluded that the accident was caused by "an adverse breathing atmosphere" in the storage vessel (ie, the workspace). Once again, acetylene probably did not make a significant

contribution to the adverse breathing atmosphere because very little free acetylene would have been present with the torch lit. The cause of loss of consciousness was probably oxygen deficiency.

In none of the above studies is the causative or even contributory role of acetylene clear. Furthermore, in all of these studies, proper attention to good work practices might have prevented these health hazards.

No reports on humans have been found in the literature in which any histopathologic effects attributable to acetylene have been established. In 1926, Brandt [29] reported that an acetylene-oxygen mixture administered as an anesthetic at an initial concentration of 70% (700,000 ppm) did not appear to have any effect on either the liver or the kidney. Mueller [39] studied the effects of Narcylene (acetylene) on blood components. He reported that it produced no untoward hematologic effects when administered to 12 patients in anesthetic concentrations.

Acetylene has not been shown to cause any abnormal effects on heart function. In studies where acetylene was used at high concentrations in anesthesia, there have been some reports of an increase in blood pressure. Brandt [29] found no effects on heart function when acetylene was administered at a concentration of 200,000-700,000 ppm in oxygen, although blood pressure was seen to increase by 20, 40, or even 50 mmHg in some of the subjects studied. Franken and Schurmeyer [40] found in 1928 that acetylene-oxygen mixtures (750,000-800,000 ppm) produced an increase in blood pressure during anesthesia. The authors concluded that this effect was attributable to stimulation of the vasomotor center by acetylene. The full significance of this finding is not clear.

No reports have been found in the literature on the effects of concentrations of acetylene lower than 200,000 ppm in oxygen or air on the cardiovascular system in humans.

Goldman and Goldman [24] reported that Gauss used 80% (800,000 ppm) acetylene-oxygen mixtures in over 2,000 anesthetic procedures lasting from 3 minutes to 3 hours and that no signs of asphyxia were noted. Brandt [29] stated that acetylene, even when administered in high concentrations (up to 900,000 ppm), was not capable of paralyzing the respiratory center. Thus, the author concluded that an overdose in anesthetic procedures was "impossible." No mention was made of increased respiration rates in either study. Franken [41] found that acetylene administered in high concentrations (700,000-800,000 ppm) as an anesthetic to seven human subjects "stimulated" respiration. [41] However, all but two of the subjects had been premedicated with a morphine-containing preparation which affects respiration. No studies on the mechanism by which acetylene stimulates respiration have been found in the literature. However, Rehn and Killian [42] reported in 1932 that the sensitivity of the respiratory center to carbon dioxide was not altered by acetylene. No studies have been found in the literature on the effects of acetylene-oxygen or of acetylene-air mixtures on the respiratory system at concentrations below 200,000 ppm.

The reported effects of acetylene on metabolism are limited to a single study in 1930 by Von Ammon and Schroeder [43] who found that the alkali reserve in humans was lowered during acetylene anesthesia in a wide variety of operative procedures. However, the value of this study is diminished by the fact that all patients were given morphine and atropine

after the baseline reading had been established. It is impossible to assign the observed changes to the premedication, the anesthetic agent, or the operative trauma. No published reports have been found concerning the effects of acetylene-oxygen or of acetylene-air mixtures on human metabolic parameters at concentrations below 200,000 ppm.

In literature published prior to 1930, narcosis has been described as the main central nervous system effect of acetylene when administered with oxygen at concentrations of 100,000 ppm or greater. [28] A summary of the anesthetic effects of different acetylene-oxygen mixtures is presented in Table XII-5. [24,28-30,40,41] No reports have been found on the effects of acetylene-oxygen or of acetylene-air mixtures on the central nervous system at concentrations below 100,000 ppm.

In summary, on the basis of the foregoing review of available reports, both of acetylene-related industrial accident histories and of clinical investigations of acetylene anesthesia, there is no evidence of toxic effects of acetylene on humans.

Epidemiologic Studies

A search of the literature on acetylene has yielded neither reports of epidemiologic studies nor data on group exposure or effects that could be analyzed epidemiologically.

Animal Toxicity

Acetylene is toxic to animals only in the sense that it will produce varying degrees of narcosis when administered with oxygen in concentrations

exceeding 200,000 ppm. Furthermore, acetylene has been described as a safe anesthetic exhibiting an almost total absence of aftereffects and no evidence of any residual or permanent toxicity. [21,44-46]

The only report on the toxic effects of acetylene in air was published by Flury [27] in 1928. The author stated that toxicity to warm-blooded animals was as follows:

500,000 ppm after 5-10 minutes	-	fatal
250,000 ppm after 30-60 minutes	-	toxic
100,000 ppm for 30-60 minutes	-	tolerated

It should be noted in interpreting this report that the author did not specify species, method of administration, duration of exposure, or experimental conditions. Furthermore, acetylene concentrations of greater than 100,000 ppm in air would have reduced the oxygen content of the mixtures to below 18%. Thus, the observed toxic effects may not have been produced by the acetylene but rather by the oxygen-deficient atmosphere.

Other studies found involved the use of acetylene-oxygen mixtures containing more than 100,000 ppm of acetylene. In 1933, Franken and Miklos [47] looked for possible organ damage from the administration of acetylene at anesthetic concentrations to rats, mice, guinea pigs, rabbits, and dogs. The authors found no evidence of cellular injury to the parenchymatous cells of the heart, lungs, liver, kidneys, or spleen. Animals were exposed to acetylene in oxygen at concentrations of 250,000, 500,000, or 800,000 ppm for 1-2 hours daily. The longest total exposure times for some of the animals were: rats, 93 hours at 250,000 ppm or 18 hours at 800,000 ppm;

guinea pigs, 18 hours at 500,000 ppm or 10 hours at 800,000 ppm; rabbits, 10 hours at 800,000 ppm; and dogs, 12 hours at 800,000 ppm. Acetylene caused slight capillary hyperemia in some animals exposed at 250,000-ppm concentrations. This effect was observed until at least the second day after the last exposure to the gas but was not evident in animals killed later (up to 5 days after the last exposure).

