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OCCUPATIONAL DISEASES IN GOVERNMENT-OWNED ORDNANCE EXPLOSIVES PLANTS

Observations on Their Prevalence and Control During World War II

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INTRODUCTION

This report shows the prevalence and trend of occupational diseases in government-owned explosives plants manufacturing 90 to 95 per cent of all explosives and ammunition produced in the United States during World War II. It also shows what was accomplished in a large industry offering many toxic exposures by a comprehensive and aggressive industrial hygiene program through the cooperative and coordinated efforts of the Ordnance Department and the Medical Department of the Army Service Forces, the United States Public Health Service and the various industrial establishments themselves.

This report is divided as follows into sections showing the general health and hygiene program, a brief description of the nine industrial groups, a description of the major occupational diseases peculiar to these plants in the order of their importance, and a presentation of other occupational diseases by industrial groups. Tabulated data and graphs are presented wherever justified.

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I. THE INDUSTRIAL HEALTH AND HYGIENE PROGRAM

During World War I, although the production of explosives and ammunition in the United States was on a relatively small scale, the International Labour Office states that during seven and one-half months 17,000 persons were poisoned by trinitrotoluene and related compounds and that of these 475 died.[1] According to the same source there were 1,389 cases of poisoning in the explosives industry by nitrous fumes, of which 28 were fatal. Although there are several conflicting and incomplete reports as to the exact scope of the occupational disease problems in the explosives industry during the period from 1914 to 1918, it is known that many cases of poisoning and fatalities seriously hampered efficiency and production and disturbed the morale of employees to the point that the man power problem was markedly aggravated.

At the beginning of the National Defense Program before the entry of the United States into World War II, the War Department determined that the mistakes in handling explosives and other toxic chemicals in World War I would not be repeated. Accordingly a cooperative arrangement was made by the Surgeon General's Office and the Ordnance Department with the United States Public Health Service to survey the industrial health problems of army-operated industrial installations until the Occupational Health Division of the Surgeon General's Office was built up sufficiently to carry on this work.

1. Nitrous Fumes; Trinitrotoluene, in Occupation and Health: An Encyclopaedia of Hygiene, Pathology and Social Welfare, Geneva, International Labour Office, 1930-1934, vol. 2.

In May 1941 the Industrial Hygiene Division of the Public Health Service began making industrial hygiene surveys of the old line ordnance arsenals, depots and proving grounds with teams of trained industrial physicians, dermatologists, engineers and chemists. These surveys, lasting from a few days to a few weeks, included an intensive medical study and evaluation of the plant medical facilities and services and the preventive medical program, an engineering study of the exposures to toxic chemicals and means for their control and other sanitary problems.

The medical survey included a study and an appraisal of:

1. The medical organization.

2. The personnel of the medical department.

3. Medical facilities, including the dispensary, laboratory, first aid stations, ambulance services and the plant and community hospitals.

4. Medical services, including preemployment physical examinations, the frequency and nature of periodic examinations, the special recheck examinations for those in toxic exposures, the placement of handicapped workers, a policy for suitably placing those with latent syphilis, reexaminations after an illness, rehabilitation, home visits, the treatment and reporting of occupational injuries and illnesses and nonoccupational illnesses, immunizations and nutritional supervision and education.

5. Sanitary supervision, including regular plant medical inspections of all operations, control of food and water sanitation, sanitation of lavoratories and bathhouses, control of daily bathing and powder uniforms and general supervision of the control of occupational health hazards in cooperation with the safety and engineering departments.

6. General benefits and records, including general welfare activities, provisions for health and accident insurance, sick benefit organizations, the proper maintenance of sickness and accident records and an analysis of sickness and accident rates for the past year with special emphasis on occupational diseases.

7. Cases of occupational illness and dermatitis, wherever found.

8. Cooperation of the medical department with physicians and health authorities in nearby communities.

9. Plans and procedures for handling large numbers of injured employees in the event of a disaster.

The engineering and chemical studies included:

1. A determination of potential health hazards.
   (*a*) The number and sex of workers by operation.
   (*b*) The nature of operations.
   (*c*) The materials to which exposed.
   (*d*) The control measures in existence.
   (*e*) The number and condition of sanitary facilities.

2. The collection of representative samples of atmospheric contaminants at all operations where potential health hazards were believed to exist.

3. The determination of temperature, humidity and air motion where extreme conditions existed in occupied areas.

4. The study of air flow in ventilating systems.

5. The study of the nature of operations at all sources of excessive atmospheric contamination.

6. The evaluation of exposures to stray radiations at all x-ray testing installations.

7. Investigations into the effectiveness of different control measures.

8. Chemical analyses of the atmospheric samples.

9. The making of recommendations to eliminate or control all health hazards uncovered during the survey.

10. The assisting of the engineering department personnel in the development of adequate control measures where needed.

11. Special consultation on proposed new processes or methods of operation to point out the potential dangers involved and to recommend control measures.

12. Special studies on new processes and operations to determine whether they created health hazards and if they did to make recommendations for their control.

13. Examination and approval of plans pertaining to the control of health hazards.

After these surveys, the observations and recommendations were forwarded through channels to the commanding officer and post surgeon in order to effect and maintain a high standard of industrial medical service and plant sanitation and thereby insure the greatest productivity with the least illness involving loss of time and the least inefficiency caused by occupational health hazards.

By the fall of 1941 surveys had been concluded in all major army-operated installations, and the Public Health Service began making surveys in the large, newly built government-owned explosive and ammunition plants operated by private contractors, while the work in the army-operated ordnance arsenals and depots along with the work in other Army Service Forces installations was carried on subsequently by the Army Industrial Hygiene Laboratory under the supervision of The Surgeon General's Office.

When the Safety and Security Division of the Office of the Chief of Ordnance was activated in Chicago in July 1942, it was desired to implement still further the industrial hygiene program in all ordnance establishments manufacturing, processing, loading or storing explosives.

By an arrangement between the Occupational Health Division of The Surgeon General's Office and the Industrial Hygiene Division of the Public Health Service, three members of the medical and engineering personnel of these two divisions were assigned to the Safety and Security Division to constitute the Industrial Hygiene Branch and to strengthen and coordinate the program. Their functions were as follows:

1. To conduct industrial hygiene surveys and special studies at assigned establishments utilizing assistance of trained personnel from the United States Public Health Service, the Army Industrial Hygiene Laboratory and state and city industrial hygiene divisions; to review all formal recommendations resulting from such surveys and to release them to assigned establishments in accordance with established policy, and to follow up to insure compliance and maintenance of highest industrial hygiene standards at assigned establishments.

2. To evaluate industrial hygiene information recorded in all inspection reports from the collateral group of ordnance safety inspectors and to approve all resulting recommendations before their release.

3. To disseminate to assigned establishments industrial hygiene information circulars concerning codes of medical services, engineering control of health hazards and environmental sanitation collected from research projects and other appropriate sources.

4. To serve as clearing house for information on all industrial hygiene aspects of new products manufactured, processed or developed in assigned establishments.

5. To collect and analyze data and to make reports pertaining to the prevalence and trend of occupational diseases in assigned establishments.

6. To initiate toxicologic research on new products by cooperating agencies.

7. To maintain liaison for the Ordnance Department with The Surgeon General's Office, Army Industrial Hygiene Laboratory, Surgeons of the Service Commands, the United States Public Health Service and other federal, state and city agencies on all matters pertaining to industrial hygiene.

It was agreed that the field surveys should be divided under the supervision of the Safety and Security Division: (1) The Army Industrial Hygiene Laboratory was to make surveys in the army-operated arsenals, depots and proving grounds; (2) the Public Health Service was to survey the new contractor-operated government plants, and (3) the state industrial hygiene divisions would serve the private explosive plants assigned to this headquarters.

Under this plan surveys were requested and made about every six months in the plants presenting more serious health hazards and about once yearly in the other plants.

The Ordnance Industrial Hygiene Branch made the necessary follow-up visits to insure compliance with all recommendations. Special studies were also made by this office in all plants from time to time as new problems developed, and technical consulting services were made available on all health problems.

On request the Industrial Hygiene Research Laboratory of the National Institute of Health, United States Public Health Service, conducted extensive but practical laboratory and field research on the toxicology of explosives such as trinitrotoluene, pentaerythritoltetranitrate (PETN) and RDX, and certain new aromatic gasoline additives and provided bulletins on these subjects.[2] This group also provided the plants with an extensive review of the literature on the toxicity and potential dangers of the aromatic amino and nitro compounds, which included most explosives.[3]

The Dermatoses Investigations Section of the Industrial Hygiene Division, United States Public Health Service, provided valuable consultation on occupational dermatoses and made field investigations concerning control of tetryl dermatitis and the possible value of protective ointments.[4]

The Water and Sanitation Investigations Station, United States Public Health Service, on request, made several field studies on the question of possibly excessive stream pollution from the by-products of explosives manufacturing and loading plants, and their reports were distributed to all plants concerned.[5]

This branch of the Safety and Security Division prepared and distributed over sixty industrial hygiene information circulars to ordnance plants to meet specific problems. These concerned such diversified sub-

2. von Oettingen, W. F., and others: Experimental Studies on the Toxicity and Potenial Dangers of Trinitrotoluene (TNT), Public Health Bulletin no. 285, Federal Security Agency, United States Public Health Service, 1944. von Oettingen, W. F., and others: Toxicity and Potential Dangers of Penta-Erythritol-Tetranitrate (PETN), Public Health Bulletin no. 282, Federal Security Agency, United States Public Health Service, 1944. Sievers, R. F.; Lawton, A. H.; Skoog, F.; Stump, R. L.; Monaco, A. R.; Neal, P. A., and von Oettingen, W. F.: A Medical Study of the Effect of TNT on Workers in a Bomb and Shell Loading Plant: Report of Fatal Case of Aplastic Anemia, Public Health Bulletin no. 291, Federal Security Agency, United States Public Health Service, 1945.

3. von Oettingen, W. F.: The Aromatic Amino and Nitro Compounds: Their Toxicity and Potential Dangers, Public Health Bulletin no. 271, Federal Security Agency, United States Public Health Service, 1941.

4. Schwartz, L.: Dermatitis from Explosives, J. A. M. A. **125**:186 (May 20) 1944.

5. Smith, R. S., and Walker, W. W.: Surveys of Liquid Wastes from Munitions Manufacturing, Reprint no. 2508 from the Public Health Reports, Federal Security Agency, United States Public Health Service, 1943.

jects as the prevention of trinitrotoluene poisoning, control of tetryl dermatitis, special indicator soaps for trinitrotoluene, tetryl and mercury fulminate, local exhaust ventilating systems for explosive dusts, the diagnosis of syphilis, health hazards in maintenance shops, nutrition in industry, nitrogen oxides poisoning, the early diagnosis of tuberculosis, the safe handling of milk, the use of handicapped workers, the cooperation of plant and private physicians, influenza, control of absence because of sickness, dust control, respirators, the disinfection of shoes, trinitrotoluene waste disposal, medical certificates and the treatment of toxic jaundice and epidemic keratoconjunctivitis. Several circulars were prepared on hazards from solvents and means for their control. In addition, an industrial safety and hygiene manual which contained minimum standard policies and procedures was prepared and distributed.[6]

Several meetings were organized by the Safety and Security Division with the medical directors of the various plants for conferring and for bringing together all recent information on troublesome subjects such as nitrogen oxides poisoning and trinitrotoluene poisoning. Representatives of The Surgeon General's Office, the United States Public Health Service and the United States Bureau of Mines and other national authorities participated in these meetings. The transactions of these meetings, which contained recommended policies for controlling occupational diseases, were distributed to all plants.

Classes were held repeatedly on industrial hygiene subjects for the safety auditors in the Inspection Branch of the Safety and Security Division. As these inspectors made quarterly visits to all plants, they provided this office with a valuable source of information concerning new or changing health hazards. Numerous recommendations regarding sanitation and the control of health hazards resulted from their inspections on matters known to be within their competence, as well as on the various subjects included in their safety and security audits.

Close liaison was maintained by this office with the Ordnance Department plant-operating echelons, The Surgeon General's Office, the Public Health Service and the state health departments, a procedure which did much to increase the effectiveness of the over-all program. Recommendations for the correction of health hazards were always placed in operational channels which directed plant compliance, as far as possible.

As pointed out in section IV B, considerable resistance was encountered at first from loading plant operators in effectively controlling the more dusty trinitrotoluene operations, such as screening, by local

6. Industrial Safety Organization and Principles, Safety Bulletin no. 103, Army Service Forces, Ordnance Department, Safety and Security Division, December 1944; Industrial Health and Hygiene Organization and Regulations for Installations Assigned to the Chief of Ordnance for Production Security Inspection, Safety Bulletin no. 104, ibid., 1944.

exhaust ventilation because of the explosive hazard associated with ductwork and fans. This apprehension was gradually overcome in all quarters after individual wet collector systems were developed that proved to be reasonably safe and efficient.[7]

Proper control of bathing and changing of clothes for trinitrotoluene workers was a troublesome problem in many plants, although the old line, experienced chemical companies that started operations with a rigid program had little difficulty. Accordingly, a continuous campaign of persuading supervisory personnel and employees as to reasons and need for a vigorous bathing program had to be carried out, with slow but generally satisfactory results. The high labor turnover in these plants aggravated this and related problems.

The plant medical facilities and services were uniformly good and were improved for the most part as the program was developed. Close medical supervision of workers in toxic exposures resulted in the detection of many early cases of occupational diseases and the transfer of the workers before the diseases could become serious and pointed out the necessity for further engineering control.[8]

The results of this comprehensive and closely integrated health and hygiene program in ordnance explosives plants is shown in succeeding sections. It is believed that this is the first large scale demonstration of what can be accomplished in a large industry offering many serious health hazards by a vigorous medical and engineering program. The amazingly good safety record achieved by the Safety and Security Division in ordnance plants has been described elsewhere and closely parallels the health record.[9] It is a matter of pride to the Ordnance Department that for the fiscal year 1944-1945 during peak production, the frequency rate of accidents involving lost time in all government-owned explosive plants was among the lowest for all American industries. This rate includes, of course, occupational diseases resulting in the loss of time.

