V. WORK PRACTICES

Control of Hazards to Health

NG and EGDN both constitute severe health and safety hazards in the industrial environment [11]. Adverse health effects can result from both inhalation and dermal contact [11,32], and they range from headaches to sudden death [58]. Therefore, it is essential to keep worker exposure to these substances to a minimum. This can be achieved by effective engineering controls, as discussed in Chapter IV, and through a rigid program of work practices. The explosive characteristics of these substances and materials containing them are well known [6]. Many organizations, including state and Federal regulatory bodies, have presented guidelines or rules and regulations for handling these substances in ways that will minimize the danger of explosion. This chapter will therefore concentrate on work practices designed to minimize effects on health; safety precautions will be mentioned, but an exhaustive review of all appropriate safety rules and regulations is beyond the scope and objectives of this document.

Occupational exposure to NG and EGDN can occur during their manufacture [14] and during the manufacture and handling of explosives and munitions containing them [30,100,132]. Occupational exposure to NG can occur also during the manufacture of drugs used primarily to relieve angina pectoris [132]. NG and EGDN are both liquids, but they are mixed with various other liquid and solid materials to form solid or semisolid explosives and munitions. Although the reported vapor pressures of the two liquids at 20 C vary [5], it is certain that the vapor pressure of NG

(0.00012-0.011 mmHg) is much lower than that of EGDN (0.038-0.050 mmHg). However, work practices designed to minimize exposure to both substances by inhalation as well as by dermal contact should be observed because of the adverse health effects that can result from minimal absorption of either substance [11,49,57]. When the substances are in the solid or semisolid state, the hazard of exposure is increased because of the difficulty of maintaining a totally enclosed system and the possibility of particle dissemination.

Direct skin contact with NG and EGDN can be controlled by the use of protective clothing and the practice of good personal hygiene. Protective clothing must be worn to shield the body and face of workers from these chemicals. The degree of protection required will depend on the severity of the potential exposure [36]; however, there is no known material currently used in protective clothing that is completely impervious to these nitroesters [11,52,65,133]. Clothing made of natural or synthetic rubbers, including neoprene, is difficult to decontaminate and does not provide any warning to the user of breakthrough. The lack of predictive sensory cue tends to prolong and promote skin contact with contaminated material. Cotton or cotton-lined products are preferred in industry because they are easily decontaminated and because breakthrough by contaminated liquid leads to a sensation of wetness [13,133]. If plastic or rubber gloves are used, cotton liners must be worn underneath them [133]. The use of fire-retardant, disposable work coveralls and booties, which are commercially available [134], is another possibility; however, information on their effectiveness for skin protection against NG and EGDN is needed before their use can be recommended.

Because the materials most commonly used in protective clothing are pervious to NG and EGDN, the approximate breakthrough time for the clothing should be calculated by observing normal operating conditions to determine the frequency of clothing change necessary to prevent skin contact. In some operations, workers may have to change gloves hourly to prevent skin contact [133]. Care must be taken to ensure that skin contact does not occur while contaminated clothing is being removed. In the event of breakthrough and skin contact, contaminated clothing must be removed and the affected area must be cleaned as soon as possible with soap and water or a waterless cleanser to minimize skin absorption.

Dynamite shells or wrappers are made of various materials, such as manila paper waxed or impregnated with paraffin and molded plastic [135]. These shells protect the explosive from moisture, but NG and EGDN in the explosive can permeate the casing, especially during prolonged storage, and pose a potential exposure hazard. Workers, such as blasters, who frequently handle individual casings should therefore wear protective gloves to prevent dermal contact. Blasters and others who handle explosives containing NG and EGDN should maintain the integrity of the shells and wrappers, both because of the increased hazard to safety posed by damaged or unwrapped shells and because of the potential for adverse health effects caused by skin and inhalation exposure to NG and EGDN.

While extreme caution should always be used to minimize dermal contact with these substances, this is especially important until a protective clothing material that is totally impervious to NG and EGDN is available or a convenient method for testing the effectiveness of current protective clothing is developed. Commercially available barrier or protective creams are not recommended at this time because none have been shown to provide specific protection against NG and EGDN, and their use may actually increase skin absorption [133].

Dermal exposure could possibly be monitored by periodically swabbing potentially exposed skin surfaces with a solvent, such as alcohol, and estimating the material recovered by gas chromatography or colorimetry. Swipe sampling methods are available to determine chemical concentrations on room and equipment surfaces [136,137]; however, these methods have not been applied generally to detection of contamination of skin. Another possible method for monitoring dermal exposure involves the periodic analysis of the inner linings of protective clothing, such as gloves, socks, and overalls. This method would be especially useful for determining breakthrough times for contaminated work shoes, which are not easily decontaminated.