Acetylene administered to cats and rabbits at concentrations greater than 200,000 ppm produced a limited and temporary rise in blood pressure. [41,48-50] The full significance of this finding is not clear. No reports were found in the literature of any studies pertaining to the effect of acetylene or acetylene mixtures on the cardiovascular system at concentrations below 100,000 ppm. Hildebrandt et al, [48] in 1926, determined that the rise in blood pressure observed in cats during surgical administration of acetylene at a concentration of 800,000 ppm in oxygen was caused by a shift in blood flow to the periphery. The authors concluded that this shift was caused by splanchnic vessel constriction initiated by acetylene. Franken et al [49] observed a rise in the blood pressure of cats administered acetylene-oxygen anesthetic mixtures containing up to 800,000 ppm of acetylene. The magnitude of this rise was found to vary among individual animals. No increase was observed if the anesthetic was administered slowly and carefully. Bollert et al, [50] in 1927, conducted 30 experiments on cats to study the effects of acetylene on the circulation. Using acetylene concentrations of 200,000-800,000 ppm in oxygen, they found that systolic blood pressure climbed to a maximum and then slowly dropped to normal. During initial anesthetic administration, the blood pressure increased by 30-40 mmHg with some animals exhibiting an

increase of 80-100 mmHg. The authors concluded that this increase was caused by a stimulation of the vasomotor center with a concurrent displacement of blood from the splanchnic to the peripheral vessels. An observed slowing of the pulse rate was judged not to be related to the blood pressure increase but to a stimulation of the vagal center by acetylene. An increase in the amplitude of the pulse was also noted to be a consequence of this direct action on the heart. In 1930, Franken [41] reported that both blood pressure and systolic output increased slightly when acetylene-oxygen anesthetic mixtures were administered to cats and rabbits.

The effects of acetylene on the respiratory system reported in the literature have not been consistent; both stimulation and depression of respiratory function have been observed. No reports pertaining to the effects of acetylene or acetylene mixtures on the respiratory system at concentrations of less than 100,000 ppm have been found. Riggs, [51] in 1925, reported that a 900,000-ppm acetylene concentration produced respiratory failure in rats after 2 hours of administration. The author, however, mentioned neither the oxygen content of the anesthetic mixture nor the numbers of animals tested. Schoen and Sliwka, [52] in 1923, reported an increase in the respiration of rabbits after the termination of anesthetic procedures in which up to 600,000 ppm of acetylene in oxygen had been used. Heymans and Bouckaert, [45] in 1925, found that both the volume and the frequency of respiration were increased in dogs during the administration of an anesthetic mixture of acetylene at a concentration of 850,000 ppm in oxygen. The authors concluded that acetylene caused an increase in respiratory frequency and volume even during deep anesthesia,

and that it slightly stimulated the elimination of carbon dioxide. In 1930, Franken [41] found that respiration was decreased in cats and rabbits which were administered acetylene-oxygen anesthetic mixtures.

There have been some reports in the literature of the effects of acetylene-oxygen anesthetic mixtures on various metabolic parameters. However, there has been no consistency in the reported data, with the exception of a slight decrease in both the carbon dioxide content and the alkali reserve of the blood. [52-54] The full significance of these findings in terms of occupational exposure is not clear because high concentrations of acetylene in oxygen were used. No studies were found in the literature on the effects of acetylene or acetylene mixtures in concentrations below 100,000 ppm on animal metabolic parameters. In 1923, Schoen and Sliwka [52] used acetylene-oxygen mixtures in anesthetic studies with rabbits. The authors observed decreases both in carbon dioxide tension in the arterial blood and in carbon dioxide-combining power of the blood and a lowering of the blood alkali reserve, but they observed no effect on the oxygen content of the arterial blood. Derra and Fuss, [53,54] in 1932, studied the effects of acetylene anesthesia on carbohydrate and acid-base regulation in the blood of dogs which had been administered acetylene at a concentration of 800,000 ppm in oxygen for 1 hour. The authors observed the following metabolic changes: a decrease in both the alkali reserve and carbonic acid levels; an increase during, and a fall after, anesthesia in both the oxygen-binding capacity of the blood and the arterial-oxygen deficit (ie, the degree of oxygen unsaturation of the blood); and a slight increase in blood sugar levels during anesthesia. The decrease in blood carbonic acid levels was reported by the authors to be a

consequence of the fall in alkali reserve.

The only reported effect of acetylene on the central nervous system of animals was the narcosis induced by acetylene when administered with oxygen in concentrations greater than 200,000 ppm. [21,44,45]

No studies were found in the literature on the effects of acetylene, or acetylene mixtures, on the central nervous systems of animals at concentrations below 100,000 ppm. In 1923, Jordan [21] administered acetylene in oxygen at concentrations of 750,000-900,000 ppm by mask to produce anesthesia in dogs. The author observed a rapid recovery (less than 5 minutes) in the dogs, with no aftereffects. Prolonged exposure to the anesthetic mixture did not produce toxic effects in animals of any age; 4 hours under anesthesia was the same as 4 minutes with respect to ease of recovery.

These animal studies are summarized in Table XII-6.

Correlation of Exposure and Effect

In both humans and animals, the principal effect attributable to acetylene is a clinically safe and reversible anesthetic effect which is observed when acetylene is administered with oxygen in concentrations of 100,000-800,000 ppm in humans or 200,000-900,000 ppm in animals. The relevance of these anesthetic studies to occupational exposure to acetylene is not clear because the acetylene used was administered (1) in high concentrations in oxygen, and (2) only for short periods of time. No experimental studies, either chronic or acute, were found in the literature pertaining to the biologic effects of acetylene or acetylene mixtures at

concentrations below 100,000 ppm in either humans or animals.

Partially purified acetylene was used successfully, although not widely, as an inhalation anesthetic gas for about two decades and was abandoned, according to Sollmann, [25] only because of the disagreeable odor caused by its impurities. Concentrations as high as 40% (400,000 ppm) have been recommended for anesthesia in humans. [20,25] Most studies on the use of acetylene as an anesthetic ended in the 1930's. None of these studies can be definitively related to present-day occupational exposure to acetylene. The low toxicity observed in these acute studies reporting high concentrations of only partially purified acetylene would seem to indicate a low toxicity at concentrations near the proposed environmental limit of 2,500 ppm. However, no reports on chronic inhalation studies of acetylene have been found in the literature.

Other biologic effects reported in association with the manufacture or use of acetylene, such as pulmonary edema, [32,33] bronchospasm, [34] urticaria, [34] and acute anesthesia, [37] are probably due to the presence of toxic impurities in acetylene, to materials produced during its use, or to physical agents. In all such instances, proper attention to good work practices might have prevented these health hazards.

Carcinogenicity, Mutagenicity, and Teratogenicity

No reports have been found in the literature pertaining to the mutagenicity, carcinogenicity, or teratogenicity of acetylene.