In the Annual Report of the Chief of Ordnance for the fiscal year ending June 30, 1945, the following statements appear:

> Although the accident rate for Government-owned Ordnance installations had touched the remarkable low of 5.6 per million man-hours worked in July, 1944, the rate improved constantly, and by May, 1945, had dropped to 4 per million man-hours, a 28.6 percent reduction. The combined rate for Government-owned and

7. Seifert, H. E.; Cralley, L. J., and Clayton, G. D.: Industrial Health Hazards and Their Control in a Bomb Loading Plant, Indust. Med. **14**:75 (Jan.) 1945.

8. McConnell, W. J.; Flinn, R. H.; Hussey, R., and Brandt, A. D.: Recent Data on Health Hazards in War Industries and Related Papers, in Proceedings of Eighth Annual Meeting of Industrial Hygiene Foundation of America, Inc. Pittsburgh, Nov. 10-11, 1943. Flinn, R. H.: Absenteeism Versus Ordnance Production: The Physician's Role, Indust. Med. **14**:12 (Jan.) 1945.

9. Shot, Shell and Bombs, Fortune **32**:131 (Sept.) 1945.

privately-operated Ordnance establishments made an even greater decline—32.8 percent below the July, 1944, rate. This not only represents an all-time low for the Ordnance Department, but is also the lowest for all American manufacturing industries . . .

During World War I, the facilities [in the United States] which produced 40 percent of the military explosives used by the Allies reported a ratio of 230 fatalities per billion pounds of explosives manufactured. In this war, the Government-owned, contractor-operated plants producing 95 percent of all (U. S. manufactured) military explosives have suffered only five fatalities per billion pounds [four hundred and fifty million Kg.] of explosives produced.

II. ORDNANCE EXPLOSIVES ESTABLISHMENTS AND THEIR REPORTS

A. DESCRIPTION OF ORDNANCE EXPLOSIVES ESTABLISHMENTS

The government-owned ordnance plants making, processing, handling or storing explosives assigned to this headquarters for production security inspections fall into nine distinct types of industries and are so treated throughout this report. From the viewpoint of industrial hygiene and from many other points of view any one industry cannot be fairly compared with another because of the wide divergence of functions and operations. Six of the industries include the war-built explosives manufacturing or loading plants operated by prime contractors from private industry. The other three groups include the army-operated arsenals, depots and proving grounds. As more than 95 per cent of all explosives and large caliber ammunition made in the United States during World War II was produced and loaded in the new contractor-operated facilities, as well as 90 per cent of the small arms ammunition, these naturally were of paramount importance in the industrial hygiene control program.

Bomb, Shell, and Fuse Loading Plants.—From seventeen to twenty contractor-operated plants were engaged in loading high explosives such as trinitrotoluene (TNT), amatol (a mixture of ammonium nitrate and trinitrotoluene), pentolite, tetryl, and trinitrotoluene and RDX compounds into bombs, shells, mines, grenades and rockets. These plants usually had additional lines where fuses were loaded with detonating agents such as lead azide and mercury fulminate and with booster charges such as tetryl. Where complete rounds of ammunition were assembled smokeless powder was used extensively, and double base powder containing nitroglycerine was used commonly for mortar shell increments and for propelling charges for rockets. Black powder and percussion elements containing sensitive explosives were used on lines manufacturing artillery primers. This industrial group, like all others, had sufficient maintenance shops to care for all equipment, buildings and vehicles.

The number of employees in these loading plants actually engaged in operations varied between 65,000 and 91,000, the average figure being

78,000 for the period of this report. The annual labor turnover was close to 100 per cent.

Because of the nature of loading operations, more employees were exposed by the open handling of dusty or fuming compounds, and the toxic exposures were normally greater than in the other industrial groups.[10] Consequently more attention and control measures for toxic exposures were required by loading plants than by any other groups.

In addition many of these loading plants were operated for the Ordnance Department by concerns that had had but little previous experience in handling toxic chemicals. These included companies previously engaged in heavy construction work, consulting engineering and the manufacture of soap, rubber products, typewriters, hospital supplies, paints, radios, cereal foods and roofing and building materials. Only one of these prime contractors had peacetime experience in handling military explosives.

These two factors placed these operating contractors at an initial disadvantage from a health and safety viewpoint, which makes their occupational disease and accident record all the more remarkable.

High Explosives Manufacturing Works.—From eleven to fifteen contractor-operated works were engaged in manufacturing trinitrotoluene, dinitrotoluene (DNT), tetryl, pentaerythritoltetranitrate (PETN), pentolite, RDX and lead azide. Trinitrotoluene was the product common to all these plants. In addition all these plants manufactured nitric acid from anhydrous ammonia for their own use, and many produced sulfuric acid from sulfur. Three of these works also produced large quantities of single base or double base smokeless powder and so might be classified as powder plants. They are here considered as trinitrotoluene plants, however, because that was the principal health hazard involved.

As many of these industrial chemical processes by nature were enclosed and relatively few employees were needed for production operations, the problem of health hazards was much less serious than in the loading plants.

The average number of employees engaged in production was 36,400 and ranged from 25,000 to 45,000. The annual labor turnover was 65 per cent.

Unlike the loading plants, most of these explosives works were operated by corporations with long experience in making and handling explosives. The remaining contractors had had considerable experience

10. Brandt, A. D.: Industrial Hygiene Engineering in the Army Explosives Manufacturing and Processing Industry, Indust. Med. **13**:629 (Aug.) 1944. Seifert, Cralley and Clayton.[7]

in the chemical field and were well prepared to recognize the potential dangers of handling toxic explosives.

Smokeless Powder Works.—From four to five contractor-operated works, not counting those mentioned previously, were engaged in the manufacture of smokeless powder, and employed an average of 19,400 workers in production, the numbers ranging from 14,000 to 29,000. The annual labor turnover was 83 per cent.

Acids, nitrocellulose, diphenylamine and nitroglycerine were manufactured as ingredients for smokeless powder, and one of the plants employed relatively few workers in the manufacture of trinitrotoluene and tetryl, and another in the manufacture of dimethylaniline. Exposures to ether and alcohol and to dinitrotoluene were the principal health hazards in the manufacture of single base powder, while exposure to nitroglycerine was the chief hazard with double base powder. The oxides of nitrogen offered a potentially serious exposure in the manufacture of nitric acid and in nitrating cellulose.

The smokeless powder works were all operated by old line powder companies which were well acquainted with the health hazards involved.

Miscellaneous Chemical Works.—From nine to ten contractor-operated works were engaged in the manufacture of basic chemicals for explosives and employed an average of 4,400 workers, the number ranging from 3,500 to 5,700, with an annual labor turnover of 25 per cent. Six of these plants manufactured anhydrous ammonia, and the others produced ammonium picrate, ammonium nitrate, ammonia, trinitrophenol, hexamethylenetetramine, formaldehyde and methanol.

These works were operated by chemical companies which had considerable experience with this type of operations. The processes were largely enclosed and required relatively few workers.

Small Arms Ammunition Plants.—From four to twelve contractor-operated plants were engaged in the manufacture of caliber .30, .45 and .50 ammunition, the number of plants being drastically reduced during the last year of the war. An average of 85,000 employees was engaged in production operations, the number varying between 31,000 and 167,000. These plants made about 90 per cent of the small arms ammunition produced in the United States during World War II. The annual labor turnover was approximately 30 per cent, which is lower than that for most other industries reported here because the plants were located in or near large centers of population where housing and transportation were not the problems they were for the plants in rural areas.

Relatively few employees were exposed to toxic chemicals in this industry, and these were largely in segregated bays or workrooms where tracer, igniter or incendiary powders were pressed into hollow bullet

cores. Many workers attended case and bullet draw machines which offered exposures to cutting oils and coolants. Also, there were sizeable numbers of workers engaged in soldering operations and in occupations involving solvents. The exposures to lead in the manufacture of bullets and in proof firing were generally well controlled, and also those in mercury-crack testing.

The peacetime background of the contractors operating these plants was mostly in the same industry, although several of the plants were operated by rubber companies, and one by an automobile manufacturer.

Bag Loading Plants.—From two to four plants employing from 4,600 to 13,700 workers in production, with an average of 9,100, were engaged in making textile bags and in loading the bags with specified amounts of smokeless powder for fixed and semifixed artillery ammunition. The chief exposure was to black powder and to finished smokeless powder which contained small amounts of dinitrotoluene. There were also the usual maintenance shops which offered the ordinary exposures to solvents and gases. No serious health hazard was encountered in these plants.

The bag loading plants were operated by a powder company, a rubber company, and a producer of soft beverages. The annual labor turnover was 112 per cent.

Arsenals.—The old line Army-operated arsenals handling explosives were essentially peacetime developers and producers of military ammunition and firearms, and they also renovated or modified sizeable quantities of obsolete or defective ammunition and equipment. A few had operated relatively small pilot lines for the experimental manufacture of explosives and for shell loading. These loading operations, however, were largely converted to other activities except for the loading of bursters for the Chemical Warfare Service when full scale production was achieved in the new ammunition plants.

During this war an average of 53,000 employees was engaged in production in the ten to twelve arsenals handling explosives, the number ranging from 40,200 to 64,700. Data as to the annual rate of labor turnover are not available, but it is known to have been rather high. Activities included the manufacture of tetryl, smokeless powder, pyrotechnics, small arms ammunition, artillery cartridge cases, artillery projectiles, time fuses, fire control instruments, small arms and target matériel. In addition a few of the arsenals were engaged in the loading of chemical and high explosive artillery and mortar shells. Several arsenals were engaged chiefly in the storage, maintenance and issuance of ordnance matériel, while several others had extensive facilities for repairing, modifying and renovating equipment such as tanks, artillery and optical equipment. Arsenals not handling explosives are not included in this report.

So far as the handling of explosives is concerned, the activities of the manufacturing arsenals provided a limited cross section of activities in the new ammunition plants, and the number and degree of toxic exposures varied considerably from one arsenal to another.

Depots.—From thirteen to eighteen Ordnance depots were engaged in the receiving, storing and issuance of ammunition and explosives. An average of 24,800 employees was engaged in depot operations, the number ranging from 21,600 to 29,400. The annual labor turnover is not known but is believed to have been fairly high.

In general, the old line depots only received, stored and issued explosives and ammunition and performed any necessary renovation and modification of defective or obsolete ammunition. Limited loading of trinitrotoluene was done for a few report periods in two of these depots, but the total number of exposed workers did not exceed 300. One of the depots that continuously loaded a number of explosives has been included with the manufacturing arsenals.

The newly built depots received, stored and issued ordnance general supplies in addition to ammunition and explosives. There were also extensive tank repair and modification operations, and in several of the depots there were sizeable numbers of employees engaged in the repair and modification of artillery and optical equipment.

It is evident that occupational exposures to toxic explosives was not a major problem in the depots. On the other hand, the extensive repair and modifying operations on ordnance matériel mean that many workers were exposed to potentially hazardous concentrations of solvents, paints, cutting oils and related chemicals.

Proving Grounds.—Six proving grounds including one small ballistics laboratory employed an average of 7,200 workers in operations, the number varying from 4,600 to 13,700. The activities included the proofing of developed types of ammunition, research on new types of ammunition, modification of artillery and the proof testing and acceptance testing of all types of weapons, including bombs and mines.

While only 20 to 25 workers were regularly exposed to trinitrotoluene, there were many and varied exposures resulting from proof firing of ammunition, including exposures to carbon monoxide, lead, nitroglycerine and nitrogen oxides, and resulting from the cleaning, degreasing and painting of ordnance matériel, including exposures to solvents, paints and cutting oils.

B. DESCRIPTION OF OCCUPATIONAL DISEASE REPORTS AND METHOD OF ANALYSIS

Shortly after the Industrial Hygiene Branch of this headquarters began functioning a plan was devised for obtaining complete occupational disease reports on a quarterly basis from all government-owned explosives

plants from the beginning of World War II production. The safety and Security Division was already receiving accident reports from these plants which presumably included fatalities and illness involving loss of time resulting from occupational diseases, but these were somewhat difficult to separate from the accidental injuries. Also, the reports of accidental injuries did not uniformly include the cases of mild non-disabling occupational disease or the medical transfers of persons away from toxic exposures because of early signs and symptoms of occupational diseases. In some instances the plant safety departments which prepared the accident statistics did not have ready access to all the medical data desired for complete reporting of occupational diseases.

Accordingly a form was developed by this Branch for obtaining complete occupational disease reports from the medical department of each plant which would be processed and checked by the plant's commanding officer and his staff representing the Ordnance Department. This form was sent with a letter of transmittal to the commanding officer of each plant requesting that each medical department complete the form, supplying all data from the beginning of World War II production but not prior to June 1, 1941, in the case of plants that had been operating during peacetime. In most plants this would mean from the beginning of war production, and in the old line arsenals it would approximate the beginning of expanded national defense activities.

Each report included the average number of employees for the period actually engaged in production or operations, the average number actually exposed to trinitrotoluene and the number of cases of general or systemic poisoning and dermatitis resulting from trinitrotoluene, tetryl, nitrogen oxides, solvents, cutting oil and other specified exposures. In these cases the poisoning and dermatitis were further classified as fatal, causing loss of time or disablement, mild or nondisabling, and those resulting in medical transfers. The persons given medical transfers included those workers who presented some signs or symptoms suggesting an excessive exposure to toxic substances and who were changed to another job on recommendation of the medical department as a protective measure. The patients given medical transfers may or may not have also been included in the disabled or mildly affected group, but are of importance in themselves because of the production factors and economics involved and as an additional index of the adequacy of other medical and engineering control measures.

The reports for the first period (through February 1943) covered production periods ranging all the way from one to twenty-one months, the weighted average being 8.6 months, taking into consideration the varying numbers of employees in each plant. In fact, some plants later reporting were not yet in active production during the first period.

