INDUSTRIAL HYGIENE SURVEY REPORT

of

Radford Army Ammunition Plant
Hercules, Incorporated
Radford, Virginia 24141

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PURPOSE OF SURVEY:	To conduct an industrial hygiene evaluation of employees exposed to nitroglycerin while engaged in the manufacture of munitions propellants.
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STANDARD INDUSTRIAL CLASSIFICATION:	3483 (Ammunition, Except for Small Arms, Not Elsewhere Classified)
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DISCLAIMER

Mention of company names or products does not constitute endorsement by NIOSH.

ABSTRACT

An industrial hygiene survey was conducted at the Radford Army Ammunition Plant to estimate worker exposure to nitroglycerin (NG) at selected operations in the manufacture of munitions propellants. Personal and area samples were collected for NG and also for ethylene glycol dinitrate (EGDN). (EGDN may be present in trace amounts in NG.) In addition, area samples were collected in selected buildings for acetone, ethyl ether, ethyl alcohol, and n-butyl acetate.

Nitroglycerin personal sample results ranged from 0.001 ppm to 0.028 ppm. These levels refer to 8-hour Time Weighted Average (TWA) exposures. Five of 77 NG personal sample results obtained were judged to be above the NIOSH recommended standard of 0.01 ppm (as measured during any 20 minute sample period). All sample results were below the 1983 ACGIH Threshold Limit Value (TLV) of 0.05 ppm for an 8-hour TWA. All sample results were judged to be below the OSHA standard (ceiling level) of 0.2 ppm (as measured during a suggested 15 minute sample period). All EGDN personal sample results obtained were below the analytical limit of detection. Area solvent sample results for those buildings measured indicated the following concentration ranges: acetone--below the analytical limit of detection (L.D.) to 21.6 ppm; ethyl ether--all results below the L.D.; ethyl alcohol--below the L.D. to 41.3 ppm; n-butyl acetate--below the L.D. to 146.9 ppm. These levels suggest that employee exposures to these substances are below the OSHA standards and 1983 ACGIH TLVs of 1000 and 750 ppm (respectively) for acetone, 400 ppm for ethyl ether, 1000 ppm for ethyl alcohol, and 150 ppm for n-butyl acetate. These levels refer to 8-hour TWA exposures. Of the four solvents evaluated, NIOSH has recommended an exposure limit for acetone only--250 ppm. This level refers to a TWA exposure for up to a 10-hour workshift, 40 hour workweek. As previously indicated, sample results for acetone suggest that employee exposure to this substance is below the NIOSH recommended level.

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), Industrywide Studies Branch* performed an industrial hygiene evaluation of worker exposure to nitroglycerin (NG) at the Radford Army Ammunition Plant (RAAP), Radford, Virginia. At RAAP, exposure to NG can occur during the manufacture of munitions propellants. The results of several recent epidemiologic studies of NG exposed workers manufacturing dynamite indicated that NG exposed workers may be at increased risk of cardiac related mortality long after their last exposure to NG.[1,2] These reports formed the primary basis for conducting the current NIOSH study.

The study is composed of two parts--epidemiology and industrial hygiene. The epidemiologic evaluation is a retrospective cohort mortality study of workers employed at RAAP between 1949-1979. Of special interest is the cardiac related mortality experience of the study cohort. The industrial hygiene evaluation is a characterization of NG inhalation exposure of workers in several job groups considered to have probable exposure to NG. Evaluation emphasis is placed on determination of the 8-hour Time Weighted Average (TWA) exposure to workers in these groups.

This report presents the results of the industrial hygiene evaluation at RAAP. Measurements made for NG and also for Ethylene Glycol Dinitrate (EGDN) are reported in several formats. Measurements made for several solvents are also reported.

DESCRIPTION OF FACILITY AND WORKFORCE

RAAP was built in 1940 and has been operated by Hercules Incorporated (formerly Hercules Powder Company) under contract to the Department of the Army. The plant is comprised of approximately 1,200 production buildings situated on 7,000 acres of land near Radford, Virginia. Since the major products manufactured are of an explosive nature, most of the buildings are relatively small and isolated. In addition, those production buildings in which the possibility of explosion is considered to be significant are bunkered.

As of February 1979, approximately 2,721 people were employed at RAAP: 896 salaried and 1825 hourly. Of the 1825 hourly, approximately 833 were engaged directly in the manufacture of propellants. Over the life of the plant, the total number of employees has fluctuated greatly. During World

* In February 1979, the NIOSH Hazard Evaluation and Technical Assistance Branch (HETAB) performed a Health Hazard Evaluation at RAAP to evaluate employee exposure to various substances used in the manufacture of rocket propellants. Substances evaluated included ethyl ether, n-butyl acetate, acetone, nitroglycerin, lead, and dinitrotoluene.[3]

War II approximately 10,500 were employed; during the post war years (1946-48) relatively few (approximately 200) were employed. During the Korean conflict, however, total employment increased sharply, reaching approximately 8500 in 1953. This employment figure was again reached in 1968 during the Vietnam conflict.

DESCRIPTION OF PROCESS

In general, propellant refers to the material that is inserted into a munition shell or a rocket motor. When combusted the force generated will propel the projectile towards a predetermined target. Three basic material matrices are used in the manufacture of propellants at RAAP: 1) single base propellants contain nitrocellulose (NC) as the matrix, 2) double base propellants contain NC and nitroglycerin (NG) as the matrix, and 3) triple base propellants contain NC, NG, and nitroguanidine as the matrix. The NC component may be either nitrated cotton linters, nitrated wood pulp, or a combination of both depending upon the desired propellant form. (For on-site transportional purposes Diethylene Glycol (DEG) is mixed with NG to lower the freezing point, increase stability, and decrease sensitivity. It is subsequently removed during matrix formulation. EGDN, as such, is not used at RAAP. There is, however the possibility of it being present in NG in very small trace amounts.) Propellants are further classified depending on whether solvent (ethyl alcohol, ethyl ether, or acetone) is added to the base matrix during propellant manufacture or whether solvent is not added. In the former case, the propellant is referred to as a solvent propellant; in the latter case it is referred to as a solventless propellant. During the week of September 14, 1981, the NIOSH evaluation centered on the NG containing double base propellants (both solvent and solventless) since work groups which were considered to have probable exposure to NG were involved with this type of propellant matrix.

Double base propellants are manufactured in two major forms: cast powder propellant and rolled powder propellant.

1. Casting powder, classified as a solvent propellant, is produced by a process which involves the addition of NG to nitrated cotton linters (Pre-Mix Operation). This "pre-mix" is then brought to the Casting Powder line for double base propellants where plasticizers (diethyl phthalate and dibutylphthalate), a stabilizer (nitrodiphenylamine) and a solvent (acetone) are added. This mixture is pressed into blocks; the blocks are then extruded into spaghetti-like strands. The strands are then cut into small grains, loaded onto trays, and then air dried at 140°F for a prescribed length of time--which varies depending on the particular granulation size. The grains are then glazed, screened, blended, and packed out for storage. From storage they are either shipped to a munitions fabricator or they are processed further in the Cast Area. This processing involves loading these small grains into a mold followed by addition of a casting solvent to form a larger monolithic cast grain. These cast grains are then cured at 145°F for

a prescribed length of time, sawed, and machined. A cellulose acetate disk is attached to each end using a solvent mixture of n-butyl acetate and ethyl lactate (Inhibiting). The internal structure is checked by X-ray. These cast grains are given acceptance tests, packed, and stored ready for shipment.