Moreover, there are no reports of studies in either humans or animals aimed at elucidating and testing acetylene metabolites for carcinogenic, mutagenic, and teratogenic activities.

IV. ENVIRONMENTAL DATA

Sampling and Analysis

The reaction of acetylene with cuprous salts to form copper acetylide was first used by Berthelot [55] in 1862 to develop an analytical method for acetylene. Berthelot's method was simplified and improved upon by Ilosvay, [56] and later by Treadwell, [57] who developed the gravimetric analytical procedure known as the Ilosvay test. In this procedure, trace quantities of acetylene were determined by shaking gas mixtures in a glass-stoppered cylinder or separatory funnel with a reagent made by adding concentrated ammonium hydroxide solution and hydroxylamine hydrochloride to cupric nitrate in water. The presence of acetylene was indicated by the formation of a red precipitate. The precipitate was then filtered, washed, treated with nitric acid, ignited, cooled, and finally weighed as copper oxide. Calculations were performed on the assumption that $(\text{Cu}_2\text{C}_2\text{H}_2)\text{O}$ (sic) was formed. [58]

Other analytical methods developed were based on a colorimetric evaluation of the red color of copper acetylide formed in Ilosvay reactions. Weaver [59] compared the red cuprous acetylide with either ruby glass slides or colored mixtures of dyestuffs. Schulze [60] passed the gas sample through a cuprous ammonium solution until the depth of color matched that of a previously prepared standard, and Riese [61] prepared his standards by adding a cuprous solution to a dilute aqueous solution of acetylene.

Coulson-Smith and Seyfang, [62] in 1942, raised the following objections to these three colorimetric methods: the dyes used by Weaver

were not readily available; Riese did not consider the solubility changes of acetylene at varying temperatures and pressures; and Schulze's procedure was erroneous because of incomplete diffusion. All three methods had a further drawback in that the gelatin used as a protective colloid caused considerable froth, which made color comparisons difficult or impossible.

Coulson-Smith and Seyfang [62] developed a colorimetric method that reduced these drawbacks. Their procedure involved a comparison in Nessler tubes between the depth of color produced by standard ferric alum solutions in an excess of potassium thiocyanate, and the depth of color produced by 100 ml of acetylene-air standards (ranging from 200 to 2,500 ppm v/v) that had been passed through cuprous ammonium chloride solutions. The resulting cuprous acetylide solutions were visually matched to the corresponding iron standards. The depth of color in the cuprous acetylide solutions bore a linear relationship to the concentration of acetylene within the concentration range of 200-2,500 ppm (v/v) acetylene-air mixtures. This method of analysis was reported by the authors to be accurate to within ± 100 ppm for mixtures with an acetylene content of 200-1,500 ppm (v/v), and to within ± 200 ppm for concentrations of up to 2,500 ppm (v/v) when a 100-ml sample was used. Modifications of this experimental procedure for determinations of acetylene in air at concentrations of 10,000-30,000 ppm were also established. [62] The authors stated that this method of analysis proved very satisfactory within the listed concentration ranges, even when reagents had been previously prepared. Geissman et al [63] pointed out two significant limitations to this method. First, there was a difference in color tone between colloidal cuprous acetylide and ferric thiocyanate that made color matching at the lower concentrations difficult.

Second, if the rate of gas passage, ie, the time of contact between the gas and the reagent, was not properly controlled in all determinations, the results would not be reproducible.

A variation of the Ilosvay test was developed by Geissman et al [63] to determine trace amounts (1-15 ppm) of acetylene in the air. Their method was based on the use of a liquid-air trap to condense acetylene from large volumes of air passed through the trap, and it improved upon earlier methods by using a colorimeter to measure color intensity and closed-container agitation of air-acetylene mixtures to reduce errors in absorption rates. Any acetylene thus concentrated reacted with a modified Ilosvay reagent to form a red precipitate which could be determined in a colorimeter equipped with a 515- μ m filter. The authors determined the precision of the method to be $\pm 0.1-0.5$ ppm over the concentration range of 1.0-15.0 ppm. In addition, sample flowrates of no more than 4-6 cu ft/hr were recommended. This was to ensure that no detectable acetylene would escape condensation before a 0.3- to 0.6-ml sample could be obtained. Because of the time and equipment required to obtain a sufficiently large sample, the method is rather impractical for establishing environmental limits in an industrial setting. Since the coils used in the liquid-air trap are made of copper, any copper salts which are present will react with the acetylene to give erroneous results.

A more rapid and accurate colorimetric method for detecting and measuring concentrations of acetylene in air as low as 10 ppb was developed in 1959 by Hughes and Gorden. [64] The required equipment was simple and portable. Acetylene from air was concentrated on silica gel by adsorption, and the gel surface was then treated with a solution of cuprous ammonium

chloride. The exact acetylene content was established by a visual comparison of the treated sample tube to other tubes that had been previously treated with the same reagent, and which contained constant amounts of adsorbed acetylene produced by exposures to known concentrations of the gas. Tubes collected in the field could be treated immediately or stored in liquid nitrogen for up to 48 hours without apparent color loss. If tubes could be returned to the laboratory within 30 minutes, storage in dry ice was possible. This method measured total adsorbed quantities of acetylene as low as 0.012 μg in 12 ml of air (1 ppm). The authors stated that interfering substances for this test were of two types: (1) those that prevented adsorption of acetylene, and (2) those that gave colored compounds with a cuprous ammonium solution. In the first group, water was the substance that caused the most difficulty, but this could be eliminated by the inclusion of a trap cooled to dry-ice temperature and placed before the detector tube. However, this is impractical for field inspections in an industrial setting. The second type of interfering substance was any low molecular weight alkyne that would pass through the trap described above. These interferences occur because the experimental method is not specific for acetylene and will detect any alkyne in which a triple bond occurs at the end of a hydrocarbon chain. Other interfering substances with relatively high vapor pressures, such as hydrogen sulfide and some mercaptans, are not trapped in the dry-ice trap. [65]

Portable acetylene detector tubes provide a quick and simple way to spot check potential exposure areas. These tubes are based on the method of adsorption of acetylene on treated silica gel, as described by Hughes and Gorden. [64] There are presently several manufacturers of these tubes.

[65] Such tubes have been calibrated to the measurable ranges of 3-600 ppm, 50-1,000 ppm, and 500-3,000 ppm. Inaccurate measurement can result because of interference by various hydrocarbons, ammonia, hydrogen sulfide, and carbon monoxide. [65] None of these tubes have yet been certified by NIOSH.