From this point on the reports were sent out for completion at quarterly intervals except in one period, the fourth, when administrative difficulties delayed the reporting procedure for two months, which resulted in one five month period. The number of plants reporting varied slightly from time to time as plants were inactivated or new plants were opened, which resulted in changing the list of plants for which this headquarters was responsible. Because of the primary mission of this headquarters, however, this list at all times included all government-owned ordnance plants handling explosives but not other ordnance plants handling only "inert" or nonexplosive matériel.

So far as possible, the method of reporting was kept standardized from period to period with two minor exceptions. In view of the fact that data for the first period were obtained after the close of the period, it was realized that accurate figures on medical transfers were not available, and these figures were not obtained. Accordingly, the following tables and graphs in this report do not show medical transfers for the first report period. Also, from the beginning it was decided to base case rates on the actual numbers of potentially exposed employees in operations or production, which would exclude sizeable numbers of non-exposed administrative employees, guards, firemen and the like; hence total numbers of employees were not obtained until later periods.

In section IV of this report, case rates on trinitrotoluene poisoning, the most important hazard, are based on the actual number of employees exposed to trinitrotoluene, a procedure which gives the true relationship of those affected to those exposed. Because it was not possible to obtain the exact figures as to the number of employees exposed to all the other chemical compounds in these plants, occupational disease rates in other sections are based on the total number of employees in production, that is, on the total number of employees with potential exposures, but not on the employees who avoided exposure by reason of working in such areas as the administration buildings. The employees engaged in production operations varied from 59 to 71.5 per cent of the total number of employees in the various industrial groups.

Because of the long first period and the five months in the fourth period, it was not possible to calculate case rates for occupational disease as per cent, or per thousand, or per ten thousand. Likewise, the accepted practice of safety men in reporting so many disabling injuries per million man hours of work means little to physicians and others in the industrial hygiene field, as this concept is difficult to visualize by those not engaged in accident reporting. Accordingly the occupational disease rates throughout this report are shown per thousand man years of production, or, in the case of trinitrotoluene poisoning, per thousand man years of actual exposure, taking into due consideration, of course, the length of each report period covered. This figure is equivalent to the potential

exposure of 1,000 men for one year, or 4,000 men for one quarterly period, and equalizes the irregularity of duration of the report periods. Rates for 1,000 man years of production can be easily converted to those for one million hours of work by dividing the former figures by 2.4 —1,000 man years being roughly equivalent to 2.4 million man hours. Wherever cases involving loss of time are discussed in the text, the rates are shown by both methods for the convenience of safety personnel.

The disabilities involving loss of time are the serious ones from the medical viewpoint and indicate that those employees were sufficiently ill to lose one daily shift or more from work. Data are not available as to the average duration of disabilities resulting in loss of time, but it is known that they ranged all the way from one day to a month or longer. From limited data it is thought that a median figure might well be between three and six days.

The cases in which the disease was nondisabling or mild were usually of little medical significance. With cases of systemic poisoning, they often consisted of only minor complaints at the first aid station or of slight changes in laboratory findings during periodic examinations. The cases of mild dermatitis in this group readily cleared up under treatment and caused no real disability. Many occupational disease reports, especially those from other countries, would not include statistics on this type of cases, but they are presented here to show the potential danger involved and the scope of the control problem.

The patients given medical transfers were drawn largely from the two previous groups and consisted of those employees sufficiently affected by toxic exposures to make a change of work advisable. In most plants the medical department gave the workers the benefit of the doubt when the cases were not definite and removed them temporarily for their protection. Occasionally workers were found to be hypersensitive to certain exposures and were transferred permanently. The proportion of permanent to temporary transfers is not known.

The medical transfers are of particular importance from the viewpoint of efficient production as the loss of trained personnel, even temporarily, from any job necessarily retards production. The pronounced decrease shown subsequently in the transfer rates during the period of this report undoubtedly more than offsets any costs incident to measures for better industrial hygiene control. Also, all these cases were potential cases of serious disability or even death had the toxic exposures been continued.

In studying the tabulated data presented here, it will be noted that in the "total" column the total numbers of cases in the different categories are presented. The total populations involved, however, and the total rates for all report periods are weighted averages taking into account the differences in the duration of the report periods. On the graphs, weighted averages for all periods are shown which will not

correspond exactly with the total rates shown in the tables. The reason for this is that the graphs were prepared at the close of the eighth report period, and the points for the ninth period were entered later. The differences for the most part are insignificant, as may be observed by comparing these graphs with the tables.

In this report, when different types of plants are spoken of, "GOCO" indicates the new government-owned and contractor-operated plants and works, while "GOGO" denotes the government-owned and army-operated arsenals, depots and proving grounds.

In section III all occupational diseases are shown for all plants for nine report periods covering an average of 34.6 months of operations. In section IV A trinitrotoluene poisoning is discussed for the three industrial groups where it was a problem, the trinitrotoluene manufacturing works, the loading plants and the arsenals. In section V tetryl dermatitis and other effects are discussed for the same three industries. In section VI nitrogen oxides poisoning is discussed for the three manufacturing groups, the explosives manufacturing works, the powder works and the miscellaneous chemical works. In section VII all other occupational diseases are shown and discussed for each industrial group. Since this report was completed the data for the last three months of the war, the tenth period, have been received and analyzed and are shown as a supplemental report in section VIII.

III. OVER-ALL OCCUPATIONAL DISEASE EXPERIENCE IN ALL ASSIGNED GOVERNMENT-OWNED ESTABLISHMENTS [11]

Despite the lack of comparability of the nine industrial groups manufacturing, loading, storing and testing explosives, it is of general interest to note the total occupational disease experience and the trend with increasing experience in present war production.

More than 317,000 employees, on the average, were engaged in production operations, and the report periods cover an average of 34.6 months of operations beginning about mid-June 1942 and extending through April 1945. This amounts to about 915,000 man years of potential exposure to the various toxic materials handled in these plants.

Table 1 shows the number and percentage of production employees sufficiently exposed to several toxic compounds to require periodic examinations in three groups of manufacturing works and the loading plants as of December 1943. Similar data are not available for the remaining industrial groups, but sections IV, V and VI show that trinitrotoluene, tetryl and the oxides of nitrogen are the most significant

11. The occupational disease data shown in this report were tabulated and analyzed by Lieut. Col. Robert H. Flinn. Miss Clara E. Lanzillo assisted in the compilation of data.

TABLE 1.—*Number and Percentage of Production Employees in GOCO Ordnance Explosives Plants Having an Exposure to Occupational Disease as of December 1943*

Industry	Number in Production	Number Exposed										
		TNT	DNT	Tetryl	N.G.* DMA† DPA‡	NOx	Ether	Solvents	Oils	Mercury	Lead	Other
TNT manufacturing works	88,800	6,905	715	586	1,801	1,659	1,644	258	68	65	85	1,981
Smokeless powder works	19,200	86	1,803	88	1,856	682	1,928	2,006	56	182	82	275
Loading plants	71,600	14,964	221	5,505	50	8	150	694	80	985	1,774	1,757
Miscellaneous chemical works	2,800	0	0	0	0	605	0	0	7	25	0	1,235
Total	181,900											
		Percentage of Employees Exposed										
TNT manufacturing works	88,800	18.0	1.9	1.4	4.7	4.3	4.3	0.7	0.2	0.2	0.2	5.3
Smokeless powder works	19,200	0.4	9.7	0.4	9.7	3.3	10.0	10.4	0.3	0.9	0.3	1.4
Loading plants	71,600	20.9	0.3	7.7	0.1	0	0.2	1.0	0.1	1.4	2.5	2.5
Miscellaneous chemical works	2,800	0	0	0	0	16.0	0	0	0.2	0.7	0	33.4

* N.G. = Nitroglycerine. † DMA = Dimethylaniline. ‡ DPA = Diphenylamine.

TABLE 2.—*Deaths, Illness, Dermatitis and Medical Transfers from All Occupational Health Hazards in All Assigned Government-Owned Ordnance Plants*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I	II	III	IV	V	VI	VII	VIII	IX		I	II	III	IV	V	VI	VII	VIII	IX	
	Through Feb. 43*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total	Through Feb. 43*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total Experience
Number of Employees in Operations:																				
Bomb and shell loading plants	91,800	87,400	87,000	71,000	66,200	69,700	67,100	70,900	66,600	73,000										
TNT manufacturing works	45,500	45,200	42,600	34,200	26,100	25,500	27,500	26,100	26,100	26,400										
Powder works	16,900	18,100	19,100	19,200	14,100	18,800	23,200	25,100	27,200	19,400										
Arsenals	54,400	57,200	51,200	40,200	40,200	54,200	54,700	56,200	54,000	53,000										
Miscellaneous chemical works	4,900	5,700	5,500	3,800	3,900	4,400	4,200	3,700	3,500	4,400										
Small arms ammunition	96,600	165,800	155,800	118,900	45,900	31,500	34,400	26,500	42,200	85,000										
Ordnance depots	21,600	25,500	22,000	26,700	22,200	24,200	22,400	22,600	23,000	24,800										
Proving grounds	9,700	9,700	5,000	5,500	6,600	5,900	5,600	5,000	5,200	7,200										
Bag loading plants	5,700	5,700	4,600	7,000	7,200	9,000	10,600	13,700	13,400	9,100										
Total	348,900	424,100	399,700	331,200	223,000	253,200	267,400	260,200	262,200	317,200										
Number of months of operations	3.6	3	3	5	3	3	3	3	3	34.6										
Number of 1,000 man years' operations	251	100	100	133	66	64	67	65	66	915										
Number of deaths	7	2	2	10	1	0	2	2	0	27	0.03	0.02	0.02	0.07	0.02	0.00	0.03	0.03	0.00	0.03
Number of Cases Involving Loss of Time:																				
Systemic poisoning	146	138	131	81	19	23	23	25	25	723	1.0	1.3	1.3	0.6	0.3	0.4	0.3	0.4	0.5	0.5
Dermatitis	573	270	96	199	79	70	66	56	53	1,466	2.3	2.5	1.0	1.4	1.4	1.1	1.0	0.9	1.2	1.6
Total	719	408	227	280	98	93	89	81	117	2,211	3.3	3.8	2.3	2.0	1.7	1.5	1.3	1.3†	1.8	2.4
Number of Cases of Mild Disease:																				
Systemic effects	6,066	2,381	2,900	3,606	1,606	1,078	1,226	856	1,226	22,351	24	27	30	26	26	17	18	13	19	24
Dermatitis	25,151	9,680	8,906	10,304	3,850	4,258	3,770	3,042	2,502	70,998	100	91	88	75	66	66	56	47	39	78
Total	31,217	12,511	12,206	13,910	5,255	5,126	5,006	3,896	3,818	93,349	124	118	122	101	92	85	75	60	58	102
Number of Medical Transfers:																				
Systemic effects	‡	2,001	2,526	1,670	456	517	429	324	909	9,021	‡	19	25	13	8	8	6	8	14	14‡
Dermatitis	‡	1,792	1,884	3,146	1,236	1,287	1,204	783	608	11,940	‡	17	19	23	21	20	18	12	9	15‡
Total	‡	3,793	4,410	4,816	1,681	1,804	1,633	1,107	1,517	20,961	‡	36	44	36	29	28	24	20	23	33‡

* From beginning of report period.
† In this and in subsequent tables, when the total rate is not the exact sum of the rates for systemic effects and for dermatitis, the discrepancy is due to failure to include sufficient decimal places.
‡ Transfers not reported for first period.

exposures, and section VII indicates the occupational disease problem from other exposures in each industrial group.

Fatalities Due to Occupational Disease.—Table 2 shows 27 fatalities due to occupational disease in 915,000 man years of operations resulting in a case rate of 0.03 per thousand man years, or 3 deaths per hundred thousand employees per year. Nine deaths occurred in approximately the first year, 14 in the second year, and only 4 in the last year. Two of the last four quarterly report periods were free from fatalities.

Twenty-one of these deaths were attributed to exposure to trinitrotoluene,[12] 18 in the loading plants, 2 in an arsenal and 1 in a trinitrotoluene manufacturing works. Three deaths were attributed to exposure to the oxides of nitrogen, 2 in the manufacture of smokeless powder and 1 in manufacture of trinitrotoluene. Two deaths resulted from exposure to carbon tetrachloride, 1 in a trinitrotoluene works and 1 in a loading plant where this solvent was inadvertently used for a mine-cleaning operation. An overwhelming acute exposure to the vapor of ether and alcohol in powder manufacture accounted for the remaining fatality, and it is questionable whether this fatality might not more properly be classified as an accidental injury rather than as occupational disease.

Cases Involving Loss of Time.—As shown in table 2, there were reported 2,211 cases in which occupational disease and dermatitis were sufficiently severe to cause loss of time from work, resulting in a rate of 2.4 cases per thousand man years of operations, corresponding to a standard accident frequency rate of 1.0 per million man hours of work. Systemic disease accounted for 723 cases and dermatitis for 1,488 cases, resulting in rates of 0.8 and 1.6 per thousand man years, respectively. Subsequent sections show that exposure to trinitrotoluene and tetryl accounts for a great majority of these cases.

As shown in chart 1, the peak rate for cases involving loss of time, 3.8, was reached in the second period, and the rate declined rapidly to an average of less than 1.5 in the last four periods. During this time the rates for cases of systemic poisoning declined from a high of 1.3 to a low of 0.3, and the dermatitis rates dropped from a peak of 2.5 to a low of 0.9. A slight rise is noted in the ninth period caused by an excess of 10 cases of systemic poisoning and 26 cases of dermatitis over the eighth period.