Some casting powder is extruded into strands (stick propellant). These strands are cut to prescribed lengths, air dried at 140°F, blended, and packed for transfer to the Cast Area for assembly into a rocket motor. Here the sticks are put into a casing, fitted with a nozzle and igniter, given acceptance tests, and then packed ready for shipment off-plant. Some are static tested at the plant's Ballistics Test Range for ballistics parameters.

2. Rolled powder, classified as a solventless propellant, is produced by a process which involves adding plasticizers and a stabilizer to the nitrated cotton linters (Slurry Mix Operation). The slurry is next processed through a wringer into a hopper and then put into bags as a paste propellant.

   This paste propellant is transported to the Rolled Powder Area and cured for a prescribed length of time. Next, it is blended with other chemicals, prerolled into sheet propellant, and then rolled again (Evenspeed Roll) for further blending and uniformity. Following the Evenspeed operation, the sheet propellant can undergo one of two manufacturing processes:

   a. The sheets are processed through a slitter, cut into 4-1/2-inch strips, and rolled into carpet rolls. These are then packed for shipment or transported to the Cast Area for further processing on-site. Additional processing on-site involves pressing and extruding of the carpet rolls into strands which are cut into prescribed lengths. These cut strands are referred to as grains. Next, these grains are cured or annealed for a prescribed length of time at 145°F. They are then sawed, inhibited, machined, and packed for shipment. The grains are given acceptance tests prior to shipment.

   b. The sheets can also be made into pads (called increments) and processed through the Increment Line (depending on the formulation). This involves further rolling (Final Roll) where the sheets are cut into very thin sheets. These sheets are then end-trimmed, made into pads of varying weights, sewed, slitted, punched, sorted, weighed, and packed for shipment as mortar propellant. They are given acceptance tests prior to shipment.

DESCRIPTION OF JOB TITLES/JOB ACTIVITIES

The following job titles were evaluated for nitroglycerin exposure: Roll Evenspeed Operator (RESO), Final Roll Operator (FRLO), Nitroglycerin Weigh Operator (NGWO), Nitroglycerin Operator (NGOP), Solventless Powder Operator (SSPO), Solvent Powder Operator (SOPO), Cast Operator (COPO), Burning Ground Chief Operator (BGCO), Pre-Mix Operator (PRMO), and Pre-Mix Chief Operator (PRCO). A list of the work activities associated with each of these job titles is presented in Appendix I. Appendix II presents details of specific work activites performed.

DESCRIPTION OF EXPOSURE CONTROL METHODS/USE OF PERSONAL PROTECTIVE EQUIPMENT

At the time of this evaluation several types of control methods were used to reduce worker exposure--both inhalation and skin--to NG and other chemical and physical agents (noise). These included: 1) Ventilation--natural, dilution, local, and general 2) Process isolation--double air locks, wall barriers with viewing ports and/or closed circuit television, and employee removal from some buildings, and 3) Personal Protective Equipment--whole body coveralls, aprons, head covering with ear and neck flaps, several types of hand gloves, hearing protection (muffs and plugs), and respirators. In addition, all personnel exposed to NG receive daily a complete change of clothes. Shower facilities are also available. Other personal protective equipment worn included special conductive safety shoes (to reduce explosion hazard potential), fire hoods, and safety glasses. See Appendix III for personal equipment usage/engineering control methods related to selected work activities.

DESCRIPTION OF RAAP GLOVE PROGRAM

RAAP reported that, in 1972, they instituted a glove program for the prevention of skin exposure to NG. This program designates the type and style of each operation and states a frequency of change to ensure that no NG penetrates the gloves. The program is continually upgraded as new materials are discovered, tested, and implemented into the program.

OCCUPATIONAL HEALTH/REGULATORY CONSIDERATIONS

A. Health Aspects

NG is an oily liquid at room temperature that is colorless in pure form and pale yellow in commercial form. The freezing point of NG varies from 40°F to 56°F depending on the isomeric form. It is sensitive to impact and its sensitivity increases as its temperature increases. NG is used in making dynamite, gun powder, and rocket propellants; it is also used as a therapeutic agent, primarily to alleviate angina pectoris (chest pains due to insufficient oxygenation of heart muscles). EGDN is a colorless liquid at room temperature; the freezing point is about

- 30°F. EGDN is less sensitive to heat and impact than NG and is used primarily in the manufacture of dynamite. (In dynamite manufacture EGDN is mixed with NG to lower the freezing point of NG and to increase its stability.)

Both NG and EGDN are potent vasodilators, i.e. their effect is to dilate the blood vessels. The health effects of short-term or intermittent exposure to NG/EGDN which can be associated with vasodilation are headache, dizziness, nausea, and decreases in blood pressure. These symptoms subside after repeated daily exposure to NG or EGDN; that is, a tolerance is developed. The disappearance of these symptoms indicates that the dilation effect of NG or EGDN has been counteracted by compensatory vasoconstriction. This constriction of the blood vessels in workers who have developed a tolerance to NG or EGDN continues in the absence of exposure to NG or EGDN. 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 of withdrawal from exposure. NG and EGDN are absorbed readily by inhalation and through the skin; available evidence indicates that the major route of entry is through the skin.[4]

B. Exposure Regulations/Recommendations

The Occupational Safety and Health Administration (OSHA) standard for NG and/or EGDN is 0.2 parts per million (ppm).[5] This level represents a ceiling value, i.e., at no time shall an employee's exposure exceed this value. The American Conference of Governmental Hygienists (ACGIH) presently recommends a Threshold Limit Value (TLV) for NG and/or EDGN of 0.05 ppm (1983) for an 8-hour TWA, and a Short Term Exposure Limit (STEL) of 0.10 ppm (1983).[6] (A STEL is defined as a 15-minute TWA exposure which should not be exceeded at any time during a work day.) The ACGIH has proposed elimination of the STEL beginning with the 1985 TLV listing. The National Institute for Occupational Safety and Health, in 1978, recommended that employee exposure to NG and EDGN be controlled so that an employee is not exposed to NG, EGDN, or a mixture of these, at concentrations greater than 0.1 mg/m^3 as measured during any 20-minute sampling period. This value is equivalent to approximately 0.011 ppm of NG or 0.016 ppm of EGDN.[4]

Appendix IV presents occupational health standards and recommended health standards data for NG and EGDN. Similar information is also presented for several other substances measured during this evaluation: acetone, ethyl ether, ethyl alcohol, and n-butyl acetate.

FIELD EVALUATION

A. Selection of Sampling Cohort

In a preliminary study activity, representatives of management, union, and NIOSH identified job titles that were considered to have probable inhalation exposure to NG. (As alluded to previously, this identification process resulted in the selection of workgroups who were

involved in the manufacture of double base propellants. See Description of Process.) Appendix I lists the major job titles selected. All employees holding these job titles and who were to be working the day shift during the time of the evaluation were identified. Within each job title category, a random selection of employees for sampling was made. Extra employees were also randomly chosen for back-up in case of employee absence. The sample size determined for each category was calculated on the basis of the number of day shift employees in each category, the overall total number of employees for all categories, and the sample surveillance capabilities of the NIOSH investigators. A detailed discussion concerning sample size determination is contained in Appendix V.

B. Evaluation Scope

Personal breathing zone samples were collected within the selected categories (as described in A above) for measurement of exposure to NG and EGDN on the day shift at RAAP during September 15-17, 1981. Area samples were collected in selected buildings for measurement of exposure potential to ethyl ether, n-butyl acetate, acetone, and ethyl alcohol.