There are several nonchemical, or dry, methods applicable to the sampling and analysis of acetylene mixtures in the range below the lower explosive limit (LEL). [66] Of these, the portable combustible gas meter equipped with a flash arrester to prevent flashback is the most commonly used detection method in the field. Some of these instruments are based on the reaction of a heated filament in contact with combustible gases. The filament is heated to operating temperature by the passage of an electric current. When the gas sample contacts the heated filament, combustion on the filament surface raises the temperature in proportion to the quantity of combustibles in the sample. A Wheatstone bridge circuit, with the filament as one arm, measures the current caused by the temperature change, which is proportional to the percentage of combustibles present in the sample. [67] Obviously, this method is not specific for acetylene, but it is practicable for field inspections and can be used to spot check for potential occupational exposure in areas where the presence of acetylene, or acetylene mixtures, might pose a fire or explosion hazard. One minor drawback of the combustible gas meter is that, in the absence of sufficient oxygen to allow combustion, readings would be inaccurate.

In recent years, gas chromatographic sampling and analytical methods of suitable specificity and sensitivity for acetylene determinations have been developed. [68] The gas chromatograph used in these analytical

procedures normally consists of three parts: a chromatographic column, a detector, and a recording system. Samples of gas mixtures are separated into their constituents when passing through the column, owing to their different retention times on the column material. Once this separation has been effected, the detector determines the concentration of each of the mixture constituents; this information is then registered by the recording system. Gas chromatography is specific and sensitive but poses a serious drawback in that portable systems are not readily available.

Appendices I and II present recommended methods for sampling and analysis based on the use of both a combustible gas meter and gas chromatography. This combination of methods affords maximum warning against any immediate fire or explosion hazards in workplace environments, while at the same time allowing for a later determination of the extent of exposure to acetylene. The procedure is twofold: (1) a reading is taken with a suitable combustible gas meter properly calibrated for acetylene; (2) if this reading indicates an acetylene concentration of 1,500 ppm or greater in the workplace environment, employees shall be advised that acetylene is present in elevated concentrations, and at the same time a sample shall be taken to determine the exact extent of the exposure. This requirement applies where combustible gas meters are used to screen exposures. If the combustible gas meter has not been calibrated for acetylene, special procedures shall be implemented where readings are in excess of 1,500 ppm. This level of 1,500 ppm was chosen because of the nonspecificity of the combustible gas meter method and because of the need for a rapid monitoring technique below the environmental limit.

Control of Exposure and Hazards

The main objective of engineering design and control measures should be the implementation of safety precautions designed to prevent fire and explosion hazards. There should be adequate engineering controls for dealing with a fire arising in any work location. In addition, in areas where acetylene is manufactured or used, adequate ventilation should be provided to maintain the concentration of acetylene and its impurities (such as phosphine) at safe levels.

Acetylene can be solidified and liquefied with relative ease but, in both states, it may explode with extreme violence when ignited. Thus, the manufacture and use of liquid acetylene should be strictly regulated. [69] Explosive limits and physical properties are listed in Table XII-1. [2-4] Gaseous acetylene may also decompose with explosive force under certain conditions at higher pressures, but 15-pounds-per-square-inch gage (psig) is generally accepted as a safe pressure limit. [70] Generation, distribution through hose or pipe, or utilization of acetylene for welding and allied purposes at pressures in excess of 15-psig or 30-pounds-per-square-inch absolute (psia) pressure should be prohibited. [70]

Work locations and procedures in which acetylene fire and explosion hazards may be prevalent include: large-scale acetylene manufacturing and charging operations; acetylene cylinder handling, transport, storage, and use; small-scale acetylene production from calcium carbide generators; and plants in which acetylene is used for chemical synthesis.

Plants engaged in the generation and compression of acetylene and in the filling of acetylene cylinders, either as their sole operation or in conjunction with facilities for filling other compressed gas cylinders,

should be properly located, constructed, ventilated, and temperature-controlled. Suitable electrical equipment should be used to control flammability hazards. Engineering design for plants compressing acetylene at 15 psig or greater should be in accordance with guidelines for each of the above as presented in NFPA No. 51A-1973. [71, R Lenhard, written communication, May 1976]

Proper plant design guidelines for reducing explosion hazards, based on predicting the possible explosion force in acetylene systems, were presented in an experimental study by Sargent. [72] The intent of the study was to estimate the predetonation distance for acetylene-manufacturing systems. Detailed specifications and safety measures written for a particular plant operation run by the British Oxygen Company in Maydown, Northern Ireland, contain procedures for ensuring safe operations in a plant producing acetylene from calcium carbide. [73]

Handling and use of acetylene cylinders represent the greatest potential sources of fire and explosion hazards because of the large number of employees involved in such operations. The present federal standard, 29 CFR 1910.102(a), provides that such operations shall be in accordance with the Compressed Gas Association pamphlet G-1. [74]

Small-scale production of acetylene from calcium carbide generators for nonchemical use has diminished with the introduction of acetylene in cylinders. In the synthetic chemical industry, most acetylene-consuming plants are located within 3 miles of acetylene-producing plants, and acetylene is often delivered via pipeline. [7]

The proper operation of generators producing acetylene from calcium carbide for welding and other purposes is detailed in 29 CFR 1910.252(a)(6).

When acetylene is used for chemical synthesis, it is generally present as a gas contained in piping systems. As indicated by data obtained during field visits, most major processes for chemical synthesis which utilize acetylene are currently closed processes. [75(pp 6,8,16)] The main hazards associated with these operations are fire and explosion; thus, acetylene transmission systems should be properly designed to minimize these hazards. The federal standard, 29 CFR 1910.102(b), provides that for piping transfer and distribution of acetylene, systems shall be designed, installed, maintained, and operated in accordance with the Compressed Gas Association pamphlet G-1.3-1959. [76] However, the Compressed Gas Association (R Lenhard, written communication, May 1976) has advised NIOSH that the recommendations contained in this pamphlet only apply to specific conditions, and that one should read the pamphlet carefully and apply the regulations contained therein only to those specific conditions.