Cases of Mild Dermatitis and Other Effects.—As might be expected, considering the numerous toxic exposures and the large number of

12. Case histories are being presented in a separate paper (McConnell, W. J., and Flinn, R. H.: Summary of Twenty-Two Trinitrotoluene Fatalities, J. Indust. Hyg. & Toxicol. **28**:76 [May] 1946). One death reported in a loading plant brings to 22 the total number of deaths due to trinitrotoluene in Ordance plants during World War II. (See report for tenth period.)

workers involved over three years of production, the total number of cases in which the patients showed some signs or symptoms suggesting occupational diseases was very sizeable, being over 93,000. This gives an over-all rate of 102 cases per thousand man years, 24 cases involving mild systemic effects and 78 cases of mild dermatitis. As stated previously, the great bulk of these cases were of little or no medical significance, except that if the patients' exposure had been continued without medical or engineering control, in many of the cases the conditions would probably have progressed and become disabilities involving loss of time and would have resulted in medical transfers or even fatalities. As it was, in most of these cases the patients had merely minor complaints which were attended to at the first aid stations, or slight changes were found during the routine periodic examinations. There were sufficient symptoms to justify a transfer to another job in not more than one third of these cases, as is seen by comparing the total rates for cases of mild disease and cases resulting in medical transfers. As shown in chart 1, there was a considerable decline in the incidence of cases of mild disease from an initial high of 124 to a low of 58 cases per thousand man years of production operations, a reduction of 53 per cent over three years of operations. The rates for dermatitis dropped from 100 to 39, and the rates for systemic poisoning dropped from a high of 39 in the third period to a low of 13 in the eighth period, differences of 61 per cent and 67 per cent respectively.

While the cases of mild dermatitis outnumber the cases of systemic effects about three to one, the latter are considered more significant because of the potentiality of serious damage to the liver or blood-forming organs if the disease in these cases had been allowed to progress.

Cases Resulting in Medical Transfers.—There was a total of 20,961 employees transferred from toxic exposures to jobs offering no significant exposure because of sufficient symptoms to suggest the possibility of danger from further absorption of toxic compounds. This resulted in an over-all case rate of 32 transfers per thousand man years of operations (transfers were not reported for the first period), a rate of 14 for systemic effects and 18 for dermatitis. Most of these intraplant transfers were temporary and for a few weeks' duration. The relatively few cases of serious systemic effects and the cases of more hypersensitive dermatitis usually resulted in permanent transfers.

This system of moving affected employees from toxic exposures is considered good preventive medicine until the toxic exposures can be controlled by standard engineering practices. On the other hand, an excessive number of transfers is an expensive and inefficient substitute for adequate control of personal hygiene and the working environment,

and any progress made in reducing the need for transfers means a real increase in production efficiency and reduction in costs.

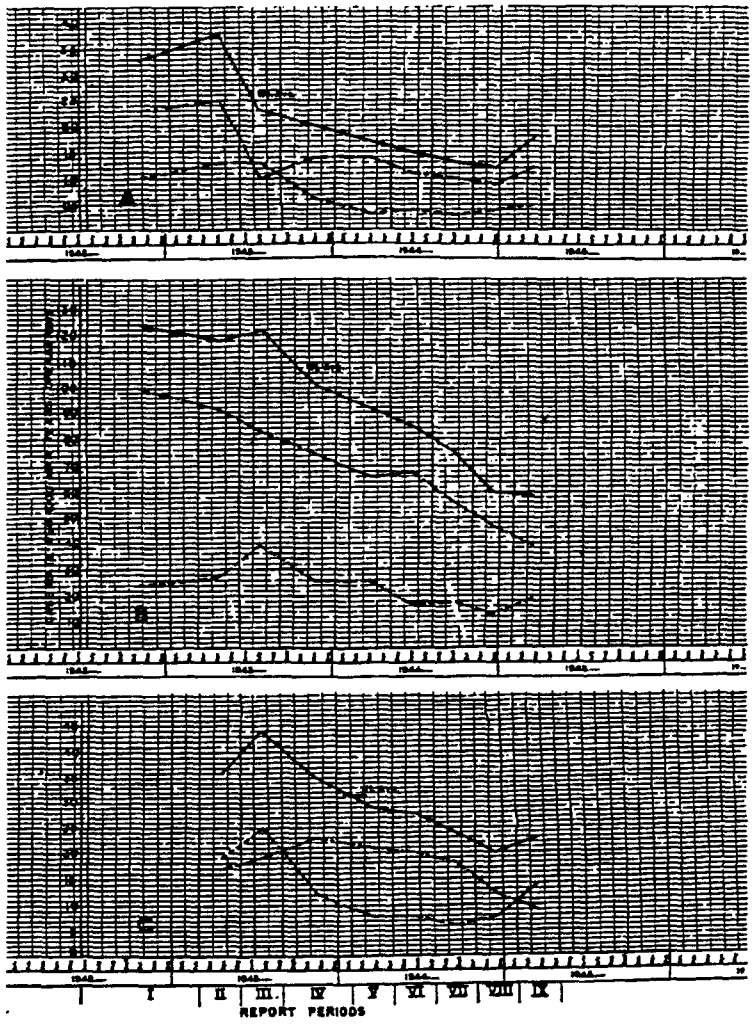

Chart 1.—All occupational diseases in all assigned Ordnance installations. Systemic effects are indicated by a line of dashes, dermatitis by a line of dashes and dots and the total cases by an unbroken line. *A*, cases of illness resulting in loss of time. *B*, cases of mild illness. *C*, cases of illness resulting in medical transfers.

As seen in chart 1, there was a well marked decline in the medical transfer rates from a high of 44 per thousand man years in the third report period to an average of 22 for the last three periods, a reduction of about one half from the higest rate, and only about two thirds of the over-all rate (32). From table 2 it can also be seen that the average rate (24) for the past year compares very favorably with the average rate (36) for the four periods comprising the preceding fourteen months, a reduction of one third.

Although the over-all transfer rate for patients with dermatitis (18) is slightly higher than that for patients with systemic effects (14), chart 1 shows that the rate for patients with systemic effects reached a slightly higher peak (25) and showed a more rapid decline, except in the last period.

IV. TRINITROTOLUENE EXPERIENCE

A. TRINITROTOLUENE POISONING

1. *In GOCO Bomb and Shell Loading Plants.*—Exposure of employees to trinitrotoluene in the bomb and shell loading plants was rather limited for some months after the beginning of operations in 1941-1942 because of the necessity of eliminating the defects in mass production, the care required in building up safe and efficient practices among employees and the difficulty in procuring a steady supply of necessary components. Also, the effects of exposure to trinitrotoluene often take some time in building up to the point of overcoming the employees' resistance and are cumulative. Consequently, the average peaks of initial exposure are not reflected in the curves for trinitrotoluene poisoning until the second and third periods, the spring and summer of 1943 (see charts 2, 3 and 4). The rate for all systemic illness due to trinitrotoluene was relatively low during the nine months comprising the average first period for all plants and increased rapidly as production and exposure increased during the second and third periods as shown in table 3. From this time on through the ninth period the converging effects of the medical and engineering control programs become apparent as shown by a sharp drop in the rates to a low level for disabling and nondisabling poisoning, medical transfers and fatalities, despite a sharp rise in production beginning in the fifth period and increasing through the ninth period.

Fatalities Due to Trinitrotoluene: There were 18 fatalities due to trinitrotoluene among an average monthly population of about 16,800 employees exposed to trinitrotoluene in 34.8 months of operations, so that the over-all death rate among employees exposed to trinitrotoluene was less than 0.4 per thousand man years of exposure. This is considered an excellent over-all record as compared to the last war when 475

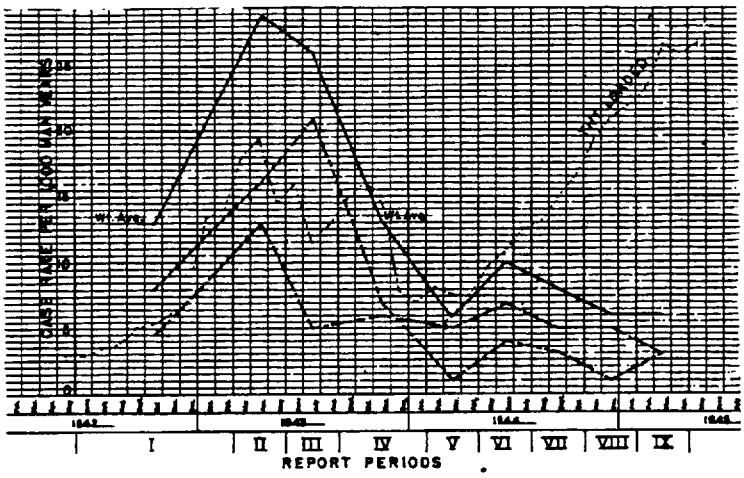

Chart 2.—Cases of illness in shell and bomb loading plants due to trinitrotoluene resulting in lost time. Systemic effects are indicated by a line of heavy dashes, dermatitis by a line of dashes and dots and the total cases by an unbroken line.

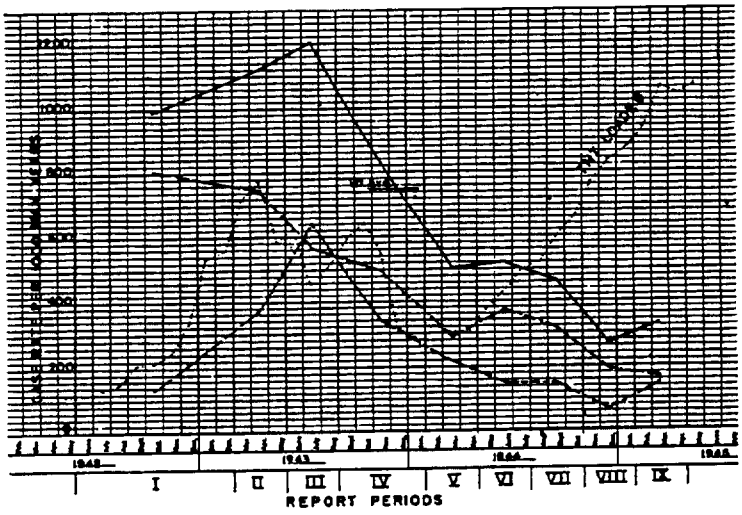

Chart 3.—Cases of mild dermatitis and other effects due to trinitrotoluene in shell and bomb loading plants. Systemic effects are indicated by a line of heavy dashes, dermatitis by a line of dashes and dots and the total cases by an unbroken line.

deaths were reported in seven and one-half months among workers handling trinitrotoluene and related compounds.[1] It is believed that the number of employees exposed to trinitrotoluene was considerably less in the United States during the war years 1914-1918 than during World War II. Also the high rate of labor turnover during the past few years, which approximated 100 per cent annually, means that many more employees were exposed to trinitrotoluene than the average figure of 16,800 suggests.

The effects of the present industrial hygiene control program are all the more apparent when it is noted that there were only 4 deaths

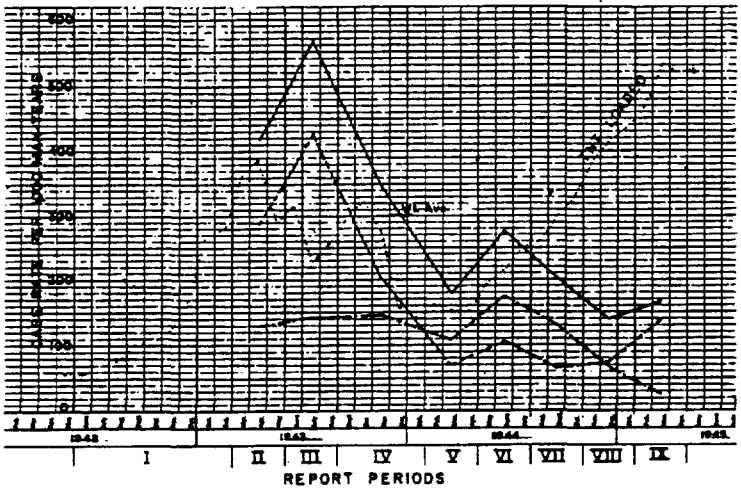

Chart 4.—Cases of illness due to trinitrotoluene in shell and bomb loading plants which resulted in medical transfers. Systemic effects are indicated by a line of heavy dashes, dermatitis by a line of dashes and dots and the total cases by an unbroken line.

in the last fifteen months as compared to 11 deaths in the preceding eleven months.

Cases of Trinitrotoluene Poisoning and Dermatitis Involving Loss of Time: The record for cases of trinitrotoluene poisoning and dermatitis involving loss of time is of particular interest for comparing with standard frequency rates for accidents resulting in loss of time. There were 340 cases of poisoning resulting in loss of time and 270 cases of dermatitis resulting in loss of time in some 49,000 man years of actual exposure to trinitrotoluene, making a rate of 12.5 cases resulting in loss of time per thousand man years of exposure. This corresponds

TABLE 3.—*Deaths, Disabling and Mild Illness and Dermatitis Due to TNT and Intraplant Medical Transfers Among Employees Exposed to TNT in GOCO Shell and Bomb Loading Plants*

Report Period	Number of Cases										Rates per 1,000 Man Years of Exposure to TNT									
	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total Experience
Number of employees in production	91,600	87,400	87,000	71,600	66,200	69,700	67,100	70,900	66,600	78,000										
Number of employees exposed to TNT	14,700	15,700	17,400	15,000	16,200	15,700	19,600	22,000	21,100	18,600										
Number of months of exposure	6.8	3	3	5	3	3	3	3	3	34.8										
Number of 1,000 man years' exposure	10.8	3.9	4.3	6.3	4.1	3.9	4.9	5.5	5.3	48.9	10.8	3.9	4.3	6.6	4.1	3.9	4.9	5.5	5.3	48.9
Number of deaths	3	2	3	4	1	0	2	1	0	16	0.2	0.5	0.7	1.0	0.2	0.0	0.4	0.2	0.0	0.4
Number of Cases Resulting in Loss of Time:																				
Systemic poisoning	39	23	29	41	6	14	13	7	18	240	3	16	21	7	1	4	3	1	3	7
Dermatitis	48	51	22	37	19	26	26	27	14	270	4	13	5	6	5	7	5	5	3	8
Total	187	114	111	78	25	40	39	34	32	510	18	29	26	13	6	11	8	6	6	12
Number of Cases of Mild Disease:																				
Systemic effects	1,467	1,470	2,760	2,073	899	891	740	890	822	11,212	136	376	641	334	219	151	151	71	156	220
Dermatitis	8,711	2,925	2,411	3,103	1,175	1,443	1,543	1,077	901	23,288	806	750	563	500	286	370	314	196	170	476
Total	10,178	4,395	5,171	5,176	2,074	2,334	2,283	1,967	1,723	34,500	942	1,126	1,205	834	505	521	465	267	325	706
Number of Medical Transfers:																				
Systemic effects	†	1,125	1,896	1,355	393	407	823	392	751	6,857	†	288	426	202	71	104	67	71	142	168
Dermatitis	†	507	615	915	450	676	687	309	122	4,841	†	130	142	147	110	173	140	67	23	114
Total	.....	1,632	2,451	2,170	743	1,083	1,015	701	873	10,733	...	418	569	349	181	277	207	138	165	282†

* From beginning of operations.