C. Sampling and Analytical Methods

1) Nitroglycerin (NG) and Ethylene Glycol Dinitrate (EGDN)

The sampling train consisted of a 150 milligram (mg) Tenax^{R}-GC sorbent tube connected via tygon tubing to an MDA Accuhaler^{R} (Model 808) low-flow pump operating at approximately 100 cubic centimeters per minute (cc/min) using a limiting orifice. The samples were collected for a period of 5-6 hours per shift. The Tenax^{R} tubes were analyzed for NG and EGDN according to NIOSH Method S-216.[7] In brief, this analytical method involves desorption of these analytes with ethyl alcohol followed by analysis in a gas chromatograph with an electron capture detector. The limit of detection (LOD) for NG was 0.6 micrograms (ug) per sample; the LOD for EGDN was 0.2 ug/sample.

2) Ethyl Ether, Ethyl Alcohol, Acetone, and N-Butyl Acetate

Area samples for ethyl ether, ethyl alcohol, acetone, and n-butyl acetate were also collected. The sampling train consisted of a standard 150 mg charcoal tube connected via tygon tubing to an MDA Accuhaler^{R} (Model 808) low-flow pump operating at 100 cc/min using a limiting orifice. Samples were collected for a period of 1-5 hours per shift and analyzed for ethyl ether, ethyl alcohol, acetone, and n-butyl acetate according to NIOSH Method S-56 (modified).[8] In brief, this analytical method involves desorption of these analytes with carbon disulfide followed by analysis in a gas chromatograph with a flame ionization detector. The LOD for each of these analytes was 0.01 mg/sample.

RESULTS AND DISCUSSION

A. Data Presentation

1. General Information

All sampling data is shown in Appendix VI. Table 1 lists individual sample results for exposure to NG and EGDN. Table 2 shows NG area sample results. Table 3 indicates ranges of exposure to NG for those job titles evaluated. Table 4 indicates area sample results for solvents measured.

2. Data Reference to Standards and Recommended Standards for NG and EGDN

Air sample measurements for NG and EGDN were collected over a 5-6 hour sample period. (Concentrations for NG and EGDN were determined for this time period and then extrapolated to an 8-hour TWA after factoring in exposure circumstances pertaining to the unsampled time period. See Appendix VI, Notes to Table 1, 2 and 3, Note 3, for details.) This length of sampling time is in marked contrast to the 15 minute sample period specified by the OSHA standard for determination of NG/EGDN concentration and the 20 minute sample period specified by the NIOSH recommended standard. There were two reasons for the selection of a longer sampling time:

- Assure collection of a sufficient volume of air. In the initial collection of NG air samples, as part of the HETAB activity, laboratory analysis of the samples (collected over a 15 minute period) indicated that all samples were below the LOD. Given the LOD for NG and the levels of airborne NG that existed, a major reason for the findings was an insufficient volume of air collected. In a follow-up collection of NG air samples, as part of the HETAB activity, a longer collection period was used. This resulted in the determination of detectable NG concentrations.[3]

- Enable the determination of NG and EGDN concentrations which can then be reliably extrapolated to TWA's. Beginning with the 1981 listing, the ACGIH specified the TLV for NG and EDGN in terms of a TWA and STEL.[9] (Beginning with the 1985 listing, ACGIH has proposed specification of the TLV for NG and EGDN in terms of a TWA only, thus eliminating the STEL.)[6] Determination of TWA's in this evaluation would thus allow direct comparison to present and future TLVs.

Since the OSHA standard and NIOSH recommended standard (0.2 and 0.01 ppm, respectively) are based on a shorter sampling period, the NG and EGDN results reported here are not directly comparable to these limits. (A concentration or TWA level of greater than these limits would indicate, however, that these limits were exceeded sometime during the sample period.) A direct comparison, though, can be made with ACGIH TLVs for NG and EGDN for an 8-hour TWA.

B. Measurement Results and Observations

Referring to Appendix VI, Table 1, five of 77 NG TWA personal sample results were judged to be above the NIOSH recommended level. The five sample results ranged from 0.014 ppm to 0.028 ppm. (One area sample result, 0.010 ppm, was judged to be above the NIOSH recommended level. See Appendix VI, Table 2.) All personal EGDN sample results were below the LOD. All NG personal sample results were below the 1983 ACGIH TLV of 0.05 ppm for an 8-hour TWA. All personal NG sample results were judged to be below the OSHA ceiling level of 0.2 ppm.

The aforementioned five exposures were experienced by employees working in rolled propellant rolling operations: 3 roll evenspeed operators, 1 final roll operator, and 1 solventless powder operator. All of these employees were working with warm propellant paste, containing NG. For comparison purposes, it is interesting to note the following additional temperature related observations:

1) NG exposures to several cast operators--person codes 51, 52, and 54--who were sawing finished NG containing propellant forms, ranged from 0.004 ppm to 0.008 ppm. Sawing of the forms would invariably elevate the temperature of the saw contact propellant surface.

2) NG exposures to several pre-mix operators--person codes 86 to 92--who were mixing liquid NG with other materials, ranged from below the analytical limit of detection to 0.003 ppm. In these cases NG was being mixed in open drums and was (in all probability) at room temperature.

3) NG exposures to several cast operators--person codes 33 to 40--who were assembling finished NG containing propellant forms, were below the analytical limit of detection. These propellant forms were (in all probability) at room temperature.

In general, then, it would appear that employees working with NG containing propellant (paste or finished form) at an elevated temperature state receive a higher inhalation exposure to NG than employees working with NG containing propellant at a room temperature state. The likely explanation for this circumstance is the increased volatilization of the NG which accompanies an increase in its temperature. Appendix VI, Table 3 provides a NG exposure summary pertaining to the job titles evaluated.

Referring to Appendix VI, Table 4, area solvent sample results for those buildings measured indicated the following ranges: acetone--below the LOD to 21.6 ppm; ethyl ether--all results below the LOD; ethyl alcohol--below the LOD to 41.3 ppm. These levels suggest that employee exposures to these substances are below the OSHA standards and 1983 ACGIH TLVs of 1000 and 750 ppm (respectively) for acetone, 400 ppm for ethyl ether, 1000 ppm for ethyl alcohol, and 150 ppm for n-butyl

acetate. These levels refer to 8-hour TWA exposures. Of the four solvents evaluated, NIOSH has recommended an exposure limit for acetone only--250 ppm.[10] This level refers to a TWA exposure for up to a 10-hour workshift, 40 hour workweek. As previously indicated, sample results for acetone suggest that employee exposure to this substance is below the NIOSH recommended level.

C. Other Measurements/Observations

- Ventilation measurements were conducted with an Alnor Junior^{R} velometer in several buildings.
- Several employees were observed handling NG products without gloves.
- Several employees complained of headaches.

Appendix III, Comments column contains information pertaining to the aforementioned measurements and observations as well as additional evaluation related information.

D. Tandem Sample Results Comparison

During the exposure evaluation, a short experiment was conducted. The purpose was to gain an indication of any systematic difference between NIOSH and RAAP sampling and analytical techniques. For this experiment selected individuals wore RAAP's Accuhuler^{R} pump and Tenax^{R} sorbent tube in addition to wearing the NIOSH sampling equipment. The sorbent tube used by RAAP was of smaller capacity--approximately 50 mg of Tenax^{R} sorbent versus 150 mg of Texax^{R} sorbent used by NIOSH. Each party's sorbent tubes were subsequently analyzed by their respective laboratories. NIOSH Method S-216 was used by both laboratories. Twenty-one pairs of samples, in which detectable sample results were reported by both NIOSH and RAAP, were evaluated. These data are shown in Appendix VII, Table 1. The result of a Paired T-Test, conducted to evaluate the differences in the sample pair results, is shown in Appendix VI, Table 2.

