I. RECOMMENDATIONS FOR A NITROGLYCERIN:ETHYLENE GLYCOL DINITRATE STANDARD

NIOSH recommends that employee exposure to nitroglycerin (NG) or ethylene glycol dinitrate (EGDN) in the workplace be controlled by adherence to the following sections. The recommended standard is designed to protect the health and provide for the safety of employees for up to a 10-hour workshift, 40-hour workweek, throughout a working lifetime. Compliance with all sections of the recommendation should prevent adverse effects of NG or EGDN on the health of employees and provide for their safety. Techniques recommended in the standard are valid, reproducible, and available to industry and government agencies. Sufficient technology exists to permit compliance with the recommended standard. Although NIOSH considers the recommended 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. It should be noted that toxicity can be produced as readily through the skin, and therefore the recommended environmental limit is protective only if skin contact is prevented. The criteria and recommended standard will be subject to review and revision as necessary.

These criteria and the recommended standard apply to exposure of employees in the workplace to NG (1,2,3-trinitropropanetriol; $C_3H_5O_3(NO_2)_3$), to EGDN (1,2-dinitroethanediol, $C_2H_4O_2(NO_2)_2$), or to mixtures of these compounds. Workers employed where NG:EGDN explosives are

used may also be exposed to byproducts from explosions of these compounds, including oxides of carbon, hydrogen, and nitrogen. Applicable health and safety standards for these compounds should also be observed.

Both safety and health hazards are present in work areas where NG or EGDN are present, but the criteria and recommended standard in this document are concerned primarily with the prevention of adverse effects on the health of workers exposed to these compounds. A manual on safe practices for nonmilitary explosives and pyrotechnics, including NG and EGDN, is being prepared currently by NIOSH.

Like other compounds with nitroester groups, NG and EGDN are potent vasodilators. NG has found extensive pharmaceutical use, primarily in the treatment of angina pectoris. Both substances are absorbed readily by inhalation and through the skin, but the available evidence indicates that the greatest danger to employees who directly handle these compounds is from skin contact. The health effects of short-term or intermittent exposure to NG or EGDN in the workplace include headache, dizziness, nausea, palpitations, and decreases in systolic, diastolic, and pulse pressures. All these symptoms are associated with vasodilation. Most workers do not experience these symptoms after repeated daily exposures to NG or EGDN, ie, they develop tolerance. The disappearance of these symptoms in workers exposed on successive days of the workweek indicates that the vasodilatory activity of NG or EGDN has been counteracted by compensatory vasoconstriction. Withdrawal from long-term exposure to NG or to NG:EGDN mixtures has been associated with angina pectoris and with sudden death in workers, particularly after weekends or holidays. The

compensatory vasoconstriction in workers who have developed tolerance to nitroesters continues in the absence of exposure to a vasodilating agent. It has been postulated that this vasoconstriction leads to spasms of the coronary arteries and that these spasms are related to the angina pectoris and sudden deaths that occur during periods when workers are not exposed to nitroesters. Although this mechanism has not been conclusively proven, exposed workers may have an increased risk of death from heart disease. Skin sensitization (dermatitis) can result from dermal contact with NG or EGDN.

"Occupational exposure" is defined as exposure to airborne NG, EGDN, or a mixture of these compounds at a concentration above the action level or as any dermal contact with these compounds. The "action level" is defined as a concentration in the air of the workplace equal to one-half the recommended environmental limit for NG, EGDN, or a mixture of these compounds (see Section 1). If there is no skin contact, and if exposures are below the action level, adherence to the recommended standard will not be required except for sections 2, 3, 4(a), 5, 6(a,b,f,h), 7, and 8. Workers occupationally exposed to NG or EGDN include those who make dynamite, propellants, and pharmaceuticals and those who use NG:EGDN dynamite in blasting operations. Workers who sell prepackaged pharmaceuticals containing NG are not considered to be occupationally exposed. "Overexposure" to NG or EGDN is defined as exposure above the recommended environmental limit or as any exposure, including dermal contact with these substances, resulting in throbbing headache, substantial decreases in blood pressure, or other observed effects on health.

Section 1 - Environmental (Workplace Air)

(a) Concentration

Occupational exposure to NG and EGDN shall be controlled so that employees are not exposed to NG, EGDN, or a mixture of these two substances at concentrations greater than 0.1 milligram per cubic meter of air (0.1 mg/cu m) measured as a ceiling concentration during any 20-minute sampling period.