Because these compounds can penetrate clothing, good personal hygiene is essential to minimize prolonged skin contact with contaminated clothing. NIOSH recommends that working garments, including underclothing, be cleaned after each workshift. Workers should be prohibited from taking soiled work clothing or personal articles, eg, handkerchiefs, to their homes. The soiled clothing must be laundered either at the plant or by a cleaning establishment. In both cases, the laundry personnel must be thoroughly informed of the contaminants and their potential adverse health effects.

Because NG and EGDN are mixed with absorbing agents in the manufacture of explosives, the potential exists for exposure to these substances through dust contact. Therefore, work garments should not have cuffs or folds that can serve as points of accumulation. Pockets on outer garments, if any, should be equipped with securable flaps to prevent dust accumulation. Articles of clothing other than issued protective clothing should be prohibited in the production area. Care should be taken to minimize contamination of work shoes by NG and EGDN. If any tears, cracks, or other signs of unusual wear appear in the shoe material, the shoes should be repaired, if possible, or else discarded.

The employer should provide locker facilities for the storage of personal belongings of employees who have changed into clean work garments. A shower facility should be provided, and it should be located to eliminate the need for workers to enter the locker area with contaminated clothing. At the end of a shift, work garments, including underclothing, should be placed in a covered receptacle, and all workers should shower before entering the locker area. Employers of blasters, who handle explosives containing NG and EGDN, should also provide these locker and shower facilities to the employees when possible.

To prevent accidental ingestion of NG and EGDN, workers should be instructed to wash their hands before eating, smoking, or using tobacco in any other form, eg, snuff. They should also be instructed to avoid touching the face and mouth with the hands, gloves, or other contaminated objects. The storage, dispensing, preparation, and consumption of food and beverages, and the carrying of materials such as tobacco and chewing gum into NG or EGDN work areas must be prohibited.

Control of Hazards to Safety

The major hazard associated with NG and EGDN is explosion. A number of government agencies have formulated regulations to protect workers and the general public from explosive materials during their manufacture, storage, transportation, and use. The regulations include: Bureau of Alcohol, Tobacco, and Firearms, Title 27 CFR, Parts 178 and 181; Occupational Safety and Health Administration, Title 29 CFR, Parts 1910 and 1926; Environmental Protection Agency, Title 40 CFR, Parts 457 and 700; Office of Surface Mining Reclamation and Enforcement, Title 30 CFR Parts 700-830; Mine Safety and Health Administration, Title 30 CFR, Parts 15, 55-57, 75, and 77; Department of Transportation, Title 49 CFR, Parts 171-178; and the Coast Guard, Title 49 CFR Part 176. All states and many local governments also have regulations concerning explosive materials [138]. In addition, many agencies and organizations have published guidelines for handling explosives. These include the Institute of Makers of Explosives [131,139,140], the Bureau of Mines [141], and the National Fire Protection Association [2]. The explosive characteristics of NG and EGDN become a problem during the manufacture of these substances and during the manufacture and use of explosives that contain them. In the pharmaceutical industry, where NG medications are prepared by adding alcoholic solutions of the ester to lactose powder [132], the danger of explosion is minimal because of the small amounts of NG used.

Administrative controls and work practices that regulate the amount of explosives within the manufacturing and packaging facilities and the number of people within these facilities can also effectively minimize the dangers of detonation and loss of life. The amounts of NG and EGDN or materials containing these substances that can be kept at the manufacturing or packaging site should be limited to prevent overstocking at the site, preferably to the amount needed for a single shift. Similarly, finished explosive products should be removed as soon as possible to a specially designed storage magazine. Such practices should help to reduce the likelihood of detonation and, should they fail to prevent detonation, should minimize the force of the resulting explosion.

Entry into the production area should be restricted to prevent any hazard to safety created by an untrained person. The number of people working in the area should be limited to those needed for the operation to reduce the possibility of accidental detonation. The amount of material and the number of people allowed within each facility should be posted outside the building. An entry log system separate from buildings containing explosives is a convenient method for determining whether the occupancy limit is being exceeded without having to enter the work area.

Work practices should be designed to eliminate sources of ignition, to prevent dust accumulation through housekeeping, and to minimize the dangers of impact detonation. Open flames, smoking, and uncovered light bulbs must be prohibited in production areas. Motor-driven portable equipment and internal combustion engines and vehicles, such as forklifts, should also be prohibited unless they are approved for use in an explosive atmosphere and correctly maintained.