Of the sample pairs, RAAP sample results exceeded NIOSH results in 19 pairs; NIOSH results exceeded RAAP results in 1 pair; and NIOSH results and RAAP results were equal in 1 pair. The result of the Paired T-Test indicated that there was a statistically significant difference between the NIOSH and RAAP sample pair data. Possible reasons for the differences and the preponderance of the lower NIOSH values are: 1) the longer storage time (before laboratory analysis) for the NIOSH sample tubes--this may result in a possible loss of NG/EGDN, 2) the experience of the laboratory analysts with the analytical method--NIOSH performs analysis for NG/EGDN less frequently than does RAAP, 3) the larger media capacity of the NIOSH sampling tube--this factor may have affected, in some undefined manner, the NIOSH sampling and analytical technique, and

4) the variation in analytical instrument detector response at the lower concentrations measured (although this would not necessarily explain the preponderance of lower NIOSH values at these levels).

While the reasons proffered for the differences in the sample pairs would suggest that overall NIOSH sample results have understated the NG concentrations, a definite statement to this effect cannot be made. Additional investigation would be necessary. At this juncture it can be stated, however, that the possibility does exist.

CONCLUSIONS

A. Five NG TWA personal sample results were judged to be above the NIOSH recommended level of 0.01 ppm (as measured during any 20 minute samling period). All of these exposures were experienced by employees working in rolled powder propellant rolling operations.

B. All NG TWA personal sample results were below the 1983 ACGIH TLV of 0.05 ppm for an 8-hour TWA.

C. Reports of headaches by several employees suggest that some uptake of NG is occurring. This symptom (i.e. headaches) is associated with vasodilation. However, it is unclear (on the basis of the type of data collected by NIOSH) whether this uptake occurs primarily from inhalation, or skin absorption, or a combination of these mechanisms.

D. Employees working with NG containing propellant at an elevated temperature state appear to receive a higher inhalation exposure to NG than do employees working with NG containing propellant at a room temperature state.

E. Results of area samples collected for acetone, ethyl ether, ethyl alcohol, and n-butyl acetate suggest that employee exposures to these substances in those buildings evaluated are probably below the exposure levels prescribed by OSHA standards and ACGIH TLVs. Also, sample results for acetone suggest that employee exposure to this substance is below the NIOSH recommended level.

F. An evaluation of the tandem sample comparisons suggests the possibility that overall NIOSH sample results have understated the NG concentrations, although the comparisons would suggest that such understatement is not large. A definitive statement to this effect, however, cannot be made. Additional investigation would be necessary.

RECOMMENDATIONS

From observations and measurements made during this evaluation, the following recommendations pertaining to workplace surveillance are offered:

1. Conduct 8-hour TWA monitoring of personal NG levels to enable comparison with present and future TLVs.

2. Impress on employees the need for proper use of and removal of personal protective equipment when working with NG/EGDN so as to minimize skin absorption of NG.

3. Consider the appropriateness of providing additional personal protective equipment and/or engineering/administrative controls in the rolled powder propellant rolling operation where NG sample results suggested exposure levels to be in excess of the NIOSH recommended level of 0.01 ppm (as measured during any 20 minute sampling period).

4. Keep abreast of developments pertaining to the testing of new materials for protective clothing, especially gloves, so that increased protection (against skin absorption) can be made available to personnel that handle NG/EGDN. Although none of the protective gloves available are completely impervious to NG/EGDN, a study of skin absorption of EGDN by Hogstedt confirmed that rubber gloves with inner cotton gloves which are changed and disposed of as frequently as once or twice an hour might diminish skin resorption(sic).[11]

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APPENDIX I

DESCRIPTION OF JOB TITLES

JOB CODE NO.	ACRONYM	JOB TITLE	JOB DESCRIPTION
01	RESO	Roll Evenspeed Operator	Prepares floor-mat like propellant sheets. Tasks include weighing of raw materials, operation of blender, and operation of mechanical roll mill (evenspeed roll mill).
02	FRLO	Final Roll Operator	Loads floor-mat like propellant sheets (from evenspeed roll mill) into 2nd mechanical roll mill to obtain final desired sheet thickness. Also weighs propellant sheets.
03	NGWO	Nitroglycerin Weigh Operator	Dispenses proper weight of NG into cart (the so-called "angel buggy"); transports NG from NG Storehouse to Pre-Mix House (angel buggy operator); cleans NG laden rags and sponges, and pre-mixes recovered NG (slum crew operations).
04	NGOP	Nitroglycerin Operator	Fills NG storage tanks in NG storehouse; cleans NG transfer equipment (gutters, catch boxes, etc).
05	SSPO	Solventless Powder Operator	Performs variety of tasks associated with preparation of solventless propellant matrix. Tasks include weighing of propellant materials; operation of mechanical roll; transferring of raw materials; weighing of rolled sheets, sewing, punching, and slitting of rolled sheets; classifying, sorting and packing of rolled sheets and increments; and clean-up of associated work areas.
06	COPO	Cast Operator	Performs variety of tasks associated with fabrication of the solventless propellant matrix or solvent containing propellant matrix into a finished propellant configuration. Tasks include weighing, mold loading, inhibitor addition, sawing, facing, machining, assembly, inspection, and packaging.
07	SOPO	Solvent Powder Operator	Performs variety of tasks associated with preparation of solvent containing propellant matrix. Tasks include mixing and weighing of matrix materials, operation of compacter (blocking), operation of extrusion and cutting machines, and preparation of propellant strands for drying. Other tasks in this job title include transportation of propellant materials to and from the air dry houses, operation of air dry houses, transportation of scrap propellant to the burning ground, and operation of incinerator.
08	BGCO	Burning Ground Chief Operator	Collects scrap propellant and transports it to burning ground; supervises burning of scrap propellant. This work also performed by employees with SOPO classification.
09	PRMO	Pre-Mix Operator	Performs mixing of nitroglycerin with nitrocellulose or nitroguanidine in an agitated water slurry. Loads trucks with mixed batches.
10	PRCO	Pre-Mix Chief Operator	Work similar to PRMO; supervises pre-mix activites.

APPENDIX II

DESCRIPTION OF WORK ACTIVITIES

ACTIVITY CODE	ACTIVITY	DESCRIPTION
01	Roll Operation-Even Speed and Pre-Roll	Weighing and blending of raw materials; operation of roll mill to form propellant sheets.
02	Roll Operation - Final Roll	Operation of roll mill to form propellant sheets to desired thickness.
03/05	NG Slum Operation, Clean-up Operations	Transportation of NG by cart; premixing of recovered NG and cleaning of NG contaminated objects.
04	NG Buggy Operation	Dispensing and weighing of NG into cart and transporting cart to Mix House; cleans NG transfer equipment.
06	Sewing	Sewing of propellant sheets by machine.
07	Punching	Punching of holes in the middle of increment pads.
08	Packing/Inspecting	Inspecting final products and packing into crates for shipping.
09	Sorting/Classifying	Sorting and classifying finished propellant.
10	Shadowgraph	Inspection of internal structure of NG containing propellant.
11	Stenciling	Stenciling of lot number on finished propellant form.
12	Inhibiting	Attaching plastic disc to end of propellant stick.
13	Assembly	Assembly of various components of the TOW launch motor; loading powder into large molds.
14	Cast Operation	Removing solvents, air, and water vapor from propellant by vacuum; loading of molds.
16	Pre-Roll Operations 7113	Weighing of pre-mix, placing pre-mix into roll hopper, removing of sheets from roller.
17	Lathe Operation	Machining of propellant form with lathe.
18	Saw Operation	Sawing of propellant stick form by remote control.
19	Cutting Machine Operation	Cutting of extruded propellant and placing on trays.
20	Press Operation	Machine pressing of propellant batch into large blocks.
21	Pre-Mix Operation	Mixing of NG with other propellant matrix materials.
22	Transportation/ Truck Driver	Transportation of dried powder to finishing area and unloading of powder.
23	Drying Operation	Activities associated with drying of propellant forms.
24	Incinerator Operation	Operation of incinerator where scrap powder and waste is burned.
25	Foreman	Supervising operations in all bldg. areas.
26	Burning Ground Operation	Transportation of scrap powder to burning ground; spreading of powder out on concrete pads and burning of powder.
27	Forced Air Dry Operation	Monitoring temperature of drying house.