(b) Sampling and Analysis

Procedures for the collection and analysis of workroom air samples for compliance with the recommended standard shall be as provided in Appendix I or by any method shown to be at least equivalent in precision, sensitivity, accuracy, and safety to those specified.

Section 2 - Medical

Medical surveillance shall be made available as outlined below to all workers subject to occupational exposure to NG or EGDN.

(a) Preplacement examinations shall include at least:

(1) Comprehensive medical and work histories with special emphasis directed to disorders of the cardiovascular system.

(2) Physical examination giving particular attention to the heart and circulatory systems, the central and peripheral nervous systems, and the skin. Recording of pulse rate, blood pressures, and electrocardiograms (ECG's) at rest and during and after exercise (Master's Test) is the minimal requirement.

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

(b) Periodic examinations shall be made available at least semiannually and more often if indicated by the responsible physician. These examinations shall include at least:

(1) Interim medical and work histories.

(2) Physical examination as outlined in paragraph (a) (2) above.

(c) During examinations, applicants or employees found to have medical conditions, such as cardiovascular disease, that would be directly or indirectly aggravated by exposure to NG or EGDN shall be counseled on the increased risk of impairment of their health from working with these substances.

(d) In the event of an illness known or suspected to be due to NG or EGDN, a physical examination as described in paragraph (a)(2) above shall be made available.

(e) Employees who may be occupationally exposed to NG or EGDN shall be counseled by the physician so that each is aware that headache, dizziness, palpitations, and nausea are symptoms of overexposure, that these symptoms usually become worse when alcohol is used, and that some of these symptoms may disappear with continued exposure as tolerance develops. Employees shall be warned that symptoms, such as headache, palpitations, and chest pain, can occur, particularly on weekends, on holidays, or at the beginning of the workweek, as a result of interruption of exposure to NG or EGDN. They shall be advised to consult a physician promptly if they experience such symptoms.

(f) Since a change in pulse rate is an early indicator of NG or EGDN exposure, pulse rate, ideally, should be taken and recorded daily.

(g) Pertinent medical records shall be maintained for all employees occupationally exposed to NG or EGDN. Such records shall be kept for at least 30 years after termination of employment. Records of environmental exposures applicable to an employee shall be included in the employee's medical records. These records shall be made available to 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

All labels and warning signs shall be printed both in English and in the predominant language of non-English-reading workers. Workers unable to read the labels and signs provided shall be informed verbally about hazardous areas and the instructions printed on labels and signs.

(a) Containers

Shipping and storage containers of NG, EGDN, or explosives containing these substances shall bear the following label in addition to labels required by other statutes, regulations, or ordinances:

NITROGLYCERIN (NG)
(and/or)
ETHYLENE GLYCOL DINITRATE (EGDN)

HIGHLY EXPLOSIVE

DANGEROUS TO HEALTH IF INHALED, SWALLOWED, OR
ABSORBED THROUGH SKIN
CAUSES HEADACHE, WEAKNESS, AND DIZZINESS

Avoid contact with eyes, skin, and clothing.
Avoid breathing vapor.
Keep away from heat, sparks, and open flames.
Keep from freezing.
Keep container closed.
Use only with adequate ventilation.
Consult a physician if persistent headaches or chest pains develop.

First aid: In case of skin contact, wash affected area with soap and water or with a waterless skin cleanser.

(b) Work Areas

Areas where airborne NG or EGDN is likely to be generated or where skin contact with these compounds is likely to occur shall be designated with clearly visible warning signs bearing the following information:

HAZARDOUS AREA

NITROGLYCERIN (NG)
(and/or)
ETHYLENE GLYCOL DINITRATE (EGDN)

HIGHLY EXPLOSIVE
SMOKING FORBIDDEN

DANGEROUS TO HEALTH IF INHALED, SWALLOWED, OR ABSORBED THROUGH THE SKIN
CAUSES HEADACHE, WEAKNESS, AND DIZZINESS

Do not use heat, sparks, or open flame.
Avoid contact with skin, eyes, and clothing.
Consult a physician if persistent headaches or chest pains develop.

If respiratory protection is required in accordance with Section 4, the following statement in large letters shall be added to the required sign:

RESPIRATORY PROTECTION REQUIRED IN THIS AREA

For buildings in which liquid NG, EGDN, or explosive mixtures of these substances are manufactured or processed, limits for the number of

persons who are authorized to be present and the amount of NG or EGDN that may be on the premises shall be posted outside the building.