V. DEVELOPMENT OF A STANDARD

Basis for Previous Standards

The literature presents several standards applicable to acetylene which have been promulgated by trade associations and professional societies. These standards, which include those published by the American National Standards Institute (ANSI) and the Compressed Gas Association (CGA), primarily refer to appropriate work practices that are designed to minimize hazards associated with the flammable and explosive properties of acetylene. In 1965, the Threshold Limits Committee of the American Conference of Governmental Industrial Hygienists (ACGIH) considered the addition of acetylene to Appendix E of their publication, which classifies some gases and vapors as simple asphyxiants. These substances are so classified because of their action when present in high concentrations in the workplace atmosphere and because they lack other significant physiologic effects. Acetylene was included in the ACGIH's Appendix E in 1970. [77] A threshold limit value (TLV) was not recommended at that time because acetylene was deemed to be nontoxic if the oxygen content in the acetylene-air mixture was above 18% by volume under normal atmospheric pressure (equivalent to a partial pressure, pO_2 , of 135 mmHg). Similarly, the Hygienic Guide Series, published by the American Industrial Hygiene Association, [2] recommended that no formal or official maximal atmospheric concentration be assigned to acetylene because of its lack of toxicity.

The present federal standard for acetylene is stipulated in 29 CFR 1915.11(a)(2) which sets a workplace environmental concentration allowable for flammable vapors or gases in any confined space of a ship. This

standard states that, "if tests indicate that the atmosphere in the space to be entered contains a concentration of flammable vapor or gas greater than 10% of the lower explosive limit (LEL), the space shall be ventilated to reduce the concentration below 10% of the lower explosive limit before men are permitted to enter." On the basis of this standard, the maximum allowable environmental concentration for acetylene is 2,500 ppm (1/10 the LEL of 25,000 ppm). The 1/10 factor appears to be arbitrary and is used solely with the intent of providing an adequate safety margin for preventing fire and explosion.

Basis for the Recommended Standard

Recommended environmental limits for airborne levels of acetylene based on health hazards other than indirect production of asphyxia have not been found in the literature. No chronic low-level toxicity studies have been found. In fact, no reports were found on biologic effects of acetylene at concentrations below 100,000 ppm. Acetylene is hazardous at concentrations below 100,000 ppm because of its flammable and explosive properties. The existing federal standard (29 CFR 1915.11(a)(2)) stipulates that the maximum allowable environmental concentration of acetylene in the confined space of a ship shall be 10% of the lower explosive limit (LEL). This standard is appropriate for all workplace environments since the maximum allowable concentration is well below the acetylene concentration at which anesthesia occurs, as well as below the concentration at which the flammable and explosive properties of acetylene present a hazard. It is therefore recommended that the present federal standard be made the basis for an acetylene environmental standard in all

workplace environments.

Because of the toxicity of some impurities, especially phosphine, arsine, hydrogen sulfide, and methyl acetylene, and combustion products of commercial grades of acetylene, it is important that compliance with federal standards applicable to these substances be ensured.

VI. WORK PRACTICES

Acetylene has not been shown to be toxic when present in concentrations below 100,000 ppm (see Chapter III). However, there have been reports in the literature of toxic effects caused by contaminants associated with the production and use of acetylene. [32-34,37] Good work practices must therefore be oriented toward minimizing these toxic hazards and any others that might be present in the workplace environment.

The Compressed Gas Association Commodity Specification for Acetylene [12] established a grading system for identifying and quantifying phosphine, arsine, and hydrogen sulfide content in commercial grades of acetylene. This grading system is given in CGA pamphlet G-1.1 and is illustrated in Table XII-3. It must be noted that if these contaminants present in commercial grades of acetylene are released from the cylinder, there is a possibility that airborne concentrations of these contaminants might exceed present federal limits. Therefore, on the basis of good work practices, it is strongly recommended that a statement of qualitative and quantitative analyses of cylinder contents be made a part of all labeling for acetylene containers, or that the employer use other means, at least as efficient, to convey to the employee such analytical results. It is also recommended that the federal standards applicable to these contaminants be considered and adhered to.

Safe work practices for the production and use of acetylene are the subject of a considerable body of literature. [13,69-73,76,78-87] Most of these references are concerned with the implementation of safety procedures and safety controls designed to protect employees from the occurrence of

fire and explosions. The four main industrial environments in which potential exposure to a flammable atmosphere created by the presence of acetylene might exist are: (1) plants for production of acetylene from small-scale calcium carbide generators, (2) plants for large-scale production of acetylene for chemical synthesis or acetylene cylinder charging, (3) areas in which there is transmission of acetylene via piping or hose systems, and (4) workplace areas which involve the handling, use, and storage of acetylene cylinders.

(a) General Considerations

Because of the flammability and explosibility of acetylene, bans on smoking, or introducing any other source of ignition, or causing any form of ignition shall be strictly enforced in all areas where acetylene is produced, used, handled, or stored. Signs relating to these safety precautions are mentioned by other standard-setting associations. [71,78,82]

Employees should be informed of the rules applying to normal operation of acetylene equipment and of the measures to be taken in the event of accidents. [13] Combustible gas meters equipped with suitable flash arresters and personnel trained in the proper use should be available for spot checking for acetylene leaks in any of the systems in use. [67]

Self-closing metal waste receptacles shall be provided for greasy, oily rags and other such waste materials.

Exits, ventilation ducts, and fire protection equipment shall be easily accessible and obstruction free.

Firefighting equipment shall be conspicuously identified and located to be readily visible and accessible in an emergency.

Before any repair work is attempted on a container or pipe which has contained acetylene, care should be taken to ensure that all such systems have been well purged, either by filling with water or by purging with an inert gas, such as nitrogen. [76]

In the presence of water vapor or certain contaminants, acetylene is likely to react with the following substances to form explosive acetylides: bromine, fluorine, iodine, potassium, and cobalt; copper, mercury, silver, and any salts of these metals; hydrides of sodium, cesium, and rubidium. [88] Therefore, contact between any of the above substances and acetylene shall be strictly prohibited.

Because of the potential formation of acetylides when acetylene is in contact with copper, recommendations have been reported in the literature [2,13,69,71,78,82,89] for the maximum percentage of copper permitted in alloyed metal potentially exposed to acetylene. These maximum limits range from 50% copper in the Matheson Data Sheets [89] to 70% copper in international codes. [69,82] It is recommended that containers, pipes, or metal parts or pieces of machinery made of copper or of alloys containing more than 50% copper should not be used if the material is potentially exposed to acetylene, unless such alloys have been found to be safe in the specific application by experience or by test. The use of unalloyed copper piping for acetylene shall be prohibited; instead, steel or wrought iron is strongly recommended.

All major equipment and piping employed in acetylene operations shall be electrically continuous and bonded to a grounding electrode, as defined by the National Electrical Code, in 29 CFR 1910.308-309.