APPENDIX III

PERSONAL PROTECTIVE EQUIPMENT AND ENVIRONMENTAL CONTROL METHODS OBSERVED AT SELECTED ACTIVITIES

ACTIVITY CODES(S)	ACTIVITY	BLDG. NO.(S)	PERSONAL PROTECTIVE EQUIPMENT	ENVIRONMENTAL CONTROL(S)	COMMENTS
21	Pre-Mix Operation	9304-00	Rubber gloves lined with cotton; hearing protection (muffs)	Dilution ventilation; natural ventilation	
19	Cutting Machine Operation	3514-00	Polyethylene gloves lined with cotton; safety glasses with side shields; hearing protection (plugs)	Local ventilation over scale and cart	Local ventilation added around 1980
20	Press Operation	3613-00	Same as cutting machine operation	2nd floor:local ventilation and updraft ventilation; intermittent use of concrete and plexiglass barrier	Part of replacement air drawn from door amd part from underneath bay containing extruded propellant
22	Truck Driver	4912-46	Gloves; respiratory protection when in finishing building	Natural ventilation	
27	Forced Air Dry Operation	4912-46	Rubber and cloth gloves	Natural ventilation; employee removal	Employee does not enter building while drying is in process
24	Incinerator Operation	4470-00	Gloves	Natural ventilation	

NOTE:
All information presented in this Appendix was applicable during week of September 14, 1981 and pertained specifically to the circumstances of the individual(s) that were evaluated. Information concerning environmental control methods and personal protective equipment usage is not necessarily relevant to the circumstances of all individuals employed within a specified activity.

In addition, all employees evaluated wore white coveralls, head coverings with ear and neck flaps, and special conductive safety shoes.

ACTIVITY CODES(S)	ACTIVITY	BLDG. NO.(S)	PERSONAL PROTECTIVE EQUIPMENT	ENVIRONMENTAL CONTROL(S)	COMMENTS
01; 02	Evenspeed, Pre-Roll, and Final Roll Operation	9309-03	Heavy cloth gloves; fire hood	Dilution ventilation and blasts of replacement air on worker; employee removal (2 breaks daily)	No ventilation in make-up bay or service hall; changed gloves every hour
03; 05	NG Slum and and Clean-Up Operation	9478-00; 9473-00	Rubber gloves lined with cotton	Natural ventilation; dilution ventilation	Gloves changed daily
04	NG Buggy Operation	9478-00	Rubber gloves lined with cotton	Natural ventilation	
01	Blending	9334-15	Respiratory protection	Natural ventilation; employee removal	Except for loading/ unloading mixer, process conducted from remote area
01	Pre-Roll Operation	7113-00	Cloth gloves	Safety barrier at roller; dilution ventilation.	Employees seemed to remove and handle gloves excessively; at times worked without gloves
06	Sewing	9310-02	Cloth gloves	Barriers; air locks	Changed gloves daily
10	Shadowgraph	9310-02	Gloves	Dilution ventilation	Changed gloves every 2 hours; Headaches-aspirin taken frequently, more often on Monday or when not exposed to NG
07	Punching	9310-02	Gloves	Barrier; double air lock	Changed gloves periodically
08	Packaging/ Inspecting	9310-02	Cloth gloves or latex gloves	Dilution ventilation	Latex gloves when handling powder; cloth gloves when handling crates

ACTIVITY CODES(S)	ACTIVITY	BLDG. NO.(S)	PERSONAL PROTECTIVE EQUIPMENT	ENVIRONMENTAL CONTROLS	COMMENTS
09	Sorting/ Classifying	9310-02	Latex gloves (surgical type)	Dilution ventilation	Operator tried to remove used gloves without touching gloves with bare hands.
12	Inhibiting	4925-00	Safety glasses; latex gloves or yellow sulfur-free pylox gloves; cloth apron	Local slot ventilation about waist high; dilution ventilation	Can of solvent left open in front of slot ventilation; heavy solvent smell present; employees had large amounts of solvent on gloves and coveralls; some employees touched outside of contaminated gloves
13	Assembly	4924-01	Polyethylene gloves with cotton lining or yellow sulfur-free pylox gloves	General ventilation; employee removal	Some employees did not wear gloves
14	Casting Operation	4912-04	Cloth and latex gloves	Employee removal; local ventilation; barrier	
17	Lathe Operation	7113-00	Hearing protection; latex gloves/cloth gloves	Barrier with plexiglass shield; general ventilation; natural ventilation	Minimal air movement indicated
18	Saw Operation	4912-03	Latex gloves	Barrier with plexi-glass shield	Mechanic entered sawing room during equipment breakdown without first ventilating the room
11	Stenciling	9310-02	Yellow sulfur-free pylox gloves	Dilution ventilation	Worker complained of headaches
14	Mold Loading	4912-11	Polyethylene gloves with cotton lining	Natural ventilation; employee removal	Only one of three operators wore gloves

APPENDIX IV

OCCUPATIONAL HEALTH STANDARDS/RECOMMENDED
HEALTH STANDARDS DATA

PRESENT APPLICABLE OCCUPATIONAL HEALTH
STANDARDS/RECOMMENDATIONS (IN PPM) PERTAINING TO SUBSTANCES SAMPLED

SUBSTANCE	OSHA[5] PEL	ACGIH (1983)[6] TLV	STEL	NIOSH
Nitroglycerin (NG)	C 0.2(a)	0.05	0.1	D 0.01[4]
Ethylene Glycol Dinitrate (EGDN)	C 0.2(a)	0.05	0.1	D 0.01[4]
Acetone	1000	750	1,000	250[10]
Ethyl Ether	400	400	500	
Ethyl Alcohol	1000	1000		
n-Butyl Acetate	150	150		

NOTES:
(a) Atmospheric concentrations of not more than 0.02 ppm, or personal protection may be necessary to avoid headache.[5]
C - Ceiling Value. Employee exposure shall at no time exceed this value.
D - Recommended level as measured during any 20-minute sampling period.

APPENDIX V

SAMPLE SIZE DETERMINATION/SAMPLE COLLECTION DATA

JOB CODE	JOB TITLE	NO.[1] EMPLOYEES DAY SHIFT	WEIGHTING[2] FACTOR	NO.[3] EMPLOYEES TO BE SAMPLED	NO.[4] EMPLOYEES ACTUALLY SAMPLED	NO.[5] EMPLOYEE SAMPLE RESULTS
01	RESO	9	.54	5	5	5
02	FRLO	4	.54	3	3	2
03	NGWO	10	.54	5	5	4
04	NGOP	6	.54	3	1	1
05	SSPO	42	.54	23	18	14
06	COPO	71	.54	37	34	29
07	SOPO	42	.54	24	19	14
08	BGCO	1	.54	1	1	1
09	PRMO	9	.54	5	5	5
10	PRCO	4	.54	2	2	2
	TOTALS	198	.54	108	93	77

NOTES:

1 Number of employees working day shift during the week of September 14, 1981. This information was obtained from work schedule records.