† Transfers not reported for first period.

to a standard accident frequency rate of 5.2 per million man hours [13] of work for employees exposed to trinitrotoluene. If the total number of man years (226,000) representing all employees in production is used instead of only the man years representing employees exposed to trinitrotoluene as a base line for the calculation of rates, then the lost time rate per thousand man years drops to 2.7, and the accident frequency rate to 1.1.

Here again it will be noted that the cases involving loss of time per thousand man years of exposure averaged less than 8 for the last fifteen months as compared with more than 22 for the preceding eleven months.

Cases of Mild Trinitrotoluene Poisoning and Dermatitis: The number of cases of mild nondisabling poisoning and dermatitis in which there were early effects of toxic absorption of trinitrotoluene is quite considerable, including over 11,000 cases in which there were general or systemic effects and over 23,000 in which there was mild dermatitis, giving over-all rates of 230 and 476 per thousand man years of exposure, respectively. Although the great majority of these cases were of little medical significance, they were all cases of potentially serious disease involving loss of time and demonstrate vividly the very real problems involved and the need for continued efforts to control exposure to trinitrotoluene. Chart 3 shows a rapid decline in cases of mild dermatitis and other effects from the peak rate of 1,205 in the third period through the last six periods to a relatively low rate of about 300 in the last two periods, again despite a rapid increase in production.

Cases Resulting in Medical Transfers: From the production viewpoint of cost and efficiency, the unrecorded loss of time and effort caused by transfers away from exposure to trinitrotoluene of employees showing some early signs or symptoms of trinitrotoluene poisoning or dermatitis is most important. Also, these employees are all facing the possibility of severe illness or death. The total rate of transfers per thousand man years of exposure rose from 418 in the second period [14] to 569 in the third period and then declined to a relatively low level (about 150) during the last two periods. Although the group of cases of mild disease and the group resulting in transfers would overlap in many instances, the fact that the two groups are different to some extent is shown by the fact that (*a*) the over-all case rate of mild disease (706) is two and one-half times the rate of cases resulting in transfers (282), and (*b*) the dermatitis rate in the group of cases of mild disease starts high (806) and steadily declines to 170 in the last period, whereas in the group of cases resulting in transfers the dermatitis rate is

13. One thousand man years is the equivalent of 2,400,000 man hours.

14. No figures for transfers are available for the first period.

relatively low and remains largely between 100 and 150 up to the last two periods, when it drops to 67 and 23. These relatively low transfer rates for dermatitis are explained by the phenomenon of "hardening," that is, by the practice of keeping employees with mild dermatitis on the job until they lose their sensitivity. On the other hand, the rate of cases of mild systemic poisoning (230) exceeds the rate of cases resulting in medical transfers by about one third (168), and the curves are quite similar.

2. *In GOCO Trinitrotoluene Manufacturing Works.*—In the GOCO works manufacturing trinitrotoluene, as contrasted with the loading

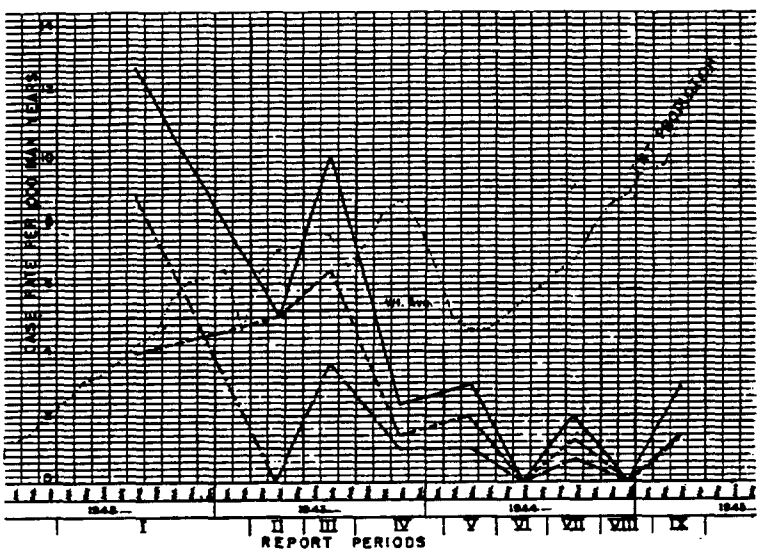

Chart 5.—Cases of illness due to trinitrotoluene in manufacturing works which resulted in lost time. Systemic effects are indicated by a line of heavy dashes, dermatitis by a line of dashes and dots and the total cases by an unbroken line.

plants, there were fewer workers employed in production operations (about 36,000), and only about 5,200 were exposed to trinitrotoluene. Many of these exposures were inconsequential in view of the enclosed nitration processes and the care taken to control operations not enclosed. Consequently, the number of cases of trinitrotoluene poisoning and dermatitis was less than one fifth of that in the loading plants, and the case rates per thousand man years of exposure to trinitrotoluene averaged less than half.

Fatalities Due to Trinitrotoluene: Only one death resulted from trinitrotoluene poisoning and that occurred early in production—September 1942. After that time no cases of patients seriously ill with trinitrotoluene poisoning were reported. This death resulted in a fatality rate of 0.06 per thousand man years of exposure to trinitrotoluene—about one sixth of that in the loading plants.

Trinitrotoluene Poisoning and Dermatitis Resulting in Loss of Time: Cases of trinitrotoluene poisoning and dermatitis resulting in disablement or loss of time totaled 81, giving a case rate of 4.8 per thousand man years of exposure to trinitrotoluene, or a rate of 0.7 if the whole population in production is considered. These rates would yield standard accident frequency rates of 2.0 and 0.3 respectively if considered on a million man hour basis.

Because of the small number of cases per report period the curves in chart 5 are rather irregular, but there is a pronounced downward trend from a high of 12.7 in the first period to an average of 1.2 for the last year. There were no cases of illness resulting in lost time in two of the last four report periods, as shown in table 4.

Cases of Mild Trinitrotoluene Poisoning and Dermatitis: The case rates of mild or nondisabling trinitrotoluene poisoning and dermatitis followed much the same pattern as in the loading plants. After a rise to a peak rate of 931 cases per thousand man years of exposure in the third period, the rate fell to less than 300 in the fourth and dropped to 155 in the eighth and ninth periods, despite a rapid rise in production during the last four periods. This decrease is heavily weighted by the rates of dermatitis (707 to 142), although the case rates of systemic poisoning decreased from a high of 224 to 13. It will be observed from chart 6 that a better degree of control was established and maintained than in the loading plants (chart 3), both industries having similar production curves.

Cases Resulting in Medical Transfers: Workers transferred away from exposure to trinitrotoluene because of early signs or symptoms of poisoning totaled 1,553, a case rate of 116 per thousand man years of exposure. Dermatitis accounted for 640 of these cases, while systemic effects accounted for 913. The transfer rate dropped from a high of 262 in the second period to about 50 for the last two periods, thereby indicating a considerable saving and improved efficiency. As in the loading plants, systemic effects accounted for the bulk of the transfers, as workers with mild dermatitis were frequently kept on the job (chart 7).

3. *In Army-Operated Arsenals.*—Exposure to and poisoning from trinitrotoluene was not an important problem in the old line arsenals, as only a few of these installations were loading trinitrotoluene and the

TABLE 4.—*Deaths, Disabling and Mild Illness and Dermatitis Due to TNT and Intraplant Medical Transfers Among Employees Exposed to TNT in GOCO Manufacturing Works*

	Number of Cases										Rates per 1,000 Man Years of Exposure to TNT									
Report Period	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total Experiences
Number of employees in production	45,500	45,900	42,600	38,900	25,100	25,500	27,500	26,100	25,100	26,400										
Number of employees exposed to TNT	5,600	5,000	5,500	6,900	4,900	5,700	6,100	7,600	8,200	5,200										
Number of months of exposure	11	3	3	5	3	3	3	3	3	37										
Number of 1,000 man years' exposure	3.3	1.3	1.4	2.9	1.0	1.4	1.5	1.9	2.1	16.7	3.3	1.3	1.4	2.9	1.0	1.4	1.5	1.9	2.1	16.7
Number of deaths	1	0	0	0	0	0	0	0	0	1	0.3	0	0	0	0	0	0	0	0	0.06
Number of Cases Resulting in Loss of Time:																				
Systemic poisoning	12	6	9	4	2	0	2	0	3	39	3.6	5.0	6.4	1.4	2.0	0	1.3	0	1.4	2.3
Dermatitis	29	0	5	3	1	0	1	0	3	42	8.8	0	3.6	1.0	1.0	0	0.7	0	1.4	2.5
Total	42	6	14	7	3	0	3	0	6	81	12.7	5.0	10.0	2.4	3.0	0	2.0	0	2.9	4.8
Number of Cases of Mild Disease:																				
Systemic effects	168	219	313	292	195	78	46	29	28	1,270	51	182	224	99	195	56	32	15	13	86
Dermatitis	1,980	884	990	598	190	331	337	265	227	5,800	600	695	707	203	190	236	225	139	143	347
Total	2,148	1,053	1,303	843	385	409	385	294	255	7,070	651	877	931	298	385	292	257	154	155	433
Number of Medical Transfers:																				
Systemic effects	†	210	207	225	94	66	51	31	40	918	†	175	148	78	94	39	34	16	19	65†
Dermatitis	†	105	144	95	46	69	59	43	74	640	†	87	103	33	46	49	39	25	35	48†
Total	.....	315	351	320	140	124	110	79	114	1,558	...	262	251	111	140	88	73	41	54	113†

* From beginning of operations.

† Transfers not reported for first period.

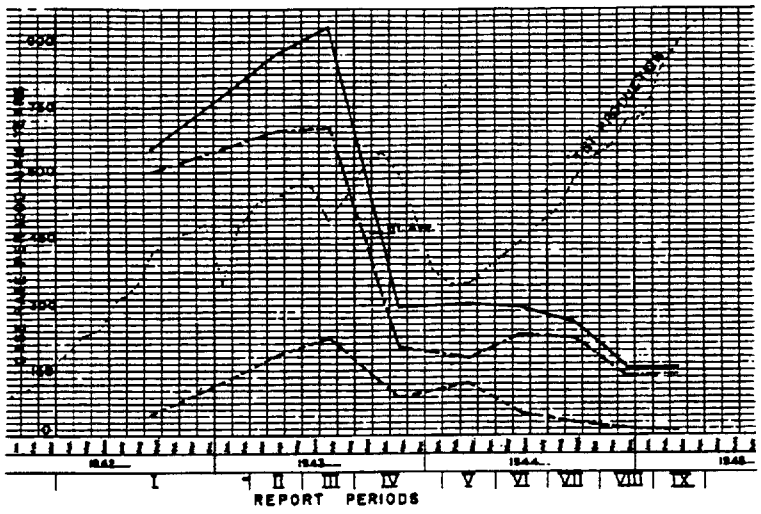

Chart 6.—Cases of mild dermatitis and other effects due to trinitrotoluene in manufacturing works. Systemic effects are indicated by a line of heavy dashes, dermatitis by a line of dashes and dots and the total cases by an unbroken line.

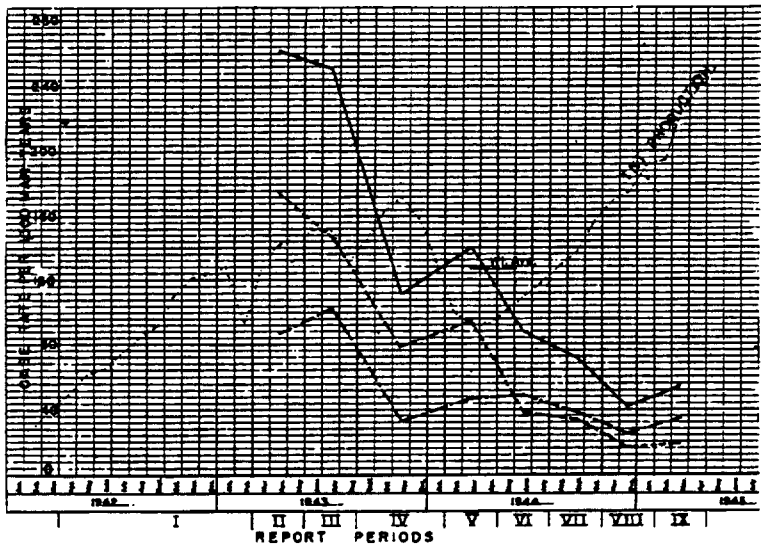

Chart 7.—Cases of illness due to trinitrotoluene in manufacturing works which resulted in medical transfers. Systemic effects are indicated by a line of heavy dashes, dermatitis by a line of dashes and dots and the total cases by an unbroken line.

number of employees exposed to trinitrotoluene varied between 500 and 1,300 in the periods in which these data were reported. In all, there were 2 deaths, 15 cases resulting in loss of time, 418 cases of mild systemic poisoning or dermatitis, and 258 medical transfers among an average of 53,000 employees in thirty-three months of operations.

As data on the number of workers exposed to trinitrotoluene are not available for the first four periods, and several arsenals stopped handling trinitrotoluene during that time, rates for exposed employees cannot be given.