Maintenance and repair work inside the buildings must be prohibited while the operation is in progress. Before such work is permitted inside the building, the operation must be shut down, all the equipment must be cleaned, and the work area must be inspected to ensure that there is no significant accumulation of liquid NG or EGDN or dust containing these substances. A permit system must be established to ensure that these steps are taken, and a responsible person, such as a shift supervisor, must sign each permit before maintenance or repair work is begun. If maintenance and repair work is being done outside the building, the above procedure may not be necessary; the shift supervisor or other responsible individual must make this determination. In this instance also, a permit system must be established and a permit signed before the work is undertaken. Once the work is completed, the workplace must be inspected to ensure that no hazardous materials, such as spark-producing metals, remain. The operation must not be resumed until the workplace has been inspected and cleared by the responsible person. Before they are turned, all screws, bolts, and nuts on equipment must be thoroughly oiled to prevent spark production. A machine that has been shut down for a long period of time or one that has been newly installed should be operated with "dummy mixes" until it has been proved to be in satisfactory operating condition.

A permit system should also be established to regulate entry into tanks that may have contained NG:EGDN. All lines should be disconnected or blanked off, and tanks should be emptied and cleaned with a dilute solution of sodium carbonate or a specific solvent. If a solvent is used for cleaning, a water wash should follow. Then the tanks must be purged with air. If possible, it is a good work practice to continue to blow air through the tank at a low rate while the employee is working in it. In any case, the concentration of oxygen within the tank should be checked before an employee enters it and periodically while the tank is occupied. Portable, battery-operated oxygen monitors are available for this purpose [142]. If possible, NG and EGDN concentrations should also be checked. Only after all these steps have been taken and a designated representative of the employer, such as the shift supervisor, has signed the permit should an employee enter the tank. Any individual entering confined spaces should be furnished with appropriate personal protective equipment, such as air-supplied respirators, and be equipped with a lifeline harness tended by another worker outside the space. This second person, or "buddy," also should be equipped for entry into a confined space with approved personal protective equipment and should maintain communication by vision, voice, signal line, telephone, radio, or other suitable means with the employee inside the confined or enclosed space. A third employee, equipped to proceed to the aid of the other two if necessary, should have general surveillance of their activities.

In general, great emphasis should be placed on the explosive hazard associated with these substances. NG is sensitive to impact and may detonate. Therefore, precautions should be taken to avoid having loose objects in the work area. Ornaments such as metal buckles, clasps, pins, and buttons should be forbidden. If flashlights are used (to look into tanks, etc), they should be nonsparking and equipped with wrist bands so that they cannot fall and cause impact. Where special areas for smoking are provided, these areas should be far from the regulated areas. Furthermore, fixed lighters should be provided in those areas so that employees will not inadvertently carry matches or lighters to the work area. Any tools used in the presence of NG or EGDN must be sparkproof. Tools should not be left lying around in regulated areas.

At the end of each workshift, all equipment should be cleaned or washed. Clean rags used for wiping powder equipment should be kept in a covered container. Soiled or wet rags should be discarded in waste containers kept outside the regulated areas and should be disposed of at the end of the workshift. Small amounts of spilled liquids may be wiped up with sponges provided for this purpose. These sponges should be kept in a sodium carbonate solution. Large spills must be washed with water and, where possible, the waste water should be piped into holding tanks where the NG:EGDN can be separated. All dry waste, such as spilled powder and rags, should be burned in open grounds.

Magazines used for storing explosive materials should be clean, dry, well-ventilated, reasonably cool, and securely locked. Safety regulations governing the operation of the magazine should be posted on the interior side of the magazine door. All magazines containing explosive materials should be opened and inspected at least every 3 days to determine whether there has been an unauthorized entry. Except while explosive materials are being placed in or removed from the magazines and during inspections, magazine doors should be kept locked. Containers of explosive materials should be stored so they can be easily counted and checked. Rigid containers should be laid flat, and cases should be stored with the top side up to minimize spilling if they were to break open accidentally.

Containers of explosive materials should be unpacked and repacked outside the magazine, and only securely closed containers should be restored in the magazine. Tools used in opening these containers should be constructed of nonsparking material. Floors should be swept and washed regularly. When magazines need interior repairs, all explosive materials should be removed and the floors cleaned thoroughly before and after repairs. In making exterior magazine repairs, when there is a possibility of causing sparks or fire, all explosive materials should be removed from the magazine before these repairs are made.

For emergency conditions, such as sparking or rapid increases in temperature, a program detailing escape and entry procedures must be formulated, written, and made available to all employees. Practice evacuation drills should be held periodically, and the emergency plan should be recapitulated at least yearly to maintain awareness of its provisions. Rapid evacuation is the most important single procedure for ensuring safety in an emergency. The employer is responsible for providing necessary training to all emergency personnel.