Section 4 - Personal Protective Equipment and Clothing

(a) Respiratory Protection

Engineering controls shall be used when needed to keep concentrations of airborne NG or EGDN at or below the recommended environmental limit. Compliance with this limit by the use of respirators is permitted only during installation and testing of engineering controls, during performance of nonroutine maintenance or repair, or during emergencies. When the 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 concentration of airborne NG or EGDN in the workplace initially and thereafter whenever control, process, operation, worksite, or climatic changes occur that are likely to increase the concentration of these compounds in the air of the workplace.

(2) The employer shall ensure that no employee is exposed to NG or EGDN at concentrations above the recommended limit because of improper respirator selection, fit, use, or maintenance.

(3) The employer shall establish and enforce a respiratory protection program. The requirements for such a program are listed in 29 CFR 1910.134.

(4) The employer shall provide respirators in accordance with Table I-1 and shall ensure that the employees use the respirators properly when they are required. The respiratory protective devices

provided in conformance with Table I-1 shall be those approved by NIOSH and the Mining Enforcement and Safety Administration (MESA) or its successor, as specified under the provisions of 30 CFR 11. Nonsparking parts, such as those made of bronze, brass, or plastic, shall be used where steel or iron is normally used on any respiratory protective device.

TABLE I-1

RESPIRATOR SELECTION GUIDE FOR NG AND EGDN

Concentration	Respirator Type Approved under Provisions of 30 CFR 11
Less than or equal to 10.0 mg/cu m	(1) Supplied-air respirator operated in continuous-flow mode with half-mask, full facepiece, hood, helmet, or suit (2) Supplied-air respirator with full facepiece operated in the positive pressure mode (3) Self-contained breathing apparatus with full facepiece operated in the positive pressure mode
Greater than 10 mg/cu m	(1) Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode (2) Combination Type C supplied-air respirator with full facepiece operated in pressure-demand mode and auxiliary self-contained air supply
Emergency (entry into area of unknown concentration for emergency purposes)	Self-contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode

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

(b) Protective Clothing

(1) The employer shall provide a daily change of clean work clothing intended to minimize access of dust to the skin of employees in areas where NG or EGDN are present. Work clothing shall be changed immediately when soiled with liquid NG or EGDN.

(2) Rubber or plastic gloves with a cotton lining or plain cotton gloves shall be provided for employees who may have skin contact with NG or EGDN. The gloves shall be changed at least daily. Cotton gloves shall be changed immediately if they become contaminated with liquid NG or EGDN. Since natural and synthetic rubber are pervious to NG and EGDN, unlined gloves made of these materials should not be used.

Section 5 - Informing Employees of Hazards from NG and EGDN

(a) All new and present employees subject to occupational exposure to NG or EGDN shall be informed orally and in writing of the hazards, relevant signs and symptoms of exposure and withdrawal from exposure, appropriate emergency procedures, including first-aid procedures, and the proper conditions and precautions conducive to the safe use and handling of these compounds. Special care should be exercised to ensure that employees unable to read the informational material provided understand the hazards of working with the nitroesters, the symptoms of intoxication by these materials, and the equipment and procedures that can be used to minimize the hazard from exposure to these compounds.

Employees shall be made aware that headache is a warning symptom and that tolerance to these compounds and withdrawal symptoms may develop as outlined in Section 2(f). This information shall be readily available to all employees involved in the manufacture, use, transport, or storage of NG, EGDN, or explosives containing these compounds, and it shall be posted in prominent positions within the workplace.

(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 II, which shall be on file and readily accessible to employees at all places of employment where exposure to NG or EGDN may occur.

(c) Information required shall be recorded on the "Material Safety Data Sheet" shown in Appendix II, 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 NG or EGDN

Engineering controls, such as process enclosure or non-sparking local exhaust ventilation, shall be used when needed to keep exposures to airborne NG or EGDN at or below the recommended environmental limit.

Ventilation systems, if used, shall be designed to prevent accumulation or recirculation of NG or EGDN in the workplace environment and to remove them effectively from the breathing zone of employees. Exhaust ventilation systems discharging to outside air must conform to applicable local, state, and Federal air pollution regulations and must not constitute a hazard to employees or to the general population. 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. These engineering control systems shall be constructed of nonsparking materials.

(b) Ignition Sources and Detonation Hazards

The danger of explosion in buildings where NG or EGDN is manufactured or handled shall be minimized by compliance with the following provisions:

(1) Facilities should consist of detached units, with explosion-venting systems if possible.