2 The calculated factor which provides for proportional sample collection treatment for each job title. For this calculation the following data are relevant: 1) 4 NIOSH investigators available for sample surveillance, 2) each NIOSH investigator assumed to be capable of observing 9 employees per day, 3) the evaluation was to be carried out over a 3 day period, and 4) 198 probable exposed employees tentatively available for personal sample measurement. Therefore:

$$WF = \frac{\text{total measurement capability}}{\text{total number of employees available}} = \frac{4 \text{ investigators} \times \frac{9 \text{ employees}}{\text{day} \quad \text{investigator}} \times 3 \text{ days}}{198 \text{ employees}} = \frac{108}{198} = .54$$

This proportional method of sample size determination was used instead of the statistical method as described by Leidel, et. al.[12] The proportional method was believed to allow for a more valid exposure characterization of certain job titles. See Note 3. At the same time the proportional method was considered to provide an objective means of determining sample size.

3 The number, rounded to the nearest (in most cases) whole number, which equals the number of available employees in each category multiplied by the weighting factor. In consideration of statistical sampling concepts developed by Leidel, et. al., the numbers arrived at for job codes 01, 02, 03, 04, 09, and 10 would be less than that required (to be 90% confident that at least one individual from the highest 10% exposure group is contained in the sub sample size). For job codes 05, 06, and 07 the numbers arrived at would be greater than that required. However, work activities (and thus exposure circumstances) of these latter codes are more varied than are the work activites of the former codes. Thus oversampling (from a statistical viewpoint) was, in this case, thought to provide for a more valid overall exposure characterization of these latter codes. At the same time, the relative lack of variation of work activities (and thus exposure circumstances) of the former codes would suggest that undersampling would not significantly reduce the validity of the exposure characterization of these codes.

4 The actual number of employees from which personal samples were obtained. The actual number was less due to absences and temporary job transfers.

5 The number of sample results reported. Sample train problems occurred for 15 sample measurements; 1 sample measurement, obtained from an employee who changed work locations frequently during the sample period, was not reported.

APPENDIX VI

SAMPLING/EXPOSURE DATA

NOTES TO TABLES 1, 2 and 3

1 - Analysis of all samples for EGDN showed employee exposure to be below the analytical limit of detection. Limit of detection for EDGN is 0.2 ug/sample.

2 - Limit of Detection for NG is 0.6 ug/sample. The symbol "<" denotes less than.

3 - The 8-hour TWA was calculated by assuming that 1) the measured NG concentration (for the sample period) constituted the employee's exposure for a 7-hour period (420 minutes), and 2) no exposure to NG occurred for a 1-hour (60 minute) period due to travel to and from worksite, work breaks, etc. However, the sampled period included an approximate 30 minute lunch break, during which most employees who were sampled left their work station and thus were not exposed to NG. The practical effect of this action is to understate, slightly, the actual workplace exposure concentration and the TWA.

4 - The calculation of the TWA from a concentration reported as less than (<) a given concentration required that a discrete value be assigned to this concentration. The discrete value assigned for this concentration was one-half of the reported less than (<) concentration.[13]

TABLE 1

PERSONAL SAMPLING/EXPOSURE DATA FOR NITROGLYCERIN (NG)[1]
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

PERSON CODE	DATE	FILTER NUMBER	SAMPLE TIME (MIN)	AIR VOLUME (L)	JOB CODE	ACTIVITY CODE	BUILDING NUMBER	ug[2] NG	NG CONC. (PPM)	NG[3] TWA (PPM)
001	9/15/81	GC-150	304	22.6	01	01	9309-04	2.0	0.010	0.008
002	9/15/81	GC-141	270	24.1	01	02	9310-02	7.2	0.032	0.028
003	9/15/81	GC-146	286	35.3	01	01	9309-03	10.4	0.032	0.028
004	9/15/81	GC-145	283	23.9	01	01	9309-03	7.1	0.032	0.028
005	9/15/81	GC-144	263	26.8	01	01	9334-15	< 0.6	< 0.002	0.001[4]
007	9/15/81	GC-143	299	26.8	02	02	9310-02	4.1	0.016	0.014
008	9/15/81	GC-147	298	31.3	02	02	9310-02	2.3	0.008	0.007
009	9/15/81	GC-2	270	21.5	03	04	9478-00	0.9	0.004	0.004
010	9/15/81	GC-3	260	26.7	03	03	9478-00	< 0.6	< 0.002	0.001
012	9/15/81	GC-5	295	28.9	03	04	9478-00	1.2	0.004	0.004
013	9/15/81	GC-8	250	20.7	03	04	9478-00	0.8	0.004	0.004
014	9/15/81	GC-1	255	29.4	04	05	9473-00	< 0.6	< 0.002	0.001
015	9/15/81	GC-61	227	24.8	05	16	7113-00	< 0.6	< 0.003	0.001
016	9/15/81	GC-62	265	21.8	05	05	9310-02	< 0.6	< 0.003	0.001
018	9/15/81	GC-64	264	26.9	05	05	9310-02	< 0.6	< 0.002	0.001
019	9/15/81	GC-67	228	18.2	05	16	7113-00	0.9	0.005	0.005

TABLE 1 (continued)

PERSONAL SAMPLING/EXPOSURE DATA FOR NITROGLYCERIN (NG)[1]
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

PERSON CODE	DATE	FILTER NUMBER	SAMPLE TIME (MIN)	AIR VOLUME (L)	JOB CODE	ACTIVITY CODE	BUILDING NUMBER	ug NG	NG CONC. (PPM)	NG TWA (PPM)
020	9/15/81	GC-68	282	33.1	05	06	9310-02	0.8	0.003	0.002
021	9/15/81	GC-69	258	25.6	05	06	9310-02	< 0.6	< 0.003	0.001
022	9/15/81	GC-70	267	25.7	05	05	9310-02	< 0.6	< 0.002	0.001
023	9/15/81	GC-23	293	16.3	05	11	9310-02	< 0.6	< 0.004	0.002
024	9/15/81	GC-24	299	33.2	05	06	9310-02	0.9	0.003	0.003
025	9/15/81	GC-30	309	30.0	05	10	9310-02	0.8	0.003	0.002
026	9/15/81	GC-20	308	35.1	05	07	9310-02	< 0.6	< 0.002	0.001
027	9/15/81	GC-19	311	27.9	05	08	9310-02	< 0.6	< 0.002	0.001
028	9/15/81	GC-27	309	28.8	05	02	9310-02	8.2	0.031	0.027
029	9/15/81	GC-22	317	31.3	05	09	9310-02	1.6	0.006	0.005
033	9/16/81	GC-6	338	31.1	06	13	4925-00	< 0.6	< 0.002	0.001
034	9/16/81	GC-9	332	34.9	06	13	4925-00	< 0.6	< 0.002	0.001
036	9/16/81	GC-12	320	34.5	06	13	4924-01	< 0.6	< 0.002	0.001
037	9/16/81	GC-59	319	24.3	06	13	4924-01	< 0.6	< 0.003	0.001
038	9/16/81	GC-53	318	30.6	06	13	4924-01	< 0.6	< 0.002	0.001
039	9/16/81	GC-52	318	30.7	06	13	4915-00	< 0.6	< 0.002	0.001
040	9/16/81	GC-50	306	31.6	06	13	4915-00	< 0.6	< 0.002	0.001