The transporting of explosive materials should conform to the regulations of the Department of Transporation in Title 49, Parts 171-178, supplemented by NFPA No. 495-1972 [2] and the Institute of Makers of Explosives Publications No. 3 [143] and 6 [128]. Liquid NG is not acceptable for transporation under Title 49, Part 172. For transportation over waterways, Title 33 CFR, Parts 6 and 126, must be followed. Users of explosive materials should adhere to the guidelines in the Institute of Makers of Explosives Publication No. 17 [131] and NFPA No. 495-1972 [2].

NG and EGDN both pose grave safety and health hazards. It is important, therefore, to train all employees to handle these substances with respect. Worker training programs, useful in many industries, are especially useful for reducing the risk to workers in the ammunition industry. Therefore, there should be a written training program for all employees who handle these two substances. These instructions should be printed both in English and in the predominant language of non-English-reading workers. Each new employee should be thoroughly informed about the process, hazards, personal protective equipment, and emergency procedures. In addition, the signs and symptoms of intoxication by the nitroesters, such as headaches, must be described to them. This information on symptoms of intoxication should also be made available to the worker's family in the event the worker becomes ill during off hours. A thorough on-the-job training program should be conducted for new employees, and safety meetings should be held regularly. Spontaneous and unannounced safety inspections should be made frequently, and quizzes should be given to the workers to ensure continuing caution on their part. Special care should be taken to ensure that employees unable to read the labels, signs, and instructional materials provided understand and know the process, the hazards of working with NG and EGDN, the need for, and use of, personal protective equipment, and the emergency procedures.

Records should be kept of maintenance schedules, written work practices, emergency procedures, storage locations, entries into the magazines, accidents, and employee exposures. These records should be readily accessible to employees.

VI. DEVELOPMENT OF STANDARD

Basis for Previous Standards

In 1945, Cook [144] compiled a list of maximum allowable concentrations (MAC's) based on a 40-hour workweek, of atmospheric industrial contaminants, including NG. He cited standards of 10-40 ppm recommended for NG by the Utah Department of Health and of 0.5 ppm recommended by the US Public Health Service. In addition, he suggested 0.5 ppm (5 mg/cu m) as an "accepted and tentative" limit, because it had been found that workers exposed briefly at concentrations as low as 0.5 ppm experienced severe headaches after regular occupational exposure had been discontinued for as few as 40 hours. Cook also mentioned that skin absorption was possibly a major route of worker exposure. No limit for EGDN was suggested.

The American Conference of Governmental Industrial Hygienists (ACGIH) also proposed an MAC of 0.5 ppm for NG in 1946 [145]. No basis for this standard was cited. In 1949, the ACGIH changed its terminology to express standards as Threshold Limit Values (TLV's) [146]. The standard of 0.5 ppm for NG remained unchanged. According to the first Documentation of Threshold Limit Values in 1962 [147], the ACGIH TLV was based on the same findings by the US Public Health Service cited by Cook [144] and on Elkin's report [148] of headache in workers exposed to NG at a concentration of 0.04 ppm. The ACGIH stated that the 0.5-ppm limit for NG might be too high in view of its ability to cause vascular dilatation, with headache, and that poorly defined cardiovascular irregularities might follow withdrawal from long-term exposure. The ACGIH further stated that both the cutaneous and inhalation routes of exposure were important, although the relative importance of each was not known.

In 1962, the ACGIH [149] lowered the TLV for NG to 0.2 ppm (1.9 mg/cu m) and added the "skin" designation to indicate that the value stated for the TLV could be relied upon only if absorption through the skin was prevented. Also in 1962, the ACGIH adopted a TLV of 0.2 ppm (1.2 mg/cu m) for exposure to EGDN. In 1963, the ACGIH [150] proposed a combined TLV as a ceiling limit of 0.2 ppm for NG and EGDN with the "skin" designation. In 1964, however, the ACGIH [151] set separate standards of 0.2 ppm (1.2 mg/cu m) for EGDN and 0.2 ppm (2 mg/cu m) for NG and EGDN. Both standards were ceiling limits, and both carried the "skin" designation.