Improved control measures, however, have resulted in a favorable experience during the last year, as there were no deaths and only 2 cases resulting in loss of time, 21 cases of mild disease and 37 medical transfers among an average of 925 employees exposed to trinitrotoluene. Based on 1,000 man years of exposure to trinitrotoluene the rates for the last year are 2.2 for cases resulting in loss of time, 23 for cases of mild disease and 40 for medical transfers, which compare favorably with the rates for similar periods in the loading plants.

B. EXPOSURES TO TRINITROTOLUENE

1. *In GOCO Bomb and Shell Loading Plants.*—As stated earlier, industrial hygiene surveys were conducted in the government-owned plants assigned to this office by personnel from the United States Public Health Service and the Army Industrial Hygiene Laboratory. One of the primary objectives of these surveys was to evaluate the workers' exposures to toxic materials and to advise on satisfactory control measures where excessive exposures were found to exist. No attempt will be made in this paper to show the results obtained in all industries, but data on concentration of atmospheric trinitrotoluene have been culled from the industrial hygiene survey reports of GOCO trinitrotoluene processing plants and charts 8, 9, 10 and 11 have been prepared to show what has been accomplished in atmospheric sanitation in this most important industry. Although similar data have not been extracted from the reports for other toxic materials in the other industries assigned to this office, it is believed that the trend as regards workers' exposures has been the same in all industries.

Before discussing these figures briefly it is necessary to point out that much of the early reduction in contamination with atmospheric trinitrotoluene in loading plants was accomplished by means of better housekeeping, more careful performance of the operation, enclosure of dust sources and isolation of dusty operations, and little was accomplished by improved ventilation.[10] Considerable improvement of working conditions by means of general and local ventilation was effected in the latter part of the war, but even then adequate ventilating systems

were not installed everywhere needed for the following reasons: (*a*) They frequently introduced an important fire and explosion hazard which was not easy to overcome; (*b*) their installation at some opera-

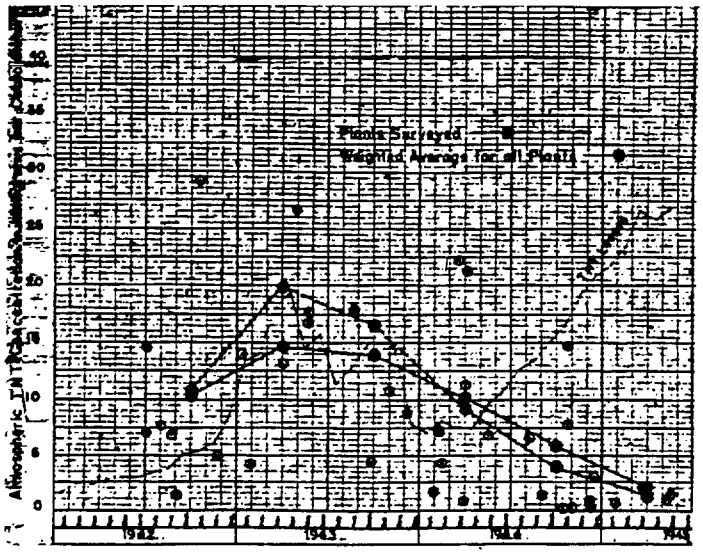

Chart 8.—Very dusty operations (trinitrotoluene screening) in loading plants.

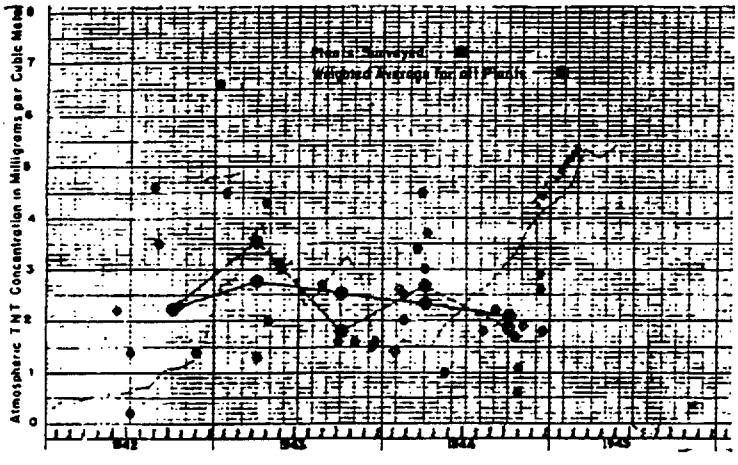

Chart 9.—Moderately dusty operations (charging melters, scrapping bombs, preparation of booster cavities and riser and tub cleaning) in loading plants.

tions involved considerable expense which could not be justified for temporary industries and (*c*) the operations and the nature of the operations were changed so frequently to keep abreast of the requirements at the fighting fronts that permanent ventilating systems were frequently obsolete shortly after installation. Much better atmospheric sanitation could have been obtained if the commoner use of ventilating systems had been possible.

The trend of the concentrations of atmospheric trinitrotoluene for very dusty, moderately dusty and slightly dusty operations in bomb and shell loading plants are shown in charts 8, 9 and 10. The individual

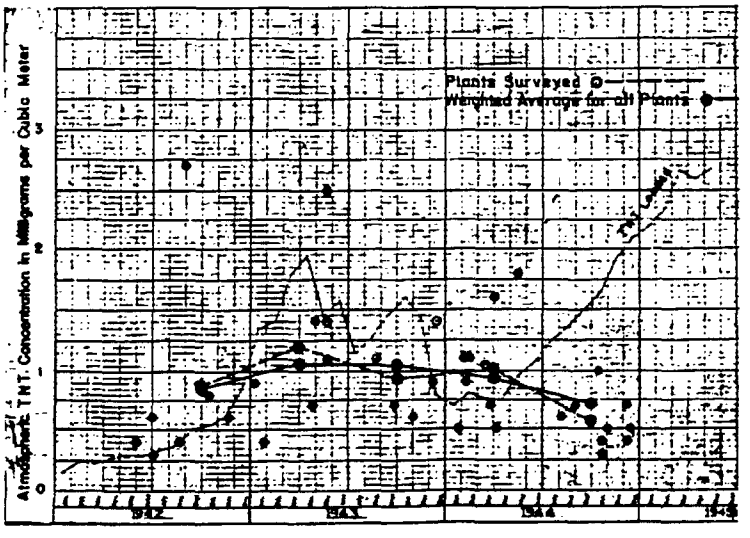

Chart 10.—Slightly dusty operations (tending melters, drawing off, pouring, cooling and shell puddling) in loading plants.

points are the average concentrations of trinitrotoluene at the operations listed on each chart for one plant. The points joined by the broken line are the arithmetic averages of the individual points in each six month period. Since only a portion of all the loading plants was surveyed during any six month period, a separate curve was prepared showing the weighted average for all plants. It was obtained by averaging the midperiod values taken from the individual curves for all plants. The points on this curve are joined by a solid line. A trinitrotoluene consumption curve for these plants is also shown on the figures for comparison (units not shown).

It is of interest to note that substantial reduction in contamination with atmospheric trinitrotoluene was accomplished at the very dusty operations (chart 8), while less reduction was accomplished at those operations which presented a less serious hazard (charts 9 and 10). The improved atmospheric sanitation for the last six month period, shown in charts 9 and 10, and for the last two periods, in chart 8, in the face of the rapid rise in the quantity of trinitrotoluene loaded is probably due to the wider use of general and local exhaust ventilation as mentioned earlier. The survey procedure was changed considerably early in 1945, making it impossible to obtain satisfactory data for the

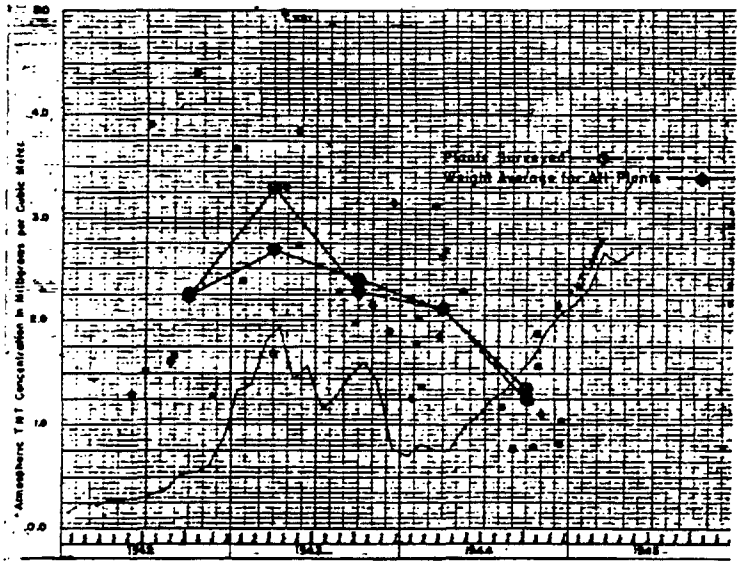

Chart 11.—Weighted average concentrations of atmospheric trinitrotoluene for all operations in loading plants.

first six month period on charts 9 and 10, while this change did not similarly affect the data for chart 8.

Charts 8, 9 and 10 cover specific operations, but they do not give an over-all trend for the loading industry as a whole and do not take into account the relative numbers of exposed workers. Since the loading industry contributed a substantial portion of the occupational diseases reported for all industries, it was desirable to derive some index which would represent the over-all average concentration of atmospheric trinitrotoluene for this industry for comparison with the occupational disease

curves, particularly the curves on mild poisoning and on transfers (charts 3 and 4). In this connection it must be mentioned, however, that trinitrotoluene may be absorbed through the skin and that lack of personal hygiene was probably an important factor also in causing trinitrotoluene poisoning.

The individual points in chart 11 were obtained for each plant by multiplying the approximate number of workers at each different operation by the atmospheric concentration of trinitrotoluene for the operation, adding all these values and dividing by the total number of workers. This procedure results in a weighted value which should be a fairly accurate index of the over-all hazard from trinitrotoluene inhalation since it is affected by both the number of persons exposed and the concentration of atmospheric trinitrotoluene to which they were exposed. Barring an inconsistent influence from cutaneous absorption from period to period this curve should parallel fairly closely the trend of the curves for systemic trinitrotoluene poisoning. Reference to charts 2, 3 and 4 (systemic effects) indicates that it does.

Here again it is of interest to note the rapid drop from the first to the second six month period in 1944 even though the "trinitrotoluene loaded" curve is rising rapidly. This has undoubtedly been brought about by the commoner use of proper ventilating measures near the end of the war. Also of interest is the fact that the weighted average concentration of atmospheric trinitrotoluene exceeded the maximum allowable concentration of 1.5 mg. per cubic meter for all periods except the last period in 1944. Even during this period, however, some of the workers were exposed to concentrations of atmospheric trinitrotoluene well above 1.5 mg. per cubic meter.

There are not sufficient specific data available to substantiate or disqualify the value of 1.5 mg. per cubic meter as the maximum allowable concentration. This value was recommended by the United States Public Health Service early in 1941 on the basis of data obtained from British and Canadian workers in industrial hygiene.[15] The over-all results seem to indicate that a somewhat lower value, in the order of 1 mg. per cubic meter, is preferable and can be attained with no great difficulty in properly engineered plants. It seems unlikely, however, that even 1 mg. per cubic meter will prevent all fatalities, since of the 22 deaths in World War II attributable to trinitrotoluene poisoning, one third were of workers employed at operations producing average concentrations of atmospheric trinitrotoluene of 1 mg. per cubic meter or less.[12] As with other toxic materials it appears that a few persons are extremely

15. Manual of Industrial Hygiene and Medical Service in War Industries, United States Public Health Service, Industrial Hygiene Division, Philadelphia, W. B. Saunders Company, 1943.

hypersensitive to trinitrotoluene. Since trinitrotoluene is absorbed also through the skin and gastrointestinal tract, it may be that unusually poor personal hygiene played an important part in the total amount of trinitrotoluene absorbed by the workers who died even though their atmospheric exposure was low.

2. *In GOCO Trinitrotoluene Manufacturing Works.*—The severity of exposure to atmospheric trinitrotoluene in the manufacturing plants was mild compared to that in the loading plants, and the number of workers exposed also was much less. The concentrations of atmospheric trinitrotoluene for two representative operations were selected from the

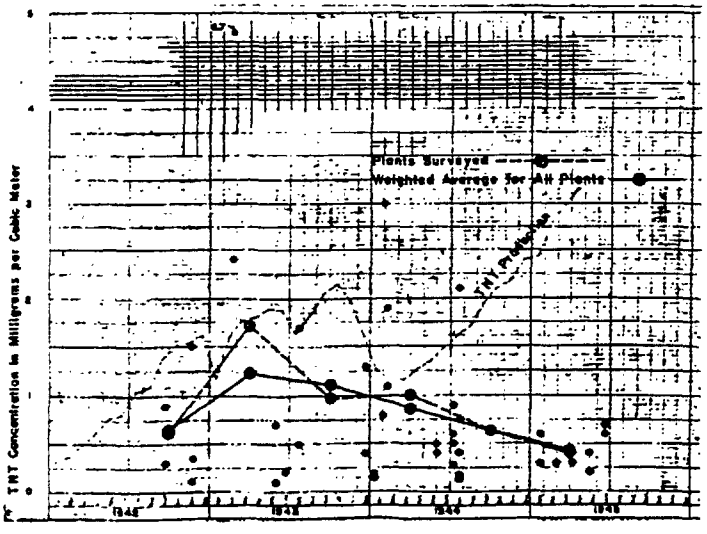

Chart 12.—Moderately dusty operations (box filling, flaker and melter tending) in trinitrotoluene manufacturing plants.

industrial hygiene survey reports and are plotted in chart 12. The two curves shown were derived as explained in section IV B 1. It will be noted that the trend of the concentrations of atmospheric trinitrotoluene is the same as for the loading plants.

