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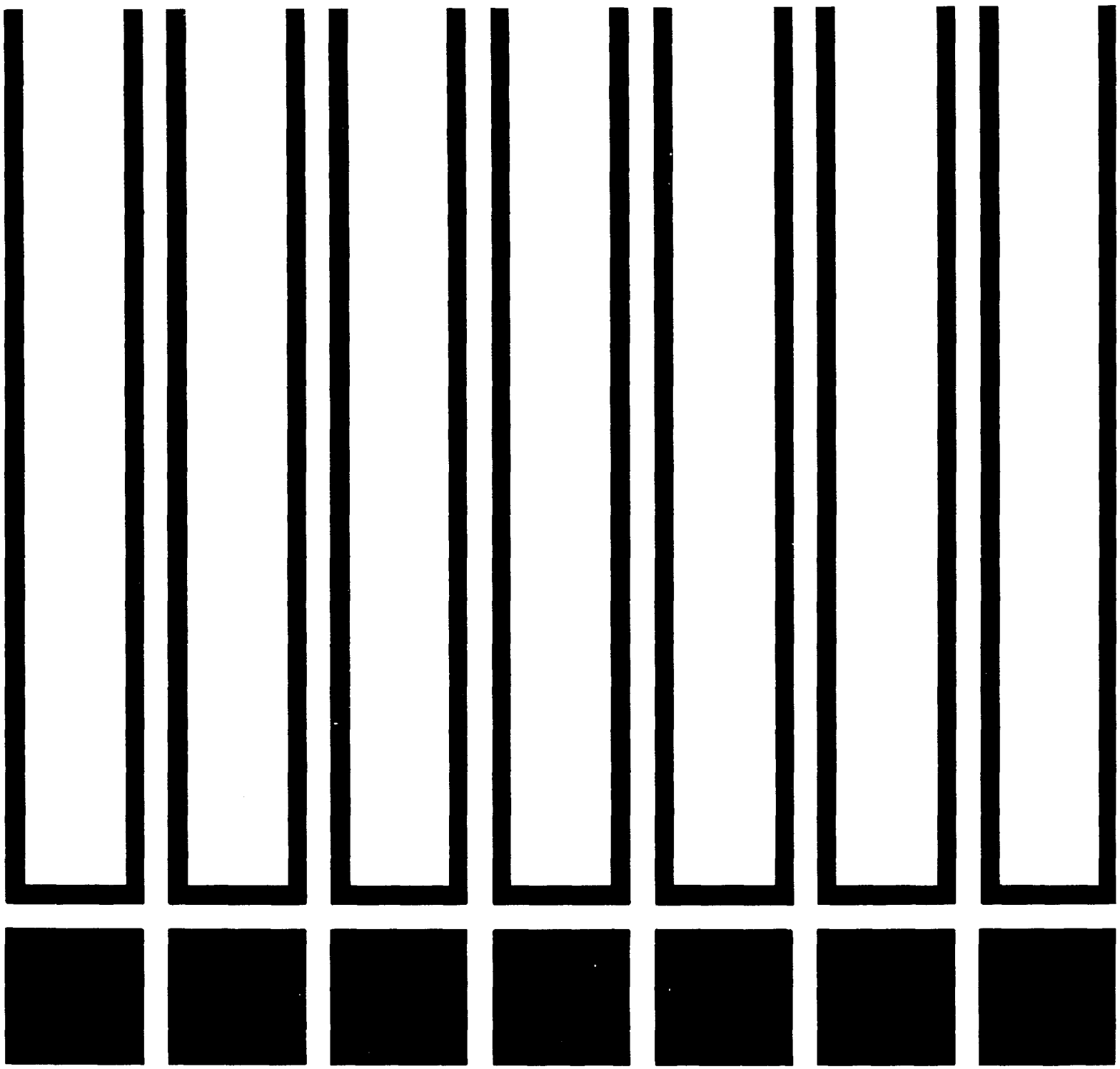

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service Center for Disease Control

National Institute for Occupational Safety and Health

criteria for a recommended standard....

OCCUPATIONAL EXPOSURE TO

VANADIUM

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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National Institute for Occupational Safety and Health

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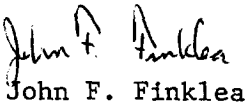
PREFACE

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and provide for the 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 vanadium by members of the NIOSH staff and the valuable constructive comments by the Review Consultants on vanadium, by the ad hoc committees of the American Academy of Industrial Hygiene, and the American Occupational 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 vanadium. A list of Review Consultants appears on page vi.