Generators, compressors, and safety relief devices for acetylene use should be plainly marked with their capacities, pressure ratings, the manufacturers' names and addresses, and model or serial numbers. The capacity and operating pressure of this equipment should not exceed the rating for which it was designed. [82]

Acetylene should not be generated, piped (except in approved cylinder manifolds), or utilized at a pressure in excess of 15 psig pressure (1 atmosphere gage pressure) or 30 psia pressure (2 atm absolute pressure). [70]

(b) Production of Acetylene from Small-Scale Calcium Carbide
Generators

Generators should be of an approved design and be operated only according to the manufacturer's instructions.

Generators should not be operated at more than the rated capacity. Only calcium carbide of correct size and grading should be used in such operations in order to allow control of acetylene-generation rates.

Good work practices should be followed when generators are replenished with carbide, when spent carbide residue is emptied, or during maintenance procedures to diminish the hazards of fire and explosion, and to ensure proper oxygen levels in the atmosphere.

Before any repairs are attempted, the generator should be completely filled with water and then drained. The emptying of carbide residue into a sewer or drain shall be avoided; instead, such residue shall be disposed of in a specially constructed pit or in some other suitable manner.

Hydraulic seals should be checked daily before commencing work and after any flashback, and the water level should be adjusted if necessary.

Only water, at a temperature not to exceed 130 F (54 C), or nonignition-producing equipment shall be used to thaw a frozen pipe or valve.

(c) Large-Scale Acetylene Production and Cylinder Charging

Such acetylene operations should be in accordance with NFPA-51A. [71] The present federal standard for the design and construction of plants engaged in the generation and charging of acetylene cylinders is 29 CFR 1910.102(c), which is the standard prescribed in the Compressed Gas Association Pamphlet G-1.4-1966. However, NIOSH was informed by the Compressed Gas Association (R Lenhard, written communication, May 1976) that Pamphlet G-1.4-1966 was obsolete and was superceded by NFPA-51A.

Rules for the use and maintenance of acetylene generators shall be obtained and shall be conspicuously posted.

(d) Transmission of Acetylene in Piping or Hose Systems

Such acetylene operations should be in accordance with the present federal standard 29 CFR 1910.102(b) which is based on Compressed Gas Association pamphlet G-1.3-1959. [76] This standard shall be used only for the special circumstances mentioned in this pamphlet which include transmission of acetylene between the source of production and the use point, and only under pressures stipulated therein (R Lenhard, written communication, May 1976). It is recommended that piping systems be constructed of material that will withstand the high pressures that may exist in such operations.

Rules and instructions covering the operation and maintenance of acetylene distribution piping systems should be readily available to employees.

The surface temperature of acetylene-containing pipelines shall not be allowed to exceed 130 F (54 C). Aboveground piping systems should be marked in accordance with the Scheme for the Identification of Piping Systems, ANSI Standard A13.1. [81]

Hoses for acetylene should comply with the Specification for Rubber Welding Hose, 1965, issued by the Compressed Gas Association and the Rubber Manufacturers Association. [81] The use of metal-clad or armored hose is not recommended, but, if used, the metal reinforcement must not be exposed to either the inside gas or the outside atmosphere. Hose connections should comply with the Standard Hose Connection Specification, 1957, issued by the Compressed Gas Association.

(e) Handling, Use, and Storage of Acetylene Containers

Such procedures shall be in accordance with the present federal standard 29 CFR 1910.102(a) which is based on Compressed Gas Association pamphlet G-1. [74] It is recommended, however, that Compressed Gas Association pamphlet P-1 [90] be used for such procedures since additional information is contained in this pamphlet. In addition, there is a substantial body of literature on safety practices for protecting against the fire and explosion hazards of acetylene stored in containers. [70,78-80,82-84,86,87]

Acetylene cylinders shall always be used with the valve end up to prevent escape of acetone solvent. The temperature of the cylinder contents shall not exceed 130 F (54 C).

Only cylinders that meet the US Department of Transportation (DOT) Specifications 8 or 8AL (49 CFR Parts 171-179) and the requirements for fillings of a porous material and a suitable solvent are authorized by DOT

for use with acetylene. Only acetylene cylinders which are suitably protected from any contact with hot metal slag or sparks shall be used in any welding or cutting operations.

Acetylene cylinders in permanent storage shall be separated from oxygen cylinders, reserve stocks of carbides, or highly combustible materials by a minimum of 20 feet (6.1 m) or by a noncombustible barrier at least 5 feet (1.5 m) high having a fire resistance rating of at least 1/2 hour. Acetylene cylinders shall be stored in assigned areas where they will not be knocked over or damaged by passing or falling objects. In addition, they shall be stored away from elevators, stairs, or gangways, and away from radiators and other sources of heat. Storage of no more than 2,000 cu ft (56 cu m) of cylinder acetylene should be allowed inside a building when a storage area is within 100 feet (30.5 m) of other acetylene storage areas not protected by automatic sprinklers. Acetylene cylinders shall be secured to prevent them from toppling over.

When acetylene cylinders are coupled, approved flash arresters shall be installed between each cylinder and the couples blocked. When no more than three cylinders are coupled for outdoor use, one flash arrester installed between the couples block and regulator is suitable.

Cylinders in excess of 40 pounds (18 kg) total weight should be transported on a hand or motorized cart. Valve caps should be kept in place except when the cylinders are in use or are connected and ready for service. [81] All cylinder valves shall be closed after use. Where a special wrench is required, it should be left in position on the stem of the valve while the cylinder is in use so that the acetylene may be quickly turned off in case of emergency. In the case of coupled cylinders, at

least one such wrench should be readily available. [81]

Fire watchers should be utilized whenever welding or cutting with acetylene is performed in locations where other than a minor fire might develop. Fire watchers shall be trained in the use of fire extinguishing equipment and be familiar with facilities for sounding a fire alarm. They shall watch for fires, try to extinguish them when feasible, or otherwise sound an alarm. A fire watch shall be maintained for at least one-half hour after completion of welding or cutting to detect or extinguish possible smoldering fires. [81]

VII. RESEARCH NEEDS

No reports have been found that revealed acute or chronic biologic effects of acetylene at concentrations below 100,000 ppm. In addition, no studies have been found on the biotransformation of acetylene in humans or animals. Thus, two areas in which research is needed are: (1) chronic inhalation studies using acetylene at concentrations reflecting environmental exposures, and (2) biotransformation studies using radioactively labeled acetylene.

The main objective of the chronic inhalation studies would be to determine if long-term exposure to acetylene might be associated with systemic toxicity, carcinogenesis, mutagenesis, teratogenesis, or other effects on reproduction. Biotransformation studies might provide information on the production of metabolites of acetylene which could produce some of the biologic effects mentioned above. An epidemiologic study of employees involved in the production and use of acetylene, with emphasis on possible biologic effects, would permit a statistical evaluation of the population of employees occupationally exposed to acetylene.