(2) Each unit shall be subdivided by fire- and pressure-resistant walls to restrict hazardous areas.

(3) The amount of NG or EGDN present in any building shall not exceed the amount being processed at any one time.

(4) To prevent accumulation of explosive dust, equipment shall be dust-tight.

(5) All electrical equipment shall have explosion-proof fixtures and wiring.

(6) Static electricity shall be minimized by humidification, bonding, grounding, and the use of conductive materials.

(7) Motor-driven portable equipment, internal combustion engines, and vehicles shall not be used unless they have been approved for use in an explosive atmosphere.

(c) Regulated Areas

Access to buildings in which NG or EGDN is manufactured or handled in liquid form or in explosive mixtures such as dynamite shall be regulated to comply with the following provisions:

(1) Access shall be restricted to authorized persons.

(2) For each such building, a limit shall be established for the number of persons who may be present, based on the minimum number necessary for efficient performance of the operation. This limit shall be posted outside the building. A log of persons entering the building should be kept in some secure location outside the building.

(3) Before maintenance or repair work is undertaken in these buildings, operations should be shut down and the work area cleaned and inspected.

(4) A permit system shall be established for such maintenance and repair work. Permits shall be signed by an authorized representative of the employer to ensure that necessary precautionary steps have been taken.

(d) Confined Spaces

(1) Entry into confined spaces, such as tanks, pits, or vessels, that may contain NG or EGDN shall be controlled by a permit system. Permits shall be signed by an authorized representative of the employer certifying that preventive and protective measures have been followed.

(2) Confined spaces that have contained NG or EGDN shall be cleaned with water and purged with air. They shall be tested for NG or EGDN and other contaminants and for oxygen and inspected for compliance with these requirements prior to each entry. Adequate ventilation shall be maintained while workers are within the confined space.

(3) Employees entering confined spaces shall wear the appropriate personal protective equipment and suitable harnesses with lifelines tended by an employee outside the confined space who shall also be equipped with the appropriate personal protective equipment. The two workers shall be in constant communication by some appropriate means and shall be under the surveillance of a third person equipped to take any action to rescue them if necessary.

(e) Storage and Handling

(1) Buildings used for storage of NG or EGDN shall be separated by at least the minimum distances for magazines required by the American Table of Distances [1].

(2) Containers of NG or EGDN shall be kept tightly closed at all times when not in use and shall be stored in a manner that will minimize the risk of spills.

(3) Only properly informed, trained, and equipped personnel shall be involved in storing, loading and unloading, or processing liquid NG, EGDN, or explosive mixtures containing these compounds.

(4) Storage areas for NG or EGDN shall be clean, dry, and well ventilated. Storage areas for explosive forms of NG or EGDN shall be in a structure that is bullet resistant, weather resistant, and ventilated. Specific requirements for magazines, including those for construction and

bullet resistance, are listed in the National Fire Codes (Volume 3) [2].

(5) Floors of storage areas shall be swept and washed regularly and kept free of dust.

(6) Transporting of NG, EGDN, or explosive mixtures containing these compounds must conform to the regulations of the Department of Transportation in Title 49 CFR, Parts 171-178 and Title 33 CFR, Parts 6 and 126 (guidelines for transportation over waterways). Any applicable state or local regulations on the transporting or use of such explosive materials shall also be adhered to.

(f) General Work Practices

(1) Smoking, matches, open flames, and spark-producing devices shall be prohibited in areas where NG or EGDN is handled.

(2) Employers shall ensure that workers do not carry smoking materials into regulated areas and should provide smoking areas located at a safe distance from NG or EGDN work and storage areas.

(g) Cleanup and Waste Disposal

(1) All equipment shall be cleaned or washed at the end of each workshift or when significant accumulation of explosive material on equipment occurs.

(2) Small liquid spills shall be wiped up promptly, using sponges or other suitable absorbent materials. These should be kept readily available in a sodium carbonate solution. Large liquid spills should be washed with water and piped into tanks where the compounds can be separated and recovered.

(3) Waste material contaminated with NG or EGDN shall be disposed of in a manner not hazardous to employees and conforming to all

applicable local, state, and Federal regulations.

(4) Clothing grossly contaminated with NG or EGDN shall be discarded into waste containers kept outside of regulated areas and disposed of at the end of each operation.