According to the 1966 Documentation of Threshold Limit Values [152], the NG and EGDN standards were lowered to 0.2 ppm because industrial experience indicated that most exposures were to a mixture of NG and EGDN and that the previous 0.5-ppm limit might not protect against fatalities. Although the ACGIH noted that there were no firm toxicologic data on which to base the 0.2-ppm limit, industrial data were cited from companies reporting no serious problems when atmospheric levels of NG and EGDN combined were kept below about 0.25 ppm. Melville [153] mentioned that therapeutic doses of 0.3 mg of NG probably considerably less than the amount obtained from workplace exposures at the 0.5-ppm concentrations, produced cardiovascular effects and headache. This was cited by the ACGIH [152] as a basis for the lowered standard. The still unknown relative importance of the cutaneous and inhalation routes and Barsotti's findings [37] that fatalities generally resulted from withdrawal rather than from actual exposure were used by the ACGIH as further justification for the ceiling limit designation [152]. The ACGIH noted that the limit for either NG or EGDN alone should be the same as that for the mixed substances. In 1966, the ACGIH announced in its list of TLV's for that year an intention to set a TLV with a ceiling designation for EGDN and/or NG of 0.02 ppm (0.1 mg/cu m) "for intermittent exposure only."

In 1968 [154], the TLV for EGDN was expanded to include NG, but remained at 0.2 ppm for either EGDN, EGDN with NG, or NG alone. The "skin" designation remained. This TLV was accompanied, for the first time, by a note that an atmospheric concentration as low as 0.02 ppm or the use of personal protective equipment might be necessary to prevent headache.

The TLV's and accompanying notations for NG and EGDN remained unchanged through 1971, and the 1971 Documentation of the Threshold Limit Values for Substances in Workroom Air [155] used some of the previously cited data [153,156] as the basis for the TLV. Additional data on intermittent exposures, however, were reported as a basis for the 0.02-ppm ceiling limit. The findings cited included those of Trainor and Jones [49], who reported an immediate decrease in blood pressure and severe headache in workers exposed to a mixture of NG and EGDN at a concentration of 2 mg/cu m, and lowered blood pressure and slight headache in volunteers exposed to the mixture of NG:EGDN at 0.7 and 0.5 mg/cu m for 25 minutes. Hanlon and Fredrick's findings [29] of headache and irritation in workers exposed to NG and EGDN at levels of 0.03-0.11 ppm in the breathing zone and the subsequent disappearance of these symptoms when concentrations were lowered to 0.01 or less were also cited as the basis for the intermittent exposure ceiling [155]. The report by Morikawa et al [65] of abnormal pulse waves and headache in workers exposed at concentrations below 0.1 ppm of combined NG and EGDN were also used to develop this limit. The ACGIH [155] stated that the intermittent exposure ceiling was primarily designed to prevent withdrawal symptoms of headache and lowered blood pressure. ACGIH TLV's for both NG and EGDN have remained unchanged since 1971, except that the 1.2 mg/cu m equivalent for EGDN was dropped in 1972 [157].

There are no current or past ANSI standards for either NG or EGDN. In 1960, however, the American Industrial Hygiene Association (AIHA) Hygienic Guide Series [158] listed a MAC of 0.5 ppm for NG for an 8-hour workday, based on unspecified observations of effects on humans. The AIHA stated, however, that the short-term exposure tolerance and the atmospheric concentration immediately hazardous to life were unknown. No standard for EGDN was recommended, although it was noted that most exposure in the workplace is to a mixture of NG and EGDN.

According to a 1977 report of the International Labour Office (ILO) [159], several foreign countries have promulgated standards for NG:EGDN, NG, and EGDN. The foreign standards vary considerably as shown in Table VI-1. No documentation for these standards was provided in the ILO report.

The present US standard (29 CFR 1910.1000(a)) for workplace exposure to NG is an 8-hour TWA concentration limit of 0.2 ppm (2 mg/cu m) and has a "skin" notation. The present US standard (29 CFR 1910.1000(a)) for workplace exposure to "ethylene glycol dinitrate and/or NG" is a ceiling concentration limit of 0.2 ppm (1 mg/cu m) and also has a "skin" notation. This standard has a note indicating that a concentration limit of 0.02 ppm or personal protective equipment may be necessary to prevent headaches in NG:EGDN dynamite workers. These standards are based on the TLV's for workplace exposure adopted by ACGIH in 1968.

TABLE VI-1

OCCUPATIONAL NG:EGDN, NG, AND EGDN
EXPOSURE LIMITS FOR VARIOUS FOREIGN COUNTRIES

Country	NG:EGDN			NG			EGDN		
	mg/cu m		ppm	mg/cu m		ppm	mg/cu m		ppm
Australia	-	S,C*	0.2	2	-	0.2	-	-	-
Belgium	-	"	0.2	2	S,C	0.2	-	S,C	0.2
Finland	1.2	"	0.2	2	"	0.2	1.2	"	0.2
Federal Republic of Germany	-	-	-	5	-	0.5	1.6	-	0.25
Hungary	-	-	-	5	S	-	-	-	-
Italy	-	-	-	1	"	-	0.3	S	-
Japan	1.2	S,C	0.2	-	-	-	1.2	"	0.2
Netherlands	-	"	0.2	2	S	0.2	-	-	-
Poland	-	-	-	2	"	-	-	-	-
Rumania	-	-	-	2	S,C	-	1	S,C	-
Sweden	1.0	S	0.1	2	S	0.2	1.0	S	0.1
Switzerland	1.2	C	0.2	2	"	0.2	1.2	"	0.2
Yugoslavia	-	S	0.02	2	"	0.2	-	"	0.02