In the area of work practices associated with acetylene production and use, further research is needed to determine the nature and amounts of impurities present in commercial acetylene and its products of combustion. Chronic inhalation studies should also be performed to determine the toxicity of these impurities and combustion products.

NIOSH strongly encourages industry to find suitable means to remove harmful contaminants, such as arsine, from commercially available acetylene to alleviate the hazards to which users of acetylene may now be subjected.

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IX. APPENDIX I

SAMPLING-MONITORING METHOD USING A COMBUSTIBLE GAS METER AND SAMPLING METHOD FOR USE WITH GAS CHROMATOGRAPHIC ANALYSIS

The method presented in Appendix I, Section A, is a modification of that published by the Mine Safety Appliances Company. [67] The sampling and analytical methods presented in Appendix I, Section B, and in Appendix II are based on those described by the Intersociety Committee in Methods of Air Sampling and Analysis. [68]

Section A - Combustible Gas Meter Method

(a) Atmospheric Sampling

A combustible gas meter shall be used to determine acetylene concentrations in areas where exposure to acetylene is suspected. Only instruments designed for use with acetylene shall be used because other combustible gas meters may contain copper or silver wires or filaments which can form dangerous acetylides on contact with acetylene.

(b) Sampling Procedure

Follow the instructions given in the manual for each combustible gas meter. Typically, the sampling procedure will require the following steps:

- (1) Sweep the combustion chamber free of combustible gases and fill it with fresh air.
- (2) Turn on the batteries and apply the proper voltage to the bridge.

(3) Balance the bridge to zero deflection on the meter while the fresh air is in the open chamber.

(4) Draw the air sample into the meter and record the meter reading. Repeat this at least three times; calculate and record the average of the readings.

(5) Determine the concentration of acetylene in the air samples from the calibration curve provided with each properly calibrated meter.

(6) Record a description of sampling location and conditions, equipment used, time, and any other pertinent information.

(7) If the concentration of acetylene as determined by this procedure is 1,500 ppm or greater, take an atmospheric sample for gas chromatography as described in Section B of this Appendix.

Section B - Sampling Method for Use with Gas Chromatographic Analysis

Samples shall be collected in areas where acetylene is in use and where acetylene concentrations might be expected to exceed 1,500 ppm. A description of sampling location and conditions, equipment used, time and rate of sampling, and any other pertinent information shall be recorded.

(a) Equipment

(1) Rigid-walled gas sample container made of glass and fitted with stopcocks.

(2) One atomizer rubber bulb set or automatic buret bulb.

(b) Sampling Procedure

(1) Flush the container out three times using the rubber

buret bulb attached to the tube stopcock.

(2) Collect the sample, close the stopcocks tightly, and remove the atomizer bulb.

(3) Give the container an identifying number and record appropriate field information.

(4) Send the samples to the laboratory for analysis as soon as possible.

X. APPENDIX II
ANALYTICAL METHOD FOR ACETYLENE

Principle of the Method

An aliquot of the atmospheric sample contained in the sampling container is injected into a gas chromatograph. The area of the resulting peak for acetylene is determined and compared with areas obtained from injection of a pure acetylene standard.

Range and Sensitivity

The lower limit of detection of this analytical procedure is 0.01 ppm/sample by volume.

Interferences

Any compound which has about the same retention time as acetylene under the gas chromatographic conditions described in this method, eg, methane, will interfere with the analysis. This type of interference can be alleviated by changing the operating conditions of the instrument, usually the column or the column temperature.

Precision and Accuracy

Replicate analyses of aliquots of uniform air samples and standards should not differ by more than 10% of the standard deviation.

Advantages of the Method

The method is rapid and especially applicable to routine collection and analysis of grab samples. Elution of acetylene from the gas chromatograph is effected in 16 minutes or less.

Apparatus

(a) Gas chromatograph equipped with a flame ionization detector and suitable sampling valve.

(b) Column (2.4 m x 3 mm) packed with activated alumina coated with 17% (by weight) B,B'-oxydipropionitrile. Other columns which achieve the desired separation may be used.

(c) Mechanical or electronic integrator, or a recorder and some method for determining peak area.

(d) Syringes: 1-ml and other convenient sizes for preparation of standards.

Reagents

(a) Acetylene with a guaranteed minimum purity of 99 mole%.

(b) Bureau of Mines Grade A helium.

(c) Hydrogen: 98.9% purity.

(d) Pure grade nitrogen.

(e) Pure grade air.

Analysis of Samples

(a) Procedure: Air samples collected in the field and returned to

the laboratory are analyzed according to the following procedure:

(1) Turn on recorder.

(2) Set the electrometer attenuation.

(3) Connect the sample tube to the inlet of the sampling valve on the gas chromatograph and flush 20 ml of the sample through the loop.

(4) Inject a 1-ml aliquot of the sample.

(5) Elute the sample from the column.

(b) Make duplicate injections of each sample and of each standard dilution used in obtaining the standard curve. No more than a 10% difference should result in the peak areas recorded for each sample.

(c) Measure the areas of the sample peaks with an electronic integrator or by some other suitable method for area measurement.

(d) Calculate the concentration of acetylene present in the sample directly from the standard curve. No corrections are necessary for the injected volume since it is the same for both the sample determinations and the standard curve.

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, "6.8 ml/kg LD50-oral-rat," "16.4 ml/kg LD50-skin-rabbit," 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. Flammable or reactive data could be

flash point, shock sensitivity, or other brief data indicating nature of the hazard.