(h) Emergency Procedures

(1) The employer shall formulate emergency evacuation and medical procedures and shall ensure that employees are instructed in these procedures and that they are posted in all work areas where emergencies involving NG or EGDN might occur. Emergency procedures shall include prearranged plans for immediate evacuation, transportation, and medical assistance for affected employees, including alerting designated medical treatment facilities of the impending arrival of affected workers.

(2) Necessary emergency equipment, including respirators, shall be available in readily accessible locations, and employees shall be instructed in its use.

(3) Nonessential employees shall be evacuated from hazardous areas during emergencies. Perimeters of these areas shall be delineated, posted, and secured. Only personnel trained in emergency procedures and protected against the attendant hazards shall shut off sources of NG or EGDN, clean up spills, and control and repair leaks in NG or EGDN areas.

(4) Showers and washroom facilities shall be provided and shall be readily accessible to workers in all areas where skin contact with NG or EGDN is likely. If NG or EGDN is spilled on clothing or skin, contaminated clothing shall be promptly removed and the skin washed thoroughly with soap and water or a waterless skin cleanser.

(5) The employer shall ensure that all emergency equipment, including washing facilities, is in proper working order through regularly scheduled inspections and maintenance.

Section 7 - Sanitation

(a) The employer shall develop and maintain a program for plant sanitation. The requirements for such a program are listed in 29 CFR 1910.141.

(b) Employees occupationally exposed to NG or EGDN shall shower and change clothing daily at the end of the workshift.

(c) The employer shall provide appropriate changing and shower facilities. Requirements for washing and change rooms are listed in 29 CFR 1910.141 (d and e).

(d) The employer shall be responsible for laundering work clothing worn during each workshift and shall ensure that employees do not remove work clothing from the premises.

(e) The employer shall ensure that personnel who launder and clean clothing or equipment contaminated with NG or EGDN are aware of the potential hazards of exposure to NG or EGDN and that the managers of commercial laundries understand the need for adequate ventilation of laundry areas and for personal protective equipment to prevent overexposure of their employees.

(f) Employers shall ensure that employees who handle NG or EGDN wash their hands thoroughly with soap and water or with a waterless cleanser before eating, smoking, or using toilet facilities.

(g) The storage, dispensing, preparation, consumption of food and

beverages, and the carrying of materials such as tobacco and chewing gum, within NG or EGDN work areas shall be prohibited.

Section 8 - Monitoring and Recordkeeping

Each employer with a place of employment where NG, EGDN, or explosives containing these compounds are manufactured, processed, handled, stored, or otherwise used shall determine by an industrial hygiene survey whether occupational exposure to NG or EGDN may occur. Records of these surveys, including the basis for concluding that there is no occupational exposure to NG or EGDN, shall be maintained. Surveys shall be repeated at least annually and within 30 days of any process or engineering change.

(a) Personal Monitoring

If it is determined that there is occupational exposure to NG or EGDN, the employer shall institute a program of personal monitoring to measure or permit calculation of the exposure of each employee. Source and area monitoring may be used to supplement personal monitoring.

(1) In all personal monitoring, samples representative of the breathing zones of the employees shall be collected.

(2) For each determination of the concentration of NG or EGDN in workplace air, a sufficient number of samples shall be taken to characterize the employees' exposures during each workshift. Variations in work and production schedules and in employees' locations and job functions shall be considered in choosing sampling times, locations, and frequencies.

(3) Each operation in each work area shall be evaluated at least every 3 months for conditions that might be conducive to skin contact

in addition to air sampling, if considered necessary.

(4) If an employee is found to be exposed to NG or EGDN in excess of the recommended environmental limit, control measures shall be initiated immediately, the exposure of that employee shall be measured at least weekly, and the employee shall be notified of the extent of the exposure and of the control measures being implemented. Such monitoring shall continue until two consecutive determinations, 1 week apart, indicate that the employee's exposure no longer exceeds the recommended environmental limit. Routine monitoring may then be resumed.

(b) Recordkeeping

Environmental monitoring records shall be retained for at least 30 years after the employee's last occupational exposure to NG or EGDN. These records shall include the dates and times of measurements, job function and location of the employee within the worksite, methods of sampling and analysis used, types of respiratory protection in use at the time of sampling, environmental concentrations found, and identification of the exposed employee. Employees shall be able to obtain information on their own environmental exposures. Environmental monitoring records shall be made available to designated representatives of the Secretary of Labor and of the Secretary of Health, Education, and Welfare.

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 occupational exposure to nitroglycerin (NG) or ethylene glycol dinitrate (EGDN). 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."