*S=skin notation;C=ceiling

Adapted from reference 159

Basis for the Recommended Standard

(a) Workplace Environmental Limits

Reports describing the effects of NG were first published over 100 years ago [12,17,19]. At present, the reported effects of exposure to NG or EGDN include throbbing headaches, dizziness, nausea, and decreases in systolic, diastolic, and pulse pressure during initial exposure to these compounds [11,21,22,25,40,41,45-47,49], angina pectoris and sudden death without any apparent cause during brief periods away from work [34-38,43-

45,48,63], and a greater proportion of deaths from cardiovascular diseases in former NG:EGDN dynamite workers than in the general population [75].

NG and EGDN are readily absorbed by inhalation and through the skin. A few authors have reported estimates of concentrations of airborne NG or EGDN to which affected workers were exposed [11,29,36,43,44,49], but estimates of the amount of these compounds that can be absorbed through the skin have not been reported in these studies. A recent study suggests, however, that workers who handle dynamite directly may absorb more NG:EGDN through the skin than through the lungs [72].

The signs and symptoms of initial exposure to NG or EGDN are indicative of the rapid and substantial shift in blood volume from the central to the peripheral circulatory system that is initiated by dilation of the blood vessels. Not all workers develop throbbing 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. In addition to the discomfort caused by headaches, affected workers may be less able to follow the stringent safety precautions necessary to prevent explosions. Headaches have been reported in workers who make dynamite [11,22,25,38,40,41,46,49,68], in workers who use dynamite [21,47,48, and Bureau of Mines, written communication, November 1977], in workers who make rocket propellants containing NG [34-36], and in workers who make NG-containing pharmaceuticals [29,30]. Decreases in blood pressure during initial exposure to NG:EGDN dynamite have also been reported [11,46,49,54].

Trainor and Jones [49] found that six of seven workers developed "mild" headaches when exposed to NG:EGDN vapor at 0.5 mg/cu m (range 0.40-

0.67 mg/cu m) for 25 minutes or less. Average decreases in blood pressure for these seven workers were 11 mmHg for systolic pressure, 6.5 mmHg for diastolic pressure, and 4.5 mmHg for pulse pressure. Since the experiment was conducted in a magazine and the subjects did not handle dynamite directly, these effects resulted only from exposure to NG:EGDN vapor. Trainor and Jones also reported that workers in a magazine developed headaches when exposed to NG:EGDN concentrations between 0.10 and 0.53 mg/cu m. It is possible that some headaches developed at the lower limit of the range. However, since the average concentrations in the magazine was considerably higher, ie, about 0.36 mg/cu m, NG:EGDN concentrations substantially greater than 0.1 mg/cu m probably predominated in the magazine and produced the headaches. Hanlon and Fredrick [29] stated that pharmaceutical workers did not develop headaches when exposed to airborne NG at concentrations below 0.09 mg/cu m, but presented no data on the topic. Findings from the study by Trainor and Jones [49] indicated that there was a dose-response relationship between pulse pressure (systolic minus diastolic pressure) and the concentration of NG:EGDN vapor; as air concentrations increased from 0.5 to 2.0 mg/cu m, pulse pressures of exposed workers decreased.

After 2-4 days of workplace exposure to NG or EGDN, most workers no longer experience headache, dizziness, nausea, or decreases in diastolic, systolic, or pulse pressures; ie, they have become tolerant to the vasodilatory activity of NG or EGDN [22,56]. The development of tolerance is probably related to an increase in sympathetic compensatory activity, as indicated by the findings that administration of amphetamine, a sympathomimetic drug, to workers with headaches relieved the pain [32] and that tolerant workers without headaches would often develop severe headaches shortly after drinking alcohol [22,25]. The development of tolerance may also be related to a decrease in the sensitivity of the vascular receptors to these compounds [83], or to a combination of these effects. Since tolerance is lost during periods without exposure, workers have often attempted to maintain tolerance to these compounds by carrying the material home with them and applying it to their bodies [22,25,34].

Many investigators have found that blood pressure measurements in dynamite workers were within normal limits [25,52-54]. These findings usually reflect the development of tolerance in exposed workers, but they may also reflect differences in physical activity before, during, and after exposure, and the removal of workers who were less able to develop tolerance by either administrative control or self-selection.