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The Division of Criteria Documentation and Standards Development, National Institute for Occupational Safety and Health, had primary responsibility for the development of the criteria and recommended standard for vanadium. Terence M. Grady of this Division served as criteria manager. SRI International developed the basic information for consideration by NIOSH staff and consultants under contract CDC-99-74-31.

The Division review of this document was provided by Keith H. Jacobson, Ph.D. (Chairman), Frank L. Mitchell, D.O., and Paul E. Caplan, with Herbert E. Stokinger, Ph.D. (Division of Biomedical and Behavioral Science), Harry M. Donaldson (Division of Surveillance, Hazard Evaluations, and Field Studies), and Seymour D. Silver, Ph.D.

The views expressed and conclusions reached in this document, together with the recommendations for a standard, are those of NIOSH. These views and conclusions are not necessarily those of the consultants, other federal agencies or professional societies that reviewed the document, or of the contractor.

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CRITERIA DOCUMENT:

RECOMMENDATIONS FOR AN OCCUPATIONAL

EXPOSURE STANDARD FOR VANADIUM

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I. RECOMMENDATIONS FOR A VANADIUM STANDARD

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to vanadium and its compounds in the workplace be controlled by adherence to the following sections. The standard is designed to protect the health and provide for the safety of employees for up to a 10-hour work shift, 40-hour workweek, over a working lifetime. Compliance with all sections of the standard should prevent adverse effects of vanadium and its compounds on the health of workers and provide for their safety. Sufficient technology exists to permit compliance with the recommended standard. Although NIOSH considers the workplace environmental limit to be a safe level based on current information, the employer should regard it as the upper boundary of exposure and make every effort to maintain the exposure as low as is technically feasible. The standard will be subject to review and revision as necessary.

"Vanadium" includes vanadium compounds, metallic vanadium, and vanadium carbide. "Vanadium compounds" include all chemically combined forms of vanadium but not alloys, intermetallics, or vanadium carbide. "Metallic vanadium" includes the element alone or in alloys or intermetallics, such as ferrovanadium and vanadium-aluminum. "Occupational exposure" to vanadium is defined as exposure to airborne vanadium above the action level. An "action level" is defined as equal to the environmental limit for that form of vanadium (see Section 1). Exposures to vanadium at lower concentrations will not require adherence to the recommended standard except for Sections 2(a,e), 3(b), 5(a,c), and 8(a).

The recommended standard is based on data which indicate that vanadium is a primary irritant to the respiratory tract, eyes, and skin. The irritation is usually reversible with no known residual systemic effects.

Section 1 - Environmental (Workplace Air)

(a) Concentrations

Occupational exposure to vanadium compounds shall be controlled so that employees are not exposed at a concentration greater than 0.05 milligrams of vanadium per cubic meter of air (0.05 mg V/cu m) measured as a ceiling concentration during any 15-minute sampling period.

Occupational exposure to metallic vanadium and vanadium carbide shall be controlled so that employees are not exposed at a concentration greater than 1.0 mg of vanadium/cu m measured as a time-weighted average (TWA) concentration for up to a 10-hour workday, 40-hour workweek, over a working lifetime.

(b) Sampling and Analysis

Environmental samples shall be collected and analyzed as described in Appendices I and II, or by any methods at least equivalent in accuracy, precision, and sensitivity.

Section 2 - Medical

Medical surveillance shall be made available as outlined below to all persons subject to occupational exposure to vanadium.

(a) Preplacement medical examinations shall include as a minimum:

(1) Comprehensive medical and work histories with special emphasis directed to evidence of chronic eye or skin disorders and respiratory conditions or allergies.

(2) Physical examination giving particular attention to the upper respiratory tract and eyes.

(3) Specific clinical tests including at least:

(A) A 14- x 17-inch posteroanterior chest roentgenogram.

(B) Tests of pulmonary function including forced expiratory volume during the 1st second (FEV 1) and forced vital capacity (FVC).

(4) A judgment of the worker's ability to use negative or positive pressure respirators.

(b) Periodic examination shall be made available at least annually, except as otherwise determined by the responsible physician, as follows:

(1) Interim medical and work histories.

(2) Physical examination as outlined in paragraph (a)(2) of this section.

(3) Pulmonary function tests as outlined in (a)(3)(B). A chest X-ray shall be taken at the discretion of the responsible physician, based on knowledge of work exposure and clinical findings.

(c) During examinations, applicants or employees found to have medical conditions, such as chronic upper or lower respiratory irritation, that could be directly or indirectly aggravated by exposure to vanadium

shall be counseled as to the possibly increased risk of impairment of their health from working with the substances.