TABLE 1 (continued)

PERSONAL SAMPLING/EXPOSURE DATA FOR NITROGLYCERIN (NG)[1]
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

PERSON CODE	DATE	FILTER NUMBER	SAMPLE TIME (MIN)	AIR VOLUME (L)	JOB CODE	ACTIVITY CODE	BUILDING NUMBER	ug NG	NG CONC. (PPM)	NG TWA (PPM)
043	9/16/81	GC-17	310	35.5	06	14	4912-04	< 0.6	< 0.002	0.001
044	9/16/81	GC-10	311	30.7	06	14	4912-04	< 0.6	< 0.002	0.001
045	9/16/81	GC-24	326	31.0	06	14	4912-04	< 0.6	< 0.002	0.001
046	9/16/81	GC-15	313	28.3	06	14	4912-04	< 0.6	< 0.002	0.001
047	9/13/81	GC-18	302	26.7	06	25	4912-04	< 0.6	< 0.002	0.001
048	9/16/81	GC-21	307	35.4	06	14	4912-04	< 0.6	< 0.002	0.001
049	9/16/81	GC-71	353	36.8	06	17	4924-06	< 0.6	< 0.002	0.001
050	9/16/81	GC-72	353	28.3	06	17	4924-06	< 0.6	< 0.002	0.001
051	9/16/81	GC-73	349	35.5	06	18	4912-03	2.6	0.008	0.007
052	9/16/81	GC-74	350	39.6	06	18	4912-03	1.7	0.005	0.004
053	9/16/81	GC-75	343	33.8	06	12	4912-03	1.4	0.004	0.004
054	9/16/81	GC-76	346	33.1	06	18	4912-03	1.4	0.005	0.004
055	9/16/81	GC-77	340	30.9	06	12	4912-03	0.9	0.003	0.003
056	9/16/81	GC-78	334	33.2	06	12	4912-03	0.9	0.003	0.003
057	9/16/81	GC-79	334	25.6	06	12	4912-03	< 0.6	< 0.002	0.001
059	9/16/81	GC-148	304	31.2	06	17	7113-00	< 0.6	< 0.002	0.001
060	9/16/81	GC-127	303	28.3	06	08	7115-00	1.3	0.005	0.004

TABLE 1 (continued)

PERSONAL SAMPLING/EXPOSURE DATA FOR NITROGLYCERIN (NG)[1]
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

PERSON CODE	DATE	FILTER NUMBER	SAMPLE TIME (MIN)	AIR VOLUME (L)	JOB CODE	ACTIVITY CODE	BUILDING NUMBER	ug NG	NG CONC. (PPM)	NG TWA (PPM)
061	9/16/81	GC-118	301	26.1	06	08	7113-00	< 0.6	< 0.002	0.001
062	9/16/81	GC-117	296	21.2	06	17	7113-00	< 0.6	< 0.003	0.001
063	9/16/81	GC-112	294	22.5	06	25	7801-00	< 0.6	< 0.003	0.001
064	9/16/81	GC-130	295	34.1	06	18	7801-00	< 0.6	< 0.002	0.001
065	9/16/81	GC-113	330	18.9	06	18	7801-00	< 0.6	< 0.003	0.001
067	9/17/81	GC-38	291	26.4	07	22	4912-46	0.6	0.002	0.001
068	9/17/81	GC-37	282	31.9	07	22	4912-46	< 0.6	< 0.002	0.002
069	9/17/81	GC-48	308	34.3	07	27	4912-46	< 0.6	< 0.002	0.001
070	9/17/81	GC-34	379	31.5	08	26	4470-00	< 0.6	< 0.002	0.001
071	9/17/81	GC-41	382	40.6	07	26	4470-00	< 0.6	< 0.002	0.001
072	9/17/81	GC-35	391	26.1	07	24	4470-00	< 0.6	< 0.002	0.001
073	9/17/81	GC-54	386	35.9	07	26	4470-00	< 0.6	< 0.002	0.001
074	9/17/81	GC-49	355	33.0	07	19	3514-00	< 0.6	< 0.002	0.001
075	9/17/81	GC-56	345	35.8	07	20	3514-00	0.7	0.002	0.002
076	9/17/81	GC-60	345	32.4	07	23	3509-00	1.1	0.004	0.003
077	9/17/81	GC-114	348	41.1	07	20	3512-00	< 0.6	< 0.002	0.001
081	9/17/81	GC-108	361	33.2	07	20	3613-00	0.7	0.002	0.002

TABLE 1 (continued)

PERSONAL SAMPLING/EXPOSURE DATA FOR NITROGLYCERIN (NG)[1]
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

PERSON CODE	DATE	FILTER NUMBER	SAMPLE TIME (MIN)	AIR VOLUME (L)	JOB CODE	ACTIVITY CODE	BUILDING NUMBER	ug NG	NG CONC. (PPM)	NG TWA (PPM)
082	9/17/81	GC-109	360	36.8	07	19	3613-00	1.1	0.003	0.003
083	9/17/81	GC-110	352	30.4	07	25	3613-00	0.6	< 0.002	0.001
084	9/17/81	GC-97	316	35.5	07	20	3613-00	0.7	0.002	0.002
086	9/17/81	GC-81	393	38.3	09	21	9304-00	< 0.6	< 0.002	0.001
087	9/17/81	GC-82	355	40.3	10	21	9304-00	< 0.6	< 0.002	0.001
088	9/17/81	GC-83	353	32.2	09	21	9304-00	< 0.6	< 0.002	0.001
089	9/17/81	GC-84	370	39.6	10	21	9303-03	0.8	0.002	0.002
090	9/17/81	GC-85	373	34.6	09	21	9303-03	1.2	0.004	0.003
091	9/17/81	GC-86	368	29.8	09	21	9303-03	0.8	0.003	0.003
092	9/17/81	GC-87	363	37.2	09	21	9303-09	< 0.6	< 0.002	0.001

TABLE 2

AREA SAMPLING/EXPOSURE DATA FOR NITROGLYCERIN (NG) AND
ETHYLENE GLYCOL DINITRATE (EGDN)
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

DATE	SAMPLE NUMBER	SAMPLE TIME (MIN)	AIR VOLUME (L)	BUILDING NUMBER	ug NG	ug[a] EGDN	NG CONC. (PPM)	NG TWA (PPM)
9/16/81	GC-14	296	24.5	4912-03	1.3	<0.2	0.006	0.005
9/17/81	GC-89	292	23.3	9304-00	2.4	<0.2	0.011	0.010

NOTE:
[a] EGDN levels were below the analytical limit of detection of 0.2 ug per sample.