Angina pectoris has been reported in workers who made NG:EGDN dynamite [38,43-45], in a worker who used NG:EGDN dynamite [48], in workers who made dynamite containing NG alone [63], and in workers who made rocket propellants containing NG [34-36]. In affected workers, angina usually occurs during periods away from work, eg, on a weekend. In contrast to findings for most other people who develop angina, the coronary arteriograms of one worker exposed to NG:EGDN [48] and of two workers exposed to NG alone [34] were considered normal; ie, the blood supply to the heart was not restricted by atherosclerotic plaques or thromboses. Spasms of the coronary arteries were revealed by the arteriograms of two workers [34,48]. The spasms, along with the pain, were relieved by taking NG sublingually.

Sudden deaths without any apparent cause have occurred in workers who made NG:EGDN dynamite [40,49,57,58], in a worker who made NG dynamite [63], and in those who made rocket propellants containing NG [34-36]. These deaths were first attributed to exposure to EGDN, but it is now apparent that workers exposed to NG alone can die suddenly also. Like attacks of angina, the sudden deaths that were reported occurred more frequently during periods away from work, particularly on Sunday nights or Monday mornings. In most cases, workers who had died suddenly had not had any premonitory signs or symptoms other than a history of angina attacks during periods away from work [58]. Atherosclerotic plaques or thromboses were occasionally found in the coronary arteries of workers who were autopsied, but their coronary arteries were usually not occluded to the same extent as those of unexposed people who had died suddenly [56,58]. Unfortunately, little information is available on the extent of exposure to NG or EGDN for workers who developed angina pectoris or died suddenly. Bille and Sivertssen [57] reported the death of a 34-year-old man employed at a dynamite plant for 6 years who had been exposed to NG:EGDN vapor at concentrations of 0.3-1.4 mg/cu m. Information provided by the Army Environmental Hygiene Agency (AEHA) [36] and by Lange et al [34] suggested that at least two workers exposed to airborne NG at average concentrations in the range 1.7-2.7 mg/cu m have died suddenly. It should be noted, however, that these workers may have also absorbed considerable amounts of NG or EGDN through the skin.

The study by Lange et al [34] indicated that symptoms of heart disease, such as chest pain, disappeared in affected rocket propellant workers when they were no longer exposed to NG but that some signs of heart disease remained. By reviewing death certificates from a county in Sweden, Hogstedt and Axelson [75] found that NG:EGDN dynamite workers were more likely to die from heart disease than were other men in the same county. Twenty-one deaths from heart disease occurred in men who had been employed at the dynamite plant for 1 year or more; 4 occurred in workers who were actively employed, but the other 17 occurred in men who had not worked at the plant for months or years. It appears, then, that the effects of long-term workplace exposure to NG or EGDN may not be completely reversed after exposure is terminated and that these changes can have severe effects on health.

NIOSH has concluded that workplace exposure to NG and EGDN should be controlled so that workers are not exposed at concentrations that will cause vasodilation, as indicated by the development of throbbing headaches or decreases in blood pressure. This standard should also protect against the development of angina pectoris, other signs or symptoms of cardiac ischemia or heart damage, and against sudden death, as a result of working with NG or EGDN, since all of these results seem to be related to compensatory vasoconstriction induced by repeated exposure to NG or EGDN and revealed by withdrawal to the vasodilatory activity of these substances during weekends or other periods of absence from regular exposure. Headaches appear to be the most sensitive and specific indicator of vasodilation in workers initially exposed to these compounds. Apparently workers initially exposed at concentrations of NG:EGDN averaging 0.36 mg/cu m (range 0.1-0.53 mg/cu m) can develop headaches [49]. Workers exposed to

0.09 mg/cu m of NG have been said not to develop headaches [29], but supporting data were not provided.

In most studies of health effects in exposed workers during which environmental concentrations were measured, a colorimetric method was used that measured the concentration of total inorganic nitrites. Therefore, there is some information available on health effects in workers exposed to dynamites composed of NG and EGDN in varying proportions, but the relative severities of the health effects associated with exposure to each of these compounds cannot be adequately determined. Because equal masses of NG and EGDN yield very nearly equal masses of nitrite ion on hydrolysis, it is appropriate to recommend one standard for workplace exposure to NG, EGDN, or a mixture of these two compounds.

The available information indicates that when absorption of NG or EGDN through the skin is controlled to the greatest extent possible, workers exposed to concentrations of airborne NG or EGDN at or less than 0.1 mg/cu m will not experience significant changes in blood pressure as demonstrated by the development of throbbing headaches. Thus, it is recommended that exposure to NG and EGDN be controlled so that workers are not exposed to airborne NG, EGDN, or mixtures of these substances at concentrations greater than 0.1 mg/cu m, as a ceiling concentration during any 20-minute sampling period.