(d) Initial medical examinations shall be made available to all employees within 6 months of the promulgation of a standard based on these recommendations.

(e) Pertinent medical records shall be kept for at least 30 years after employment has ended for all employees exposed to vanadium in the workplace. These records shall be made available to the designated medical representatives of the Secretary of Health, Education, and Welfare, of the Secretary of Labor, of the employer, and of the employee or former employee.

Section 3 - Labeling and Posting

(a) All labels and warning signs shall be printed both in English and in the predominant language of non-English-reading workers. Illiterate workers and workers reading languages other than those used on labels and posted signs shall receive information regarding hazardous areas and shall be informed of the instructions printed on labels and signs. Recommended labels and signs apply to all forms of vanadium except solid metallic forms, such as ingots, sheets, rods, and bars.

(b) Containers of vanadium shall carry a label which bears the chemical name of the compound contained therein and information on the effects of the particular compound on human health. The name and pertinent information shall be arranged as in the example below:

(CHEMICAL NAME)

HARMFUL IF INHALED OR SWALLOWED

IRRITATING TO SKIN AND EYES

Avoid contact with eyes, skin, and clothing.
Keep container closed.
Use only with adequate ventilation.

First Aid: In case of skin or eye contact, flush immediately and thoroughly with running water and consult a physician. If swallowed, consult a physician.

(c) In areas where vanadium is used, a sign containing information on the effects of the specific compound on human health shall be posted in readily visible locations. This information shall be arranged as in the example below:

(CHEMICAL NAME)

HARMFUL IF INHALED OR SWALLOWED

IRRITATING TO SKIN AND EYES

Avoid inhaling vapor, dust, or fume.
Avoid contact with skin, eyes, mouth, and clothing.
Provide adequate ventilation.

First Aid: In case of skin or eye contact, flush immediately and thoroughly with running water and consult a physician. If swallowed, consult physician.

(d) If respirators are required, the following statement shall be added in large letters to the sign required in Section 3(b):

RESPIRATORY PROTECTION REQUIRED IN THIS AREA

Section 4 - Personal Protective Equipment and Clothing

The employer shall use engineering controls if needed to keep the concentration of airborne vanadium at or below the limits specified in Section (1)(a) and shall provide protective clothing and equipment resistant to the penetration of vanadium when necessary to prevent gross skin and eye contact with liquid vanadium compounds or vanadium solutions. Protective equipment suitable for emergency use shall be located at clearly identified stations outside the work area.

(a) Protective Clothing

(1) The employer shall provide chemical safety goggles or face shields (8-inch minimum) with goggles and shall ensure that employees wear the protective equipment during any operation in which vanadium may enter the eyes.

(2) The employer shall provide appropriate clothing and equipment, including gloves, aprons, suits, boots, or face shields and goggles, and shall ensure that employees wear these where needed to prevent gross skin and eye contact.

(b) Respiratory Protection

Engineering controls shall be used when needed to maintain airborne vanadium concentrations at or below the recommended environmental limits. Compliance with the permissible exposure limits by the use of respirators is permitted only during installation and testing of engineering controls, during performance of nonroutine maintenance or repair, when working in confined spaces, or during emergencies. When use of a respirator is permitted, it shall be selected and used in accordance with the following requirements:

(1) To determine the type of respirator to be used, the employer shall measure the concentrations of airborne vanadium in the workplace initially and thereafter whenever control, process, operation, worksite, or climatic changes occur that are likely to increase the concentration of airborne vanadium.

(2) The employer shall ensure that no employee is exposed to vanadium above the recommended limits because of improper respirator selection, fit, use, or maintenance.

(3) A respiratory protection program meeting the requirements of 29 CFR 1910.134 that incorporates the American National Standard Practices for Respiratory Protection, Z88.2-1969, shall be established and enforced by the employer.

(4) The employer shall provide respirators in accordance with Tables I-1 and I-2 and shall ensure that the employees properly use the respirators provided when wearing respirators is required. The respiratory protective devices provided in conformance with Tables I-1 and I-2 shall be those approved by NIOSH and the Mining Enforcement and Safety Administration (MESA) as specified under the provisions of 30 CFR 11.

(5) Respirators specified for use in higher concentrations of airborne vanadium may be used in atmospheres with lower concentrations.

(6) The employer shall ensure that employees are properly instructed in the use of respirators assigned to them and on how to test for leakage, proper fit, and proper operation.