TABLE 3

EXPOSURE SUMMARY: NG PERSONAL SAMPLE RESULTS
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

JOB CODE	JOB TITLE	DATE	NO. OF VALUES	NG CONCENTRATION RANGE (PPM)	NG TWA RANGE (PPM)	NG TWA MEDIAN (PPM)
				Low - High	Low - High	
01	Roll Even Speed Operator (RESO)	9/15/81	5	< 0.002 - 0.032	0.001 - 0.028	0.028
02	Final Roll Operator (FRLO)	9/15/81	2	0.008 - 0.016	0.007 - 0.014	0.011
03	Nitroglycerin Weigh Operator (NGWO)	9/15/81	4	< 0.002 - 0.005	0.001 - 0.004	0.004
04	Nitroglycerin Operator (NGOP)	9/15/81	1	< 0.002	0.001	--
05	Solventless Powder Operator (SSPO)	9/15/81	14 13	< 0.002 - 0.031[a] < 0.002 - 0.006[b]	0.001 - 0.027[a] 0.001 - 0.005[b]	0.001[a] 0.001[b]
06	Cast Operator (COPO)	9/16/81	29	< 0.002 - 0.008	0.001 - 0.007	0.001
07	Solvent Powder Operator (SOPO)	9/17/81	14	< 0.001 - 0.004	0.001 - 0.003	0.001
08	Burning Ground Chief Operator (BGCO)	9/17/81	1	< 0.002	0.001	--
09	Pre-Mix Operator (PRMO)	9/17/81	5	< 0.002 - 0.004	0.001 - 0.003	0.001
10	Pre-Mix Chief Operator (PRCO)	9/17/81	2	< 0.001 - 0.002	0.001 - 0.002	0.001

NOTES:

[a]Figures include 1 data point of SSPO doing Final Roll operations.

[b]Figures exclude 1 data point of SSPO doing Final Roll operations.

TABLE 4

AREA SAMPLING/EXPOSURE DATA FOR SOLVENTS
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

DATE	BLDG. NO.	SAMPLE #	SAMPLING TIME (MIN)	AIR VOLUME (L)	mg ACETONE	mg ETHYL ETHER	mg EHTYL ALCOHOL	mg N-BUTYL ACETATE	CONC. ACETONE (PPM)	CONC. ETHYL ETHER (PPM)	CONC. ETHYL ALCOHOL (PPM)	CONC. N-BUTYL ACETATE (PPM)
9/15/81	9309-00	CT-8	150	13.3	< 0.01	<0.01	< 0.01	< 0.01	< L.D.	< L.D.	< L.D.	< L.D.
9/15/81	9310-02	CT-4	313	27.0	< 0.01	<0.01	< 0.01	< 0.01	< L.D.	< L.D.	< L.D.	< L.D.
9/15/81	9455-00	CT-31	100	11.2	0.04	<0.01	< 0.01	< 0.01	1.5	< L.D.	< L.D.	< L.D.
9/16/81	4925-00	CT-33	333	35.9	< 0.01	<0.01	0.42*	25.0	< L.D.	< L.D.	6.2*	146.9
9/16/81	4924-01	CT-36	255	21.4	1.1	<0.01	0.12	< 0.01	21.6	< L.D.	3.0	< L.D.
9/16/81	4912-03	CT-29	135	14.1	< 0.01	<0.01	< 0.01	0.26	< L.D.	< L.D.	0.4	3.9
9/16/81	4912-04	CT-40	219	22.8	< 0.01	<0.01	< 0.01	0.33	< L.D.	< L.D.	0.2	3.1
9/16/81	4912-03	CT-26	102	6.6	< 0.01	<0.01	0.02	0.35	< L.D.	< L.D.	1.6	11.2
9/16/81	4912-03	CT-30	194	12.5	< 0.01	<0.01	0.02	0.37	< L.D.	< L.D.	0.9	6.2
9/16/81	7801-00	CT-3	284	25.9	< 0.01	<0.01	0.12	< 0.01	< L.D.	< L.D.	2.5	< L.D.
9/16/81	7113-00	CT-5	243	19.9	< 0.01	<0.01	0.06	< 0.01	< L.D.	< L.D.	1.6	< L.D.
9/17/81	3514-00	CT-42	292	30.9	0.86	<0.01	0.62	0.03	11.7	< L.D.	10.7	0.2
9/17/81	3613-00	CT-2	300	25.9	0.35	<0.01	0.56	< 0.01	5.7	< L.D.	11.5	< L.D.
9/17/81	3613-00	CT-6	307	25.7	0.23	<0.01	0.42	< 0.01	3.8	< L.D.	8.7	< L.D.
9/17/81	9303-03	CT-45	**	33.5	0.05	<0.01	2.6	< 0.01	0.6	< L.D.	41.3	< L.D.
9/17/81	9304-00	CT-46	287	28.5	< 0.01	<0.01	< 0.01	< 0.01	< L.D.	< L.D.	0.1	< L.D.

NOTES:

Several concentrations are expressed without regard to rules governing significant figures.

The limit of detection (L.D.) for ethyl ether, ethyl alcohol, n-butyl acetate, and acetone is 0.01 mg/sample. The symbol "<" denotes less than.

* Greater than 33% of the total reported weight was found on the back-up portion of the charcoal tube. The reported concentration should thus be considered suspect.

** Not reported.

APPENDIX VII

TANDEM SAMPLE RESULTS DATA

TABLE 1

TANDEM SAMPLE RESULTS DATA
RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA
SEPTEMBER 1981

OBS	RAAP		NIOSH	
	SAMPLE NO.	CONCENTRATION (PPM)	SAMPLE NO.	CONCENTRATION (PPM)
1	5940	0.005	GC-108	0.002
2	5910	0.009	GC-75	0.004
3	5936	0.006	GC-56	0.002
4	5911	0.014	GC-76	0.004
5	5913	0.016	GC-118	0.008
6	5904	0.035	GC-150	0.010
7	5909	0.010	GC-74	0.005
8	5912	0.010	GC-77	0.003
9	5937	0.002	GC-60	0.004
10	5899	0.006	GC-30	0.003
11	5902	0.052	GC-143	0.016
12	5932	0.004	GC-37	0.002
13	5900	0.038	GC-27	0.030
14	5903	0.017	GC-147	0.008
15	5907	0.039	GC-145	0.032
16	5941	0.004	GC-97	0.002
17	5919	0.019	GC-127	0.005
18	5894	0.006	GC-27	0.006
19	5906	0.041	GC-141	0.032
20	5914	0.007	GC-78	0.003
21	5942	0.005	GC-109	0.003

TABLE 2

PAIRED T-TEST

OBS	RAAP CONCENTRATION (PPM)	NIOSH CONCENTRATION (PPM)	D[1]
1	0.005	0.002	0.003
2	0.009	0.004	0.005
3	0.006	0.002	0.004
4	0.014	0.004	0.010
5	0.016	0.008	0.008
6	0.035	0.010	0.025
7	0.010	0.005	0.005
8	0.010	0.003	0.007
9	0.002	0.004	-0.002
10	0.006	0.003	0.003
11	0.052	0.016	0.036
12	0.004	0.002	0.002
13	0.038	0.030	0.008
14	0.017	0.008	0.009
15	0.039	0.032	0.007
16	0.004	0.002	0.002
17	0.019	0.005	0.014
18	0.006	0.006	0.000
19	0.041	0.032	0.009
20	0.007	0.003	0.004
21	0.005	0.003	0.002

1 D = Concentration (RAAP) - Concentration (NIOSH)

Hypothesis: The mean difference between RAAP and NIOSH sample pair results is 0.

Test Statistic: $TS = D/(S_D/(N)^{1/2})$
where D = the mean of the sample differences
S_D = standard deviation of the sample differences
N = number of observations

Calculations: $D = 0.0076$
$S_D = 0.0086$
$TS = 4.04$
$t_{20,0.975} = 2.08$

Observation: The calculated test statistic exceeds the t value predicted for this sample size and confidence level. (In the science of hypothesis testing, the test statistic is said to have fallen into the Rejection Region).

Conclusion: The hypothesis is rejected and it is concluded that there is a statistically significant difference between RAAP and NIOSH sample pair results.