(b) Sampling and Analysis

Personal sampling with a NIOSH-certified sampling pump for coal mine dust and a Tenax-GC adsorption tube is recommended. This type of sampling pump is recommended because of the potentially explosive environments, similar to those in coal mines, in which NG and EGDN are to be sampled. The Tenax-GC adsorption tube has been shown to be an effective collection medium for NG and EGDN and is not affected by variations in humidity [103]. This sampling technique involves no liquids and the equipment is small, facilitating personal sampling.

Gas chromatography with an electron-capture detector is recommended for the analysis of NG and EGDN so that the necessary sensitivity and specificity can be attained. The bases for the recommended sampling and analytical methods are discussed in Chapter IV, and detailed directions are provided in Appendix I.

(c) Medical Surveillance

In view of the effects of exposure to NG and EGDN on the cardiovascular system, NIOSH recommends that comprehensive preplacement and periodic examinations be made available to all workers occupationally exposed to these substances. ECG's taken during rest and during exercise should be conducted at least annually, as these tests are indicators of cardiovascular damage. The worker should be informed that symptoms such as headaches, dizziness, or nausea (that can develop during working hours) and chest pains or palpitations (that can develop during periods away from work) may be indicative of NG or EGDN toxicity and that these symptoms should be immediately reported to the responsible physician. All pertinent medical records, with supporting documents, must be kept for at least 30 years after termination of employment.

(d) Personal Protective Equipment and Clothing

Personal protective equipment must be used in accordance with 29 CFR 1910. Because of skin irritation from exposure to NG or EGDN [66,67] and demonstrated dermal absorption [11,63,70,76,79], proper gloves and protective clothing for exposed skin must be provided and used. Clothing that becomes spattered with NG or EGDN must be replaced immediately. Disposable garments may have some advantage as work clothing because of the ease of disposal, particularly for those made of regenerated cellulose. Respiratory protection, as designated in Table I-1, should be used to protect against harmful concentrations of NG or EGDN vapor, but it is not a substitute for ventilation and other engineering controls intended to keep concentrations in workplace air below the recommended environmental limit. Table I-1, specifying the requirements for respiratory protection, is based on the toxicologic and physical properties of NG and EGDN. Because of the explosive nature of both NG and EGDN and materials containing these compounds, nonsparking parts must be used where steel or iron is normally used on any respiratory equipment.

(e) Informing Employees of Hazards

Employee awareness is important in an overall effort to reduce occupational injuries and illness. Therefore, employers must inform employees of the toxic and explosive hazards of NG and EGDN. Keogh [160] has recently written a pamphlet for workers on the health effects of exposure to these compounds. A continuing education program, conducted at least annually, should be instituted by employers. This program should include instruction for employees on the need for, and proper use of, personal protective equipment, emergency procedures, proper work practices, and sanitation.

(f) Work Practices

Exposures to NG and EGDN in occupational environments can best be prevented by engineering controls and good work practices. NG and EGDN are readily absorbed through the skin. The protective gloves currently available will minimize but not prevent cutaneous absorption of these compounds. Workers should wear rubber or plastic gloves with a cotton lining or plain cotton gloves. Gloves should be changed at least daily. Cotton gloves should be changed immediately whenever they become contaminated with liquid NG or EGDN.

The extreme explosiveness of NG and EGDN necessitates conformance to stringent work practices. Smoking, matches, open flames, spark-producing devices, firearms, and welding apparatus must be prohibited in areas containing NG or EGDN. Dynamite and pure NG or EGDN should be stored in clean, cool, well-ventilated, bullet- and missile-resistant areas that are located away from all sources of ignition. Engineering controls are recommended to prevent accumulation of airborne NG and EGDN in work areas. Employers must establish procedures for emergency situations, sanitation, and maintenance, and must ensure that these procedures are understood and followed by all occupationally exposed workers.

(g) Monitoring and Recordkeeping Requirements

Because of the toxicity of NG and EGDN, employers must determine by an industrial hygiene survey whether employees are exposed to these compounds above the action level of 0.05 mg/cu m for any sampling period. If this survey reveals that exposure is at or below 0.05 mg/cu m, then the same type of survey must be made once every 3 years and be supplemented by semiannual personal sampling of employees. If exposure should be found to be above 0.05 mg/cu m, more frequent sampling is required.

Records of such monitoring must be kept for each employee occupationally exposed to NG or EGDN. These records must be kept for 30 years after the individual's employment has ended and must be made available upon request to the appropriate Federal agencies and to the employee or to the employee's authorized representatives.