TABLE I-1

RESPIRATOR SELECTION GUIDE FOR VANADIUM COMPOUNDS

Concentration	Respirator Type Approved under Provisions of 30 CFR 11
Less than or equal to 0.5 mg/cu m	(1) High-efficiency particulate filter respirator with full facepiece (2) Supplied-air respirator with full facepiece, helmet, or hood (3) Self-contained breathing apparatus with full facepiece
Less than or equal to 70 mg/cu m	(1) Powered air-purifying respirator with full facepiece and high-efficiency particulate filter (2) Type C supplied-air respirator with full facepiece operated in pressure-demand or other positive pressure mode or with full facepiece, helmet, or hood operated in continuous-flow mode
Greater than 70 mg/cu m or emergency entry (into area of unknown concentration)	(1) Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode (2) Combination respirator that includes Type C supplied-air respirator with full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode
Firefighting	Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode

TABLE I-2

RESPIRATOR SELECTION GUIDE FOR METALLIC VANADIUM AND VANADIUM CARBIDE

Concentration	Respirator Type Approved under Provisions of 30 CFR 11
Less than or equal to 5 mg/cu m	Dust and mist respirator except single-use type
Less than or equal to 10 mg/cu m	(1) Dust and mist respirator except single-use or quarter-mask type (2) Supplied-air respirator (3) Self-contained breathing apparatus
Less than or equal to 50 mg/cu m	(1) High-efficiency particulate filter respirator with full facepiece (2) Supplied-air respirator with full facepiece, helmet, or hood (3) Self-contained breathing apparatus with full facepiece
Less than or equal to 500 mg/cu m	(1) Powered air-purifying respirator with full facepiece and high-efficiency particulate filter (2) Type C supplied-air respirator with full facepiece operated in pressure-demand or other positive pressure mode or with full facepiece, helmet, or hood operated in continuous-flow mode
Greater than 500 mg/cu m or emergency entry (into area of unknown concentration)	(1) Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode (2) Combination respirator that includes Type C supplied-air respirator with full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode
Firefighting	Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode

(7) The employer shall establish and conduct a program of cleaning, sanitizing, inspecting, maintaining, repairing, and storing of respirators to ensure that employees are provided with clean respirators that are in good operating condition.

(8) The employer shall periodically monitor the use of respirators to ensure that the proper type of respirator is worn, to evaluate the effectiveness of the respiratory protection program, and to eliminate any deficiencies in use and care of respirators.

(9) Respirators shall be easily accessible, and employees shall be informed of their location.

Section 5 - Informing Employees of Hazards from Vanadium

(a) At the beginning of employment and at least annually thereafter, the employer shall provide information to employees subject to occupational exposure to vanadium.

(b) The employer shall institute a continuing education program, conducted by persons qualified by experience or training, to ensure that all employees have current knowledge of job hazards, proper maintenance and cleanup methods, and proper respirator usage. The instructional program shall include a description of the general nature of the environmental and medical surveillance procedures and of the advantages to the employee of participating in these surveillance procedures. As a minimum, instruction shall include the information in Appendix III, which shall be kept on file, and it shall be readily accessible to employees at all places of employment where exposure may occur.

(c) Required information shall be recorded on the "Material Safety Data Sheet" shown in Appendix III or on a similar form approved by the Occupational Safety and Health Administration, US Department of Labor.

Section 6 - Work Practices

(a) Control of Airborne Vanadium

Engineering controls, such as process enclosure or local exhaust ventilation, shall be used when needed to keep exposures to vanadium concentrations within the recommended environmental limits. Ventilation systems, if used, shall be designed to prevent the accumulation of vanadium in the workplace environment and to effectively remove vanadium from the breathing zone of employees. Exhaust ventilation systems discharging to outside air must conform with applicable local, state, and federal air pollution regulations and must not constitute a hazard to employees. Ventilation systems shall be subject to regular preventive maintenance and cleaning to ensure effectiveness, which shall be verified by airflow measurements taken at least every 3 months.

(b) Storage

Containers of vanadium shall be kept tightly closed at all times when not in use. Containers shall be stored in a safe manner to minimize accidental breakage, spillage, or contact with moisture. Combustible materials, such as finely ground vanadium carbide, vanadium-aluminum alloys, vanadium metal, or ferrovanadium should be kept away from heat, sparks, or flames.

(c) Handling and General Work Practices

(1) Before maintenance work is undertaken, sources of vanadium shall be shut off. If respiratory protection is needed, see Section 4 for appropriate direction.

(2) Employees who have gross skin contact with vanadium, excluding vanadium ores, shall wash or shower, if necessary, to remove vanadium from the skin. Contaminated clothing shall be removed and discarded or cleaned before reuse. Prior to cleaning, contaminated clothing for reuse shall be stored in a container which is impervious to the compound. Personnel involved in cleaning contaminated clothing shall be informed of the hazards involved and be provided with safety guidelines on the handling of these compounds.