After reviewing data and consulting with others, NIOSH formalized a system for the development of criteria upon which standards can be established to protect the health and provide for the safety of employees exposed to hazardous chemical and physical agents. Criteria for a 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 regarded as a final goal.

These criteria for a standard for NG or EGDN are part of a continuing series of criteria developed by NIOSH. The proposed standard applies to the processing, manufacture, and use of NG and/or EGDN. The standard was not designed for the population-at-large, and any application to situations other than occupational exposures is not warranted. The standard is intended to (1) protect against the hazards to safety posed by NG or EGDN,

(2) protect against the toxic effects of exposure to NG or EGDN, (3) be measurable by techniques that are valid, reproducible, and available to industry and government agencies, and (4) be attainable with existing technology.

NG is used to make dynamite, gun powder, and rocket propellants and as a therapeutic agent, primarily to alleviate angina pectoris. EGDN is used only in the manufacture of dynamite. EGDN is mixed with NG, currently in a ratio of about 8:2, to lower the freezing point of the dynamite mixture and increase its stability, making it safer to manufacture and use.

The byproducts of explosion of NG or EGDN include the oxides of carbon, hydrogen, and nitrogen. In this document, NIOSH recommends a standard to control workplace exposure to NG and EGDN but not to byproducts of explosion of these compounds. Information on the health effects and control of exposure to oxides of carbon and nitrogen may be found in NIOSH Criteria and Recommended Standards for Carbon Monoxide, Carbon Dioxide, and the Oxides of Nitrogen (Nitrogen Dioxide and Nitric Oxide).

NG and EGDN are absorbed through the lungs and the skin. Absorption through the skin is usually the major route of exposure for workers who have direct dermal contact with NG or EGDN. Thus, work practices designed to limit skin absorption of these compounds should be followed carefully.

The recommended standard for NG, EGDN, or a mixture of these two compounds is based on their effects on the cardiovascular system. The initial physiologic effect of exposure to these compounds is dilatation of the blood vessels, and the initial signs and symptoms of exposure include headache, dizziness, nausea, palpitations, and decreases in systolic, diastolic, and pulse pressures. These signs and symptoms tend to disappear

after 3-4 days of repeated exposure, probably as the result of compensatory vasoconstriction. After a brief period of withdrawal from exposure, eg, a weekend, workers may develop angina pectoris. Some workers exposed to NG:EGDN mixtures or to nitroglycerin alone have died suddenly, often on Monday or Tuesday mornings, from no apparent cause. The mechanisms producing posthiatal precordial distress (angina pectoris) and sudden death are not clearly understood, but these effects may be related to spasms of the coronary arteries that tend to occur during periods when workers are not exposed to vasodilatory actions of these compounds but still have compensatory vasoconstrictive mechanisms in operation. A recent epidemiologic study also suggests that men who once manufactured NG:EGDN dynamite were at increased risk of death from heart disease, even though most of them had not worked at the plant for months or years.

Not all workers develop headaches or changes in blood pressure during initial exposure to NG or EGDN, but the available data indicate that these are usually the first and most consistent effects of initial exposure. Compensatory vasoconstriction following prolonged exposure may promote more serious effects, including angina pectoris, heart disease, and sudden death. The recommended standard for workplace exposure to NG or EGDN is designed to prevent significant changes in the diameters of cerebral blood vessels during initial exposure, as indicated by the development of throbbing headaches or by decreases in blood pressure, thereby preventing the development of the compensatory vasoconstrictive mechanisms that may eventually result in more serious effects.

Further research is needed in several areas. The concentration below which exposure to NG or EGDN will not cause significant changes in blood

vessel diameters, as indicated by throbbing headaches or definite changes in blood pressure, is not known. Diagnostic methods that are reliable and easy to use are needed to determine whether workers are overexposed to NG or EGDN. It appears that workers with prolonged exposure to NG or EGDN can develop spasms of the coronary arteries that may lead to angina or to sudden death, but further information on the mechanisms responsible for these effects should be developed. Epidemiologic studies are needed to assess the effect of prolonged exposure to these compounds on the risk of developing heart disease or precursors of heart disease. Potential effects on reproduction and the potential mutagenicity and carcinogenicity of these compounds and their metabolites should be explored more thoroughly.

Additional information on the toxicity of NG and EGDN is provided in two other reviews. The available literature was reviewed by Von Oettingen [3] of the US Public Health Service in 1946. Dacre and Tew [4] reviewed literature on the toxicity of NG and EGDN for the Army Medical Research and Development Command in 1973.