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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR NITROUS OXIDE

INTRODUCTION

This guideline summarizes pertinent information about nitrous oxide for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine whether new information is available.

SUBSTANCE IDENTIFICATION

* Formula

N(2)O

* Structure

(For Structure, see paper copy)

* Synonyms

Dinitrogen monoxide, factitious air, hyponitrous acid anhydride, laughing gas, nitrogen oxide

* Identifiers

1. CAS No.: 10024-97-2

2. RTECS No.: QX1350000

3. DOT UN: 1070 14 (compressed); 2201 23 (refrigerated liquid)

4. DOT label: Nonflammable gas, oxidizer (nitrous oxide, compressed); nonflammable gas (nitrous oxide, refrigerated liquid)

* Appearance and odor

Nitrous oxide is a colorless gas at room temperature with a slightly sweet odor and taste.

CHEMICAL AND PHYSICAL PROPERTIES

* Physical data

1. Molecular weight: 44.02
2. Boiling point (at 760 mm Hg): -88.5 degrees C (-127.3 degrees F)
3. Specific gravity (air = 1): 1.97 at 25 degrees C (77 degrees F)
4. Vapor density: 1.53
5. Melting point: -91 degrees C (-132 degrees F)
6. Vapor pressure: 760 mm Hg at 88.5 degrees C (191.3 degrees F)
7. Solubility: Slightly soluble in water; soluble in alcohol, ether, oils, and sulfuric acid .
8. Evaporation rate: Data not available.

* Reactivity

1. Conditions contributing to instability: Nitrous oxide can form an explosive mixture with air.
2. Incompatibilities: Contact of nitrous oxide with aluminum, boron, hydrazine, lithium hydride, phenyllithium, phosphine, sodium, tungsten carbide, hydrogen, hydrogen sulfide, organic peroxides, ammonia, or carbon monoxide may cause violent reactions to occur.
3. Hazardous decomposition products: Toxic gases (such as carbon monoxide and oxides of nitrogen) may be released in a fire involving nitrous oxide.
4. Special precautions: None reported.

* Flammability

Nitrous oxide is a non-flammable gas at room temperature.

The National Fire Protection Association has not assigned a flammability rating to nitrous oxide.

1. Flash point: Not applicable.
2. Autoignition temperature: Not applicable.
3. Flammable limits in air: Not applicable.
4. Extinguishant: For small fires use dry chemical or carbon dioxide. Use water spray, fog, or standard foam to fight large fires involving nitrous oxide.

Fires involving nitrous oxide should be fought upwind from the maximum distance possible. Keep unnecessary people away; isolate the hazard area and deny entry. Isolate the area for 1/2 mile in all directions if a tank, rail car, or tank truck is involved in the fire. For a massive fire in a cargo area, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from the area and let the fire burn. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapors are an explosion hazard indoors, outdoors, or in sewers. Containers of nitrous oxide may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool fire-exposed containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Firefighters should wear a full set of protective clothing and self-contained breathing apparatus when fighting fires involving nitrous oxide.

EXPOSURE LIMITS

* OSHA PEL

The Occupational Safety and Health Administration (OSHA) does not currently regulate nitrous oxide.

* NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for nitrous oxide of 25 parts per million (ppm) parts of air (45 milligrams per cubic meter (mg/m³)) as a time-weighted average (TWA) for the duration of the exposure [NIOSH 1992].

* ACGIH TLV

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned nitrous oxide a threshold limit value (TLV) of 50 ppm (90 mg/m³) as a TWA for a normal 8-hour workday and a 40-hour workweek [ACGIH 1994, p. 28].

* Rationale for Limits

The NIOSH limit is based on the risk of reproductive system effects and decreases in audiovisual performance [NIOSH 1992]. The ACGIH limit is based on the risk of reproductive, hematological, and nervous system effects [ACGIH 1991, p. 1137].

HEALTH HAZARD INFORMATION

* Routes of Exposure

Exposure to nitrous oxide occurs through inhalation.

* Summary of toxicology

1. Effects on Animals: Nitrous oxide has central nervous system, teratogenic, bone marrow, and liver effects in animals [ACGIH 1991]. Rats exposed to an 80 percent concentration for 2 or more days showed signs of bone marrow toxicity [ACGIH 1991]. However, rats exposed to a 1 percent concentration of nitrous oxide for periods ranging from 7 days to 6 months showed no bone marrow effects [ACGIH 1991]. Exposure to nitrous oxide also causes neurotoxic (spinal cord lesions, demyelination, peripheral neuropathy) and hepatotoxic (focal inflammatory lesions) effects in experimental animals [ACGIH 1991]. In one study, pregnant rats were exposed to 50 percent nitrous oxide for 24 hours/day starting on day 8 of gestation and continuing for 1, 2, 4, or 6 days; dose-related embryolethal and teratogenic effects occurred among the offspring. The most common effects were embryonic death, resorption, and abnormalities of the ribs and vertebrae [Rom 1992]. Nitrous oxide was negative in three carcinogenicity assays in mice and rats exposed to concentrations as high as 400,000 ppm for 4 hours/day, 5 days/week for 78 weeks [ACGIH 1991]. The results of mutagenicity assays involving nitrous oxide were negative [ACGIH 1991].