Section 7 - Sanitation

(a) The preparation, storage, or consumption of food should not be allowed in vanadium work areas.

(b) Employees who handle vanadium or equipment contaminated with vanadium should be advised to wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

(c) Waste material contaminated with vanadium shall be disposed of in a manner not hazardous to employees. The disposal method must conform with applicable local, state, and federal regulations and must not constitute a hazard to the surrounding population or environment.

Section 8 - Environmental Monitoring and Recordkeeping

(a) Industrial Hygiene Surveys

Within 6 months of the promulgation of a standard based on these recommendations, employers shall conduct an industrial hygiene survey at locations where there is vanadium in the workplace air to determine if there is exposure to airborne vanadium at concentrations greater than the limits recommended in Section 1(a). Records of these surveys, including the basis for concluding that concentrations of airborne vanadium are at or below the action level, shall be maintained. Surveys shall be repeated at least annually and within 30 days of any change likely to result in increased concentrations of airborne vanadium.

(b) Personal Monitoring

If it has been determined that the environmental concentration of vanadium exceeds the action level, then the employer shall fulfill the following requirements:

(1) A program of personal monitoring shall be instituted to identify and measure, or permit calculation of, the exposure of each employee occupationally exposed to vanadium. Source and area monitoring may be used to supplement personal monitoring.

(2) In all personal monitoring, samples representative of the exposure in the breathing zone of the employee shall be collected.

(3) For each determination of the TWA or ceiling concentration, a sufficient number of samples shall be taken to characterize employee exposure. Variations in the employee's work schedule, location, or duties and changes in production schedules shall be considered in deciding when samples are to be collected.

(4) Each operation in each work area shall be sampled at least once every 6 months or as otherwise indicated by a professional industrial hygienist. If an employee is found to be exposed to vanadium at concentrations above the limits recommended in Section 1(a), the exposure of that employee shall be measured at least once every week, control measures necessary to reduce the concentration of vanadium in the employee's environment to less than or equal to the limits recommended in Section 1(a) shall be initiated, and the employee shall be notified of the exposure and of the control measures being implemented. Such monitoring shall continue until two consecutive determinations, at least 1 week apart, indicate that the employee's exposure no longer exceeds the recommended environmental limits. At that point, semiannual monitoring may be resumed.

(c) Recordkeeping

Environmental monitoring records shall be maintained for at least 30 years. These records shall include the name of the employee being monitored, duties performed and job locations within the worksite, dates of measurements, sampling and analytical methods used, the number, duration, and results of samples taken, TWA and ceiling concentrations estimated from these samples, and the type of personal protection used, if any, by the employee. Employees shall be able to obtain information on their own environmental exposures. Environmental records shall be made available to designated representatives of the Secretary of Labor and of the Secretary of Health, Education, and Welfare.

Pertinent medical records shall be retained for 30 years after the last occupational exposure to vanadium. Records of environmental exposures applicable to an employee should be included in that employee's medical

records. These medical records shall be made available to the designated medical representatives of the Secretary of Labor, of the Secretary of Health, Education, and Welfare, of the employer, and of the employee or former employee.

II. INTRODUCTION

This report presents the criteria and the recommended standard based thereon which were prepared to meet the need for preventing impairment of health from exposure to vanadium and its compounds. 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 and to provide for the safety of employees exposed to hazardous chemical and physical agents. The criteria and recommended standard should enable management and labor to develop better engineering controls resulting in more healthful work environments and simply complying with the recommended standard should not be the final goal.

These criteria for a standard for vanadium and its compounds are part of a continuing series of criteria developed by NIOSH. The proposed standard applies to the processing, manufacture, use of, or other occupational exposure to vanadium and its compounds as applicable under the Occupational Safety and Health Act of 1970. The standard was not designed for the population-at-large, and any extrapolation beyond occupational exposures is not warranted. It is intended to (1) protect against injury

from vanadium and its compounds, (2) be measurable by techniques that are valid, reproducible, and available to industry and government agencies, and (3) be attainable with existing technology.

Occupational exposure to vanadium presents an inhalation hazard, primarily respiratory tract irritation, with possible eye and skin irritation. Although comparative toxicities of various vanadium compounds have not been completely defined, it appears that ferrovanadium and other metallic forms of vanadium do not present as severe an occupational hazard.

Significant research needs include more information on toxicities of, sampling and analysis of, and preventive procedures for volatile vanadium compounds such as vanadium oxytrichloride.