Local exhaust ventilation was used much more commonly in the manufacturing than in the loading plants even from the beginning of operations. All operations in the manufacturing works which caused considerable atmospheric contamination were provided with local exhaust ventilation. Some of these systems were unsatisfactory at first, as indicated by the points on chart 12 above 1.5 mg. per cubic meter, but

all in all they were very successful in preventing what otherwise would have been severe exposures. For instance, one of the operations shown in chart 12 is strictly comparable to one of the operations included in the data plotted in chart 8. The concentrations of trinitrotoluene at this operation in the loading plants were roughly twelve times as high as in the manufacturing plants for all except the first six months of 1945 when local exhaust systems had been installed at the trinitrotoluene screening operations of most loading plants.

V. TETRYL DERMATITIS AND OTHER EFFECTS

Exposure to tetryl or trinitrophenylmethylnitramine was limited almost entirely to the loading plants, trinitrotoluene and tetryl manufacturing works and arsenals. These three industrial groups had an average employment of 167,400 employees in operations over an average period of 34.7 months, resulting in 482,600 man years of operations. The average first report period began in June 1942—usually with the beginning of operations in the new facilities.

Tetryl, used as a booster charge in large caliber ammunition and as the high explosive in small caliber shells, was next in importance to trinitrotoluene as an occupational disease problem in loading and manufacturing plants. Because tetryl is a powerful sensitizer, a large proportion of new employees handling this material showed some degree of tetryl dermatitis, as described by Schwartz,[16] Probst[17] and others.[18] Its action sometimes caused local irritation of the conjunctiva, nose, throat and bronchial tubes, thereby producing symptoms of the common cold, nosebleed, cough and occasionally asthma-like symptoms until the workers were removed from exposure. No evidence of systemic or internal poisoning, i.e., of the liver, heart, lungs, nervous system or blood-forming organs, has been reported from ordnance plants. Table 5 shows reported cases of tetryl dermatitis and other effects which include irritation of the upper respiratory system, as described previously.

Data as to the average number of persons exposed to tetryl by report periods are not available, so that rates in table 5 are based on all employees in production in the three industrial groups of plants handling tetryl. This is opposed to the rates in section IV, which are based on the number of employees actually exposed to trinitrotoluene. It will be noted from table 1 that in December 1943, however, 5,505 (7.7 per cent) of the 71,600 employees in the loading plants and 536 (1.4 per cent) of the 38,300 employees in the manufacturing works were receiving periodic examinations because of exposure to tetryl. No

16. Schwartz.[4] Footnote 15.

17. Probst, E. W.: Effects of Tetryl, J. A. M. A. **126**:424 (Oct. 14) 1944.

18. Fischer, C. N., and Murdock, H. D.: Tetryl Exposure: Analysis of Four Years' Experience with Tetryl, to be published.

TABLE 5.—*Tetryl Dermatitis and Other Irritating Effects Among Production Workers in Bomb and Shell Loading Plants, Manufacturing Works and Arsenals*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I	II	III	IV	V	VI	VII	VIII	IX		I	II	III	IV	V	VI	VII	VIII	IX	
	Through Feb. 43*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total	Through Feb. 43*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total Experience
Employees in Production (in Thousands):																				
Loading plants	91.6	87.4	87.0	71.6	66.2	69.7	67.1	70.9	66.6	78.0										
Manufacturing works	45.5	45.2	42.6	38.2	35.1	35.5	37.5	36.1	35.1	36.4										
Arsenals	54.4	57.3	51.1	40.3	40.2	34.2	34.7	35.6	34.0	53.0										
Total	191.5	189.9	180.8	150.1	180.5	139.4	139.3	158.6	147.7	167.4										
Number of months in period	3.7	3	3	5	3	3	3	3	3	34.7										
1,000 man years of operations	139.3	47.5	45.2	62.6	32.6	39.3	39.3	38.4	36.9	483.6	139.3	47.5	45.2	62.6	32.6	39.3	39.3	38.4	36.9	483.6
Cases Resulting in Loss of Time:																				
Dermatitis:																				
Loading plants	396	45	18	64	18	14	25	22	24	422	....	....	....	....	....	....	....	....	....	0.90
Manufacturing works	1	0	0	0	0	0	1	0	0	2	....	....	....	....	....	....	....	....	....	0.00
Arsenals	3	3	0	10	5	5	0	0	1	26	....	....	....	....	....	....	....	....	....	0.05
Total	201	51	18	74	23	19	26	22	25	450	1.4	1.1	0.4	1.2	0.7	0.5	0.7	0.6	0.7	0.95
Other Effects:																				
Loading plants	8	0	4	0	0	0	0	1	0	13	....	....	....	....	....	....	....	....	....	0.03
Manufacturing works	0	0	0	0	0	0	0	0	0	0	....	....	....	....	....	....	....	....	....	0.00
Arsenals	0	3	0	0	1	0	0	0	0	4	....	....	....	....	....	....	....	....	....	0.01
Total	8	3	4	0	1	0	0	1	0	17	0.06	0.06	0.09	0.0	0.03	0.0	0.0	0.03	0.0	0.04
Cases of Mild Disease:																				
Dermatitis:																				
Loading plants	9,880	1,557	1,225	2,014	755	754	663	416	311	17,505	....	....	....	....	....	....	....	....	....	36
Manufacturing works	185	9	13	76	73	65	29	69	31	550	....	....	....	....	....	....	....	....	....	1
Arsenals	238	144	212	222	278	212	134	205	160	1,860	....	....	....	....	....	....	....	....	....	4
Total	10,303	1,710	1,450	2,312	1,116	1,031	806	690	502	19,994	74	36	32	37	34	26	20	18	14	41
Other Effects:																				
Loading plants	1,346	125	134	179	71	32	66	41	65	2,071	....	....	....	....	....	....	....	....	....	4.3
Manufacturing works	62	0	0	0	1	0	0	0	0	63	....	....	....	....	....	....	....	....	....	0.1
Arsenals	0	0	20	29	0	0	0	0	0	56	....	....	....	....	....	....	....	....	....	0.1
Total	1,408	144	154	208	72	32	66	41	65	2,192	10.1	3.1	3.4	3.3	2.2	0.8	1.7	1.1	1.8	4.5
Transfers:																				
Dermatitis:																				
Loading plants	†	624	699	910	338	314	239	198	216	3,958	....	....	....	....	....	....	....	....	....	10.5
Manufacturing works	†	15	3	30	25	11	7	11	8	110	....	....	....	....	....	....	....	....	....	0.3
Arsenals	†	51	48	130	81	44	33	45	53	485	....	....	....	....	....	....	....	....	....	1.4
Total	.....	690	750	1,070	494	369	279	249	277	4,178	†	14.5	16.6	17.1	15.1	9.3	7.0	6.5	7.5	11.2†
Other Effects:																				
Loading plants	†	122	51	50	51	10	18	29	55	396	....	....	....	....	....	....	....	....	....	1.2
Manufacturing works	†	0	0	0	1	0	0	0	0	1	....	....	....	....	....	....	....	....	....	0.0
Arsenals	†	3	27	25	1	0	0	2	0	58	....	....	....	....	....	....	....	....	....	0.2
Total	.....	125	78	75	53	10	18	31	55	455	†	2.6	1.7	1.2	1.6	0.3	0.5	0.8	1.5	1.3†

* From beginning of report period.
† Transfers not reported for first period.

data are available as to the number of workers exposed to tetryl in the arsenals.

Cases of Disease Resulting in Loss of Time.—There were 477 cases resulting in loss of time from exposure to tetryl, 460 cases of dermatitis, and 17 of other effects, resulting in an over-all rate of 1 case resulting in loss of time per thousand man years of operations, or a standard accident frequency rate of 0.4 per million man hours. The great majority of these cases (445) occurred in the loading plants, which had a rate of 2 per thousand man years of operations. This corresponds closely to the rate of 2.7 cases of trinitrotoluene poisoning resulting in loss of time per thousand man years of loading plant operations, described previously. Only 2 cases of tetryl poisoning resulting in loss of time occurred in the manufacturing works, while 30 occurred in the arsenals.

Considerable improvement in cases of tetryl dermatitis involving loss of time is shown, as the rate for the last year was only 0.6 as compared with the over-all rate of 0.95 per thousand man years of operations.

Cases of Mild Effects from Tetryl.—Although not of great medical significance, the mild, nondisabling effects of exposure to tetryl were very numerous. In all there were 19,924 cases of mild tetryl dermatitis and 2,192 cases of other mild effects, giving a total of 22,116 cases of mild disease, or a case rate of 46 per thousand man years of operations. Again, the great majority, 19,576 or 88 per cent, of these cases occurred in the loading plants, while 3 per cent occurred in the manufacturing works and 9 per cent occurred in the arsenals. The large labor turnover accounted for many of these cases, as new employees are especially prone to acquire sensitivity to tetryl before becoming desensitized or "hardened." The annual labor turnover among wage earners in loading plants and manufacturing works was about 100 per cent and 66 per cent respectively, and it is estimated that the turnover in the arsenals was of similar order.

With increasing experience, technologic advances and the emphasis on the industrial hygiene program, there was remarkable improvement in the incidence of tetryl dermatitis. Table 5 shows that the frequency of cases of mild dermatitis dropped rapidly from a high of 74 per thousand man years in the first period to a low rate of 14 in the ninth period. The incidence of other tetryl effects dropped from a rate of 10.1 to 1.8 during the same time, resulting in an over-all decrease in rates from 84.1 to 15.8 for all cases of mild effects from exposure to tetryl, as shown in chart 13, a reduction of 81 per cent.

Cases of Disease Resulting in Medical Transfers.—As seen in table 5 and chart 13, the medical transfer rates for workers exposed to tetryl

was less than one half of the rates for those affected. In view of the tendency of workers to overcome their sensitivity to tetryl, the majority of the workers with dermatitis were kept on the job while attention was being given to controlling the exposure and to improving personal hygiene. Ordinarly only those affected workers who showed no signs of becoming hardened or who showed extreme sensitivity to tetryl were transferred away from exposure to tetryl permanently.

Despite this fact the transfer rate improved considerably after remaining about the same for the report periods from the second [14]

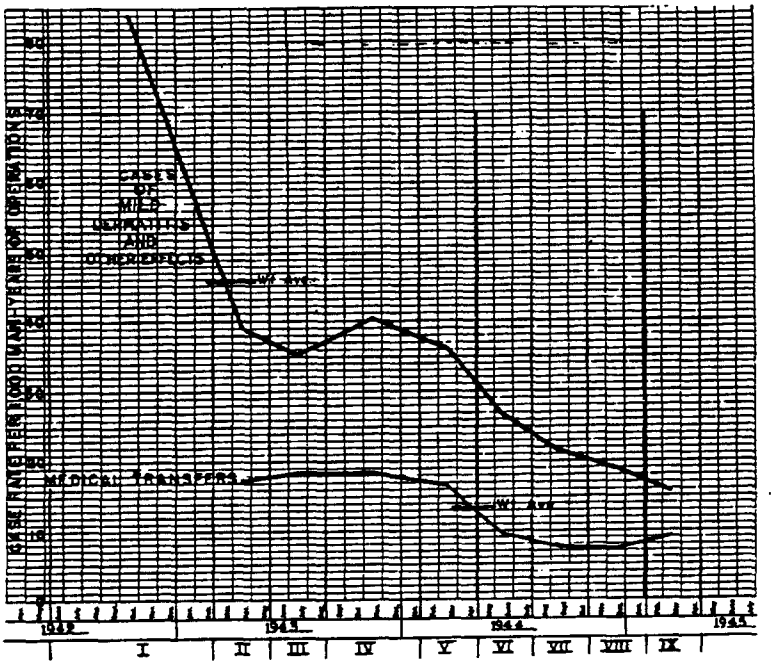

Chart 13.—Cases of mild dermatitis and other effects, and medical transfers due to exposure to tetryl.

through the fifth, as may be seen in chart 13. The average rate for transfers due to tetryl for the last four quarterly periods was 8.4 as compared with an average rate of 17.7 for the preceding four periods, which reflects a considerable saving in the costs incident to transfer.

VI. NITROGEN OXIDES POISONING

As the basic principle involved in the manufacture of high explosives and smokeless powder is the nitration of organic compounds, the prevention of exposure to lethal concentrations of nitrous "fumes," more

properly the oxides of nitrogen, is of paramount importance. These processes are largely enclosed in ordnance works, and where there is the possibility of leakage exhaust ventilation is provided. Accordingly the chances for serious exposure during normal operations are not great unless there is an accidental spill or a breakdown in equipment.

Following a serious exposure, there may be a latent period of five to twenty-four hours during which the employee may feel well and go about his business or leave the plant at the end of his shift. Some hours later there may be a sudden onset of congestion of the lungs which may progress rapidly to shock and death if not vigorously treated.[19] Accordingly every effort was made throughout the industry to impress supervisory personnel and employees with the necessity of prompt medical observation and treatment of any workers exposed to unusual concentrations of nitrogen oxides, which closely simulate phosgene in their effects. Plant hospitals also kept oxygen breathing equipment for the early treatment of affected cases. Pure oxygen was often given by mask under positive pressure as described in the Ordnance Industrial Hygiene Information Circular No. 11, dated March 20, 1943, entitled "Nitrogen Oxides Poisoning," and by Carlisle.[20]

Exposure to the oxides of nitrogen was confined almost entirely to three industries, the smokeless powder works, the trinitrotoluene and explosive works and the chemical works, whose experience is shown in table 6. The average number of employees engaged in production operations in these plants was 60,200 for an average duration of slightly more than three years (36.8 months), resulting in a total of 184,900 man years of operations. Data as to the actual number of employees potentially exposed to nitrogen oxides are not available, but table 1 indicates that 1,659 (4.3 per cent), 621 (3.2 per cent) and 606 (16 per cent) of the employees in the trinitrotoluene manufacturing works, smokeless powder works and chemical works, respectively, were considered sufficiently exposed in December 1943 to justify periodic physical examinations.

Fatalities Due to Nitrogen Oxides.—Only 3 fatalities were reported as attributable to exposure to nitrogen oxides, 2 in the powder works and 1 in trinitrotoluene manufacture, resulting in a fatality rate of 0.02 per thousand man years of operations. This is considered a remarkably good record in view of the tremendous magnitude of nitrating operations and reflects great credit on the control measures instituted by the

19. von Oettingen, W. F.: The Toxicity and Potential Dangers of Nitrous Fumes, Public Health Bulletin no. 272, Federal Security Agency, United States Public Health Service, 1941.