2. Effects on Humans: Nitrous oxide is an asphyxiant at high concentrations. At lower concentrations, exposure causes central nervous system, cardiovascular, hepatic, hematopoietic, and reproductive effects in humans [Hathaway et al. 1991]. At a concentration of 50 to 67 percent (500,000 to 670,000 ppm) nitrous oxide is used to induce anesthesia in humans [Rom 1992]. Patients exposed to a 50:50 mixture of nitrous oxide:oxygen for prolonged periods to induce continuous sedation developed bone marrow depression and granulocytopenia [Hathaway et al. 1991; ACGIH 1991]. Although most patients recover, several deaths from aplastic anemia have been reported [Hathaway et al. 1991]. Neurotoxic effects occur after acute exposure to concentrations of 80,000 to 200,000 ppm and above; effects include slowed reaction times and performance decrements [Hathaway et al. 1991]. Long-term occupational exposure (dentists, dental assistants) has been associated with numbness, difficulty in concentrating, paresthesias, and impairment of equilibrium [Hathaway et al. 1991; ACGIH 1991]. In one study, exposure to 50 ppm nitrous oxide was associated with a decrement in audiovisual performance, but this result has not been duplicated in other studies [ACGIH 1991]. Epidemiological studies, primarily of operating room personnel, have shown increased risks of spontaneous abortion, premature delivery, and involuntary infertility among these occupationally exposed populations [ACGIH 1991; Hathaway et al. 1991].

* Signs and symptoms of exposure

1. Acute exposure: The signs and symptoms of acute exposure to nitrous oxide include dizziness, difficult breathing, headache, nausea, fatigue, and irritability. Acute exposure to nitrous oxide concentrations of 400,000 to 800,000 ppm may cause loss of consciousness [Sittig 1991].

2. Chronic exposure: The signs or symptoms of chronic overexposure to nitrous oxide may include tingling, numbness, difficulty in concentrating, interference with gait, and

reproductive effects.

EMERGENCY MEDICAL PROCEDURES

* Emergency medical procedures: [NIOSH to supply]

3. Rescue: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the Material Safety Data Sheet required by OSHA's Hazard Communication Standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and methods of protecting themselves during rescue operations.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve nitrous oxide and lead to worker exposures to this substance:

- * The manufacture and transportation of nitrous oxide
- * Use as an anesthetic gas
- * Use as a propellant (foaming agent) in whipped creams
- * Use as a leak detecting agent on natural gas pipelines
- * Use as an oxidant for the production of organic compounds
- * Use in rocket fuel formulations
- * Use in the manufacture of nitrates from alkali metals

Methods that are effective in controlling worker exposures to nitrous oxide, depending on the feasibility of implementation, are as follows:

- * Process enclosure
- * Local exhaust ventilation
- * General dilution ventilation
- * Personal protective equipment

Workers responding to a release or potential release of a hazardous substance must be protected as required by paragraph (q) of OSHA's Hazardous Waste Operations and Emergency Response Standard [29 CFR 1910.120].

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation--a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
2. Burton DJ [1986]. Industrial ventilation--a self study companion. Cincinnati, OH:

American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL SURVEILLANCE

OSHA is currently developing requirements for medical surveillance. When these requirements are promulgated, readers should refer to them for additional information and to determine whether employers whose employees are exposed to nitrous oxide are required to implement medical surveillance procedures.

Medical Screening:

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical surveillance program is intended to supplement, not replace, such measures. To detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

* Preplacement medical evaluation

Before a worker is placed in a job with a potential for exposure to nitrous oxide, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the respiratory, reproductive, central nervous, and hematological systems. Medical surveillance for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society. A preplacement medical evaluation is recommended to assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to nitrous oxide at or below the prescribed exposure limit. The health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with diseases of the respiratory, reproductive, central nervous, or hematological systems.

* Periodic medical evaluations

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to nitrous oxide exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of nitrous oxide on the respiratory, reproductive, central nervous, or hematological systems. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

* Termination medical evaluations

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of placement should be repeated at the time of job transfer or termination to determine the worker's medical status at the end of his or her employment. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

* Biological monitoring

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for nitrous oxide.