(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 flash point 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 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 ₂ O=1)		VAPOR PRESSURE
VAPOR DENSITY (AIR=1)		SOLUBILITY IN H ₂ O, % 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. TABLES

TABLE XII-1

PHYSICAL PROPERTIES OF ACETYLENE

Chemical formula	C ₂ H ₂
Formula weight	26.04
Boiling point	-84.0 C (sublimation occurs)
Melting point	-80.80 C
Autoignition temperatures:	
Pure	644 C
Commercial	Minimum of approximately 300 C for mixtures of 30-70% in air.
Flammable limits (by volume)	2.5-81% (in air) 2.8-93% (in oxygen)
Solubility	1.1 volumes of gas/volume of water at 15.5 C; soluble in many organic solvents
Color	Colorless
Odor	Odorless (reported odors attributed to impurities)
Specific gravity of gas at -32 C	0.6181
Vapor density at 25 C and 760 mmHg	1 mg/l = 939 ppm

From references 2, 3, and 4

TABLE XII-2

DOMESTIC ACETYLENE CONSUMPTION

(IN MILLIONS OF POUNDS)*

Year	Acrylic Acid and Esters	Acrylo- nitrile	Neoprene	Perchloro- ethylene	Trichloro- ethylene	Vinyl Acetate	Vinyl Chloride	Other	Total
1935			1		3			13	17
1936			2		5			13	20
1937			2	1	8	1		17	29
1938			3	1	6	1	1	18	30
1939			5	2	8	2	2	21	40
1940			8	2	13	2	5	25	55
1941			11	2	19	5	5	27	69
1942			17	2	30	9	12	30	100
1943			57	9	35	16	23	35	175
1944			97	12	40	18	33	43	243
1945			78	10	43	17	33	37	218
1946			81	10	43	17	47	35	233
1947			54	9	44	18	57	42	224
1948			60	9	44	19	73	50	255
1949			60	10	48	18	70	43	249
1950			85	10	50	23	94	52	314
1951			100	11	58	25	101	35	330
1952	2		112	9	63	24	83	18	309
1953	3	10	137	10	75	24	104	9	372
1954	4	11	118	7	58	30	101	24	353
1955	7	39	155	8	61	39	136	25	470
1956	8	47	169	8	67	44	154	40	537
1957	10	78	188	9	66	46	162	35	594
1958	13	84	167	8	57	53	164	42	588
1959	15	103	196	8	70	64	223	29	708
1960	16	92	211	8	69	66	232	19	713
1961	19	103	186	9	58	74	229	18	696
1962	21	147	202	12	67	85	271	18	823
1963	26	171	202	11	66	114	296	18	904
1964	31	198	221	12	66	125	317	19	989
1965	41	196	220	15	77	147	339	19	1,054
1966	50	174	235	15	86	173	318	20	1,071

*Conversion factors in lb acetylene/lb product:

Acrylonitrile:	-	0.6
Neoprene:	1935-1958	0.76
	1959-1966	0.70
Perchloroethylene:	1937-1953	0.22
	1954-1966	0.17
Trichloroethylene:	1935-1953	0.23
	1954-1966	0.21
Vinyl acetate:	-	0.33
Vinyl chloride:	1938-1951	0.46
	1952-1966	0.43

Adapted from Erskine [7]

TABLE XII-3

ACETYLENE SPECIFICATIONS

Limiting Characteristics	Grades					
	A	B	C	D	E	F
Acetylene minimum assay, % (v/v)	95.0	98.0	98.0	98.0	99.5	99.5
Phosphine and arsine, ppm	*	*	500	50	500	50
Hydrogen sulfide ppm	*	*	500	50	500	50

*Not available

Adapted from CGA specification G-1.1 [12]

TABLE XII-4

OCCUPATIONS WITH POTENTIAL EXPOSURE TO ACETYLENE

Acetaldehyde makers	Foundry workers
Acetic acid makers	Glassblowers
Acetone makers	Gougers
Acetylene black makers	Hardeners
Acetylene production workers	Heat treaters
Acrylonitrile makers	Lead burners
Alcohol makers	Metallizers
Braziers	Metal refiners
Butadiene makers	Motorboat fuel makers
Carbon black makers	Organic chemical synthesizers
Ceramic makers	Oxyacetylene cutters
Chloro-derivative makers	Oxyacetylene solderers
Copper purifiers	Oxyacetylene welders
Descalers	Rubber makers
Drug makers	Scarfers
Dyemakers	Tetrachloroethane makers
	Vinyl-derivative makers

Adapted from Gafafer [17]

TABLE XII-5

EFFECTS ON HUMANS FROM INHALATION OF ACETYLENE

Exposure Concentration (ppm)	Exposure Duration	Number of Subjects	Effects	Reference
700,000 - 800,000	Up to 0.5 hr	7	Stimulated respiration	41
300,000 - 800,000	1.25 - 4.5 hr	*	Increased blood pressure	40
750,000			Full anesthesia	40
300,000 - 800,000	3 min - 3 hr	2,000	Complete anesthesia with no aftereffects	24
800,000			Narcosis in 1 min	24
700,000			Profuse salivation	24
200,000 - 700,000	Several hours	*	Increase (up to 50 mmHg) in blood pressure, unconsciousness in 1-2 min	29
400,000	*	*	Insensitivity to pain in 5 min	30
350,000	*	*	Unconsciousness in 5 min	40
330,000	*	1	Unconsciousness in 7 min	28
300,000	*	1	General incoordination	28
200,000	*	1	Staggering gait	28
100,000	*	1	Slight intoxication	28

*Not available

TABLE XII-6

EFFECTS ON ANIMALS FROM INHALATION OF ACETYLENE

Species	No.	Exposure Concentration (in Oxygen)	Effects	Reference
Dogs	*	750,000 - 900,000 ppm	Anesthesia with rapid recovery, no after-effects	21
"	50	850,000 ppm	Increased respiratory volume and frequency, anesthesia with excitement and rapid recovery	45
	9	700,000 - 800,000 ppm	Decreased alkali reserve and carbonic acid blood levels, blood O ₂ -binding capacity and arterial O ₂ deficit higher during and lower after anesthesia, slightly increased blood sugar during anesthesia	53, 54
"	*	500,000 ppm	Rapidly induced anesthesia with no excitement	44
Cats	*	800,000 ppm	Slightly raised blood pressure	48
"	*	400,000 - 800,000 ppm	Reduced respiration, slightly raised blood pressure	41
"	*	200,000 - 800,000 ppm	Slightly raised blood pressure	50
"	*	Up to 800,000 ppm	"	

TABLE XII-6 (CONTINUED)

EFFECTS ON ANIMALS FROM INHALATION OF ACETYLENE

Species	No.	Exposure Concentration (in Oxygen)	Effects	Ref- erence
Rabbits	*	600,000 - 800,000 ppm	Reduced respiration, slightly raised blood pressure	41
"	*	Up to 700,000 ppm	Increased respiration after anesthesia, de- creased arterial blood CO ₂ tension and CO ₂ - combining power	52
Not specified	*	250,000 ppm	Slight capillary hyper- emia	47
"	*	500,000 ppm**	After 5-10 min, death	27
"	*	250,000 ppm**	After 30-60 min, toxi- city	27
"	*	100,000 ppm**	Toleration for 30-60 min	27

*Not available

**In air

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