WORKPLACE MONITORING AND MEASUREMENT

Determination of a worker's exposure to airborne nitrous oxide can be made using one of the following techniques: 1) a Landauer Passive Dosimeter badge, which can be used for a minimum sampling duration of 1 hour (maximum duration 40 hours). Analysis is performed by the manufacturer of the badge as described in the OSHA Computerized Information System [OSHA 1994], or 2) an ambient air or bag sample with a minimum collection volume of two spectrophotometer cell volumes. Analysis is conducted using a long-pathlength portable infrared spectrophotometer as described in NIOSH Method No. 6600 [NIOSH 1994b].

PERSONAL HYGIENE PROCEDURES

If liquid nitrous oxide contacts the skin, workers should flush the affected areas immediately with tepid water to reduce the likelihood of frostbite.

STORAGE

Nitrous oxide should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's Hazard Communication Standard [29 CFR 1910.1200]. Containers of nitrous oxide should be protected from physical

damage and should be stored separately from cylinders containing oxygen. Nitrous oxide should also be stored separately from aluminum, boron, hydrazine, lithium hydride, phenyllithium, phosphine, sodium, tungsten carbide, hydrogen, hydrogen sulfide, organic peroxides, ammonia, and carbon monoxide.

SPILLS AND LEAKS

In the event of a spill or leak involving nitrous oxide (liquid or gas), persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak:

1. Do not touch the spilled material; stop the leak if it is possible to do so without risk.
2. Use water spray to protect persons attempting to stop the leak.
3. Notify safety personnel of large spills or leaks.
4. Minimize all sources of ignition because a fire may cause nitrous oxide to accelerate the burning of other combustibles; keep combustible materials (wood, paper, oil, etc.) away from the spilled material.
5. Isolate the area until the gas has dispersed.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

*** Emergency planning requirements**

Nitrous oxide is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) (Title III) in 42 USC 11022.

*** Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release notification provisions in 40 CFR Part 355.40 to notify the National Response Center of an accidental release of nitrous oxide; there is no reportable quantity for this substance.

*** Community right-to-know requirements**

Employers are not required by EPA in 40 CFR Part 372.30 to submit a Toxic Chemical Release Inventory form (Form R) to EPA reporting the amount of nitrous oxide emitted or released from their facility annually.

*** Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA has specifically listed many chemical wastes as hazardous. Although nitrous oxide is not specifically listed as a hazardous waste under RCRA, EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above. Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (703) 412-9810 (in the Washington, D.C. area) or toll-free at (800) 424-9346 (outside Washington, D.C.). In addition, relevant State and local authorities should be contacted for information on any requirements they may have for the waste removal and disposal of this substance.

RESPIRATORY PROTECTION

*** Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of nitrous oxide exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should only use respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

*** Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's Respiratory Protection Standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the latest edition of the NIOSH Respirator Decision Logic [NIOSH 1987b] and the NIOSH Guide to Industrial Respiratory Protection [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Workers should use appropriate personal protective clothing and equipment that must be carefully selected, used, and maintained to be effective in preventing skin contact with liquid nitrous oxide. The selection of the appropriate personal protective equipment (PPE) (e.g., gloves, sleeves, encapsulating suits) should be based on the extent of the

worker's potential exposure to liquid nitrous oxide and the PPE material's ability to protect workers from frostbite. There are no published reports on the resistance of various materials to permeation by liquid nitrous oxide.

To evaluate the use of PPE materials with liquid nitrous oxide, users should consult the best available performance data and manufacturers' recommendations. Significant differences have been demonstrated in the chemical resistance of generically similar PPE materials (e.g., butyl) produced by different manufacturers. In addition, the chemical resistance of a mixture may be significantly different from that of any of its neat components.

Any chemical-resistant clothing that is used should be periodically evaluated to determine its effectiveness in preventing dermal contact. Safety showers and eye wash stations should be located close to operations that involve nitrous oxide.

Splash-proof chemical safety goggles or face shields (20 to 30 cm long, minimum) should be worn during any operation in which a solvent, caustic, or other toxic substance may be splashed into the eyes.

In addition to the possible need for wearing protective outer apparel (e.g., aprons, encapsulating suits), workers should wear work uniforms, coveralls, or similar full-body coverings that are laundered each day. Employers should provide lockers or other closed areas to store work and street clothing separately. Employers should collect work clothing at the end of each work shift and provide for its laundering. Laundry personnel should be informed about the potential hazards of handling contaminated clothing and instructed about measures to minimize their health risk.

Protective clothing should be kept free of oil and grease and should be inspected and maintained regularly to preserve its effectiveness.

Protective clothing may interfere with the body's heat dissipation, especially during hot weather or during work in hot or poorly ventilated work environments.

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