20. Carlisle, J. M.: Pulmonary Edema, J. A. M. A. 123:947 (Dec. 11) 1943.

TABLE 6.—*Deaths, Disabling Illness, Cases of Mild Disease and Medical Transfers Among Employees in GOCO Manufacturing Works from Exposure to the Oxides of Nitrogen*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total Experience
Employees in Production (in Thousands):																				
Powder works	16.9	18.1	19.1	19.2	14.1	18.8	22.8	25.1	27.8	19.4										
TNT works	45.6	48.2	42.6	38.2	25.1	25.5	27.5	26.1	25.1	36.4										
Miscellaneous chemical works	4.9	5.7	5.5	5.8	3.9	4.4	4.8	3.7	3.5	4.4										
Total	67.8	69.0	67.2	61.2	43.1	48.7	55.6	54.9	56.4	60.2										
Number of months in period	10.8	3	3	5	3	3	3	3	3	36.8										
Number of 1,000 man years' operations	60.5	17.3	16.8	25.6	10.8	13.2	13.9	13.7	14.1	184.9	60.5	17.3	16.8	25.6	10.8	13.2	13.9	13.7	14.1	184.9
Number of Deaths:																				
Powder works	1	0	0	1	0	0	0	0	0	2										
TNT works	1	0	0	0	0	0	0	0	0	1										
Miscellaneous chemical works	0	0	0	0	0	0	0	0	0	0										
Total	2	0	0	1	0	0	0	0	0	3	0.03	0.0	0.0	0.04	0.0	0.0	0.0	0.0	0.0	0.02
Number of Cases Resulting in Loss of Time:																				
Powder works	16	0	5	2	0	0	0	0	0	23										
TNT works	72	33	5	13	1	4	4	0	0	132										
Miscellaneous chemical works	0	0	0	0	0	0	0	0	0	0										
Total	88	33	10	15	1	4	4	0	0	155	1.5	1.9	0.6	0.6	0.1	0.3	0.3	0.0	0.0	0.8
Number of Cases of Mild Disease:																				
Powder works	426	45	30	50	18	15	55	40	29	718										
TNT works	1,445	477	315	478	144	111	126	177	174	3,448										
Miscellaneous chemical works	12	0	12	0	0	0	0	0	0	25										
Total	1,883	522	356	528	162	126	181	217	203	4,186	31	30	21	20	15	10	13	16	14	23
Number of Medical Transfers:																				
Powder works	†	0	0	0	0	0	0	4	2	6										
TNT works	†	0	21	0	0	1	1	1	0	24										
Miscellaneous chemical works	†	0	0	0	0	0	0	0	0	0										
Total	†	0	21	0	0	1	1	5	2	30	†	0.0	1.3	0.0	0.0	0.1	0.1	0.4	0.1	0.2†

* From beginning of operations.
† Transfers not reported for first period.

plants and the effectiveness of their medical program. Two of the fatalities occurred early in operations and 1 in the second year. None was reported in the last five report periods when production was at an all time peak (see chart 2).

Cases of Illness Resulting in Loss of Time.—Remarkably few employees were sufficiently exposed to the oxides of nitrogen to lose time from work, the total number being 155, or an over-all case rate of less than 1 (0.8) per thousand men per year. Considerable progress is shown even here, as all but 9 of the cases occurred in the first four report periods and there was none reported in the last two periods. The average rate for the last five report periods was only 0.1 as compared with the over-all rate of 0.8 per thousand man years of operations. It will also be noted from table 6 that the smokeless powder works had no cases of illness resulting in loss of time in the last 5 report periods and that the chemical works had none at all.

Many of these cases of illness resulting in loss of time were found to be of little medical significance, but the patients were hospitalized for a few days for moderate symptoms in order to be on the safe side. On the other hand, a few patients are known to have been treated who had severe pulmonary edema and roentgenograms of whose chests showed extensive mottling and yet who responded promptly to treatment and appeared to be entirely well within a few weeks.

Cases of Mild Illness.—The total number of cases of mild, non-disabling illness was 4,185, resulting in a rate of 23 cases per thousand man years of operations. The great majority of these cases, 3,442, occurred in the trinitrotoluene works, while 718 were reported from the powder works and 25 from the chemical works. Considerable improvement may be noted from table 6, as the average rate for the first year of operations was about 31 as compared with an average rate for the last year of 13, a reduction of 58 per cent. Most of these illnesses were either mild complaints attributed to exposure to nitrogen oxides or minor degrees of irritation of the respiratory tract that did not justify extended treatment. In numerous instances the patients were observed at the plant dispensary for several hours to be certain that no serious effects would develop.

Illness Resulting in Medical Transfers.—Medical transfers because of exposure to nitrogen oxides were not a problem, the total number being only 30. The employees who received transfers were largely persons who because of some real or fancied sensitivity to "fumes" kept complaining until moved to other work.

VII. OTHER OCCUPATIONAL DISEASES IN ASSIGNED INSTALLATIONS

A. IN SHELL AND BOMB LOADING PLANTS

The problems of trinitrotoluene poisoning and tetryl dermatitis in shell and bomb loading plants have been described in preceding sections. In addition there is a fairly large number of other toxic exposures associated with the loading of shells, bombs, fuses and their components and with their final processing for shipment overseas. The more important exposures involved were shown in table 1.

Table 7 indicates the occupational disease experience in loading plants from exposure to substances other than trinitrotoluene and tetryl. It will be noted that dermatitis accounted for the great bulk of these cases.

Illness Resulting in Loss of Time.—There were reported 377 cases of illness resulting in loss of time, 29 of systemic poisoning and 348 of dermatitis, resulting in a rate of 1.7 cases per thousand man years of operations. This is somewhat less than the case rates for illness resulting in loss of time from exposure to trinitrotoluene (2.7) and from exposure to tetryl (2), previously reported. If these rates are combined the total is 6.4 cases of illness resulting in loss of time per thousand man years of operations, which corresponds to a standard accident frequency rate of 2.7 cases per million man hours.

Considerable improvement was made in the control of occupational diseases from these miscellaneous exposures, as is shown by the fact that the lost time rate for the first year was 3.1 per thousand man years of operations as compared with an average rate of only 0.3 for the last year, a decline of 90 per cent.

The cases of systemic illness resulting in loss of time shown here were caused by exposure to carbon tetrachloride, primer and tracer mixtures, pentaerythritoltetranitrate, lead, cadmium and other solvents. Carbon tetrachloride accounted for 8 of the cases in the same incident in which a fatality occurred. The cases of dermatitis resulting in loss of time were attributed to exposure to solvents, mercury fulminate, ammonium picrate, smokeless powder, pentaerythritoltetranitrate and ammonium nitrate.

Cases of Mild Dermatitis and Other Effects.—A total of 4,740 cases of mild or nondisabling illness was reported, 235 of systemic effects and 4,505 of dermatitis, resulting in an over-all rate of 20.9 cases per thousand man years of operations. The rates by report periods declined from a peak of 42.9 in the third report period to an average of 5.8 the last year, a reduction of over 85 per cent.

In the groups of systemic illness, ammonium picrate, solvents, primer mix, pentaerythritoltetranitrate, nitroglycerine, dinitrotoluene and cad-

TABLE 7.—*Occupational Illness Resulting in Loss of Time and Mild Illness from Causes Other than TNT and Tetryl Among Employees in GOCO Shell and Bomb Loading Plants*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total Experience
Number of employees in production (in thousands)	91.6	87.4	87.0	71.8	65.2	69.7	67.1	70.9	66.6	76.0										
Number of months of operations	3.8	3	3	5	3	3	3	3	3	34.8										
Number of 1,000 man years' operations	67.5	21.8	21.7	29.8	16.3	17.4	16.8	17.7	17.2	226.2	67.5	21.8	21.7	29.8	16.3	17.4	16.8	17.7	17.2	226.2
Number of Cases Resulting in Loss of Time:																				
Systemic Poisoning																				
Solvents	0	0	1	1	0	0	0	3	2	13										
Miscellaneous explosives	3	3	2	0	0	0	0	0	5	13										
Lead and cadmium	0	0	0	1	3	0	0	0	0	4										
Total	3	3	3	2	3	0	0	3	7	30	0.0	0.1	0.1	0.1	0.2	0.0	0.0	0.5	0.4	0.1
Dermatitis																				
Solvents	106	10	4	2	3	0	0	0	1	125										
Mercury fulminate	0	77	12	29	9	0	0	1	1	129										
Ammonium picrate	54	10	0	7	1	0	0	0	1	73										
Smokeless powder	0	0	1	0	0	2	0	0	0	3										
Miscellaneous explosives	0	10	0	1	0	0	0	0	0	11										
Other	0	1	0	2	2	1	0	0	1	7										
Total	160	108	17	41	14	3	0	1	4	348	2.4	5.0	0.8	1.4	0.8	0.2	0.0	0.1	0.2	1.5
Total cases resulting in lost time	163	111	20	43	17	3	0	3	11	377	2.4	5.1	0.9	1.4	1.0	0.2	0.0	0.5	0.6	1.7
Number of Cases of Mild Illness:																				
Systemic Effects:																				
Solvents	12	6	3	2	3	5	2	31	6	76										
Ammonium picrate	13	16	53	0	5	4	1	0	0	91										
Miscellaneous explosives	7	5	0	2	6	10	5	0	3	38										
Other	0	0	20	2	7	1	0	0	1	31										
Total	31	27	76	6	26	20	8	31	10	236	0.5	1.2	3.5	0.2	1.6	1.2	0.5	1.7	0.6	1.0
Dermatitis																				
Solvents	149	137	95	67	17	8	11	7	4	495										
Mercury fulminate	766	570	419	321	58	1	9	6	2	1,852										
Ammonium picrate	40	92	226	313	67	66	12	80	31	861										
Smokeless powder	0	0	2	4	2	0	0	1	0	10										
Primer and tracer	190	9	0	1	0	0	1	1	0	202										
Ammonium nitrate	39	56	0	0	7	0	0	0	0	102										
Black powder	0	0	0	32	8	4	1	1	1	47										
Miscellaneous explosives	17	37	0	76	4	0	2	70	13	229										
Other	37	10	111	29	3	4	3	7	9	213										
Total	1,238	861	854	1,049	164	82	44	122	61	4,505	18.3	39.5	39.4	35.2	10.0	4.7	2.6	6.8	3.5	19.9
Total cases of mild illness	1,269	888	930	1,055	190	102	52	153	71	4,740	18.8	40.7	42.9	35.4	11.6	5.9	3.1	10.3	4.1	20.9
Number of Medical Transfers:																				
Systemic, total, miscellaneous	†	15	27	5	1	18	3	4	7	80	†	0.7	1.3	0.2	0.1	1.0	0.2	0.2	0.4	0.5†
Dermatitis																				
Solvents	...	6	6	2	4	4	1	3	2	28										
Mercury fulminate	...	114	180	340	53	10	15	3	1	716										
Ammonium picrate	...	18	18	66	21	11	0	3	3	140										
Smokeless powder	...	0	3	2	7	0	1	4	0	17										
Miscellaneous explosives	...	81	0	10	14	3	12	3	1	125										
Other	...	4	0	21	0	1	2	0	5	33										
Total	†	223	207	440	99	29	33	21	17	1,068	†	10.2	9.5	14.8	6.1	1.7	1.9	1.2	1.0	6.7†
Total transfers:	†	238	234	445	100	47	35	25	24	1,148	†	10.9	10.8	14.9	6.1	2.7	2.1	1.4	1.4	7.2

* From beginning of operations.

† Transfers not reported for first period.

mium each accounted for cases. The illness resulting from exposure to ammonium picrate and primer mix were chiefly irritation of the upper respiratory tract. Dermatitis was attributed to a great many causes but principally to mercury fulminate, ammonium picrate, solvents, black powder, primer and tracer mix, smokeless powder, pentaerythritoltetranitrate, graphite, lead azide, ammonium nitrate, pentachlorophenol, cutting oil and soap. In many of these cases the effects were rather mild, and it is questionable whether all should be considered as occupational in origin.

Cases Resulting in Medical Transfers.—A total of 1,148 persons exposed to these various health hazards required a transfer to a non-exposure job to relieve the symptoms, which resulted in an over-all rate of 7.2 transfers per thousand man years of operations, 6.7 for dermatitis and 0.5 for systemic effects. The transfer rates by periods rose from 10.9 in the second period to 14.9 in the fourth, and declined rapidly to 1.4 in the last two periods, a decline of 91 per cent from the peak rate of 14.9. The list of agents responsible for medical transfers was essentially the same as that for cases of mild illness.

B. IN EXPLOSIVES MANUFACTURING WORKS

As in the loading plants, there was a considerable number of toxic exposures in the explosives manufacturing works other than the exposures to trinitrotoluene, tetryl and nitrogen oxides described previously. Table 8 indicates the numbers and rates of occupational diseases resulting from these miscellaneous causes in an average population of 36,400 over thirty-seven months of operations.

Cases of Illness Resulting in Lost Time.—There were 53 cases of illness resulting in lost time reported, 44 of systemic illness and 9 of dermatitis, resulting in a rate of 0.5 per thousand man years of operations, which combined with the rates of 0.7 for cases of illness from exposure to trinitrotoluene, 0.02 for cases of illness from exposure to tetryl and 1.2 for cases of nitrogen oxides poisoning gives a total lost time rate of 2.4 per thousand man years of operations. This corresponds to an over-all standard accident frequency rate of 1.0 per million man hours of work for all occupational diseases resulting in loss of time in the manufacturing of explosives, slightly more than one third of the over-all frequency rate (2.7) for loading plants.

As shown in table 8, only 6 cases resulting in lost time were reported from these miscellaneous causes during the last four quarters resulting in an average rate of 0.2 per thousand man years as compared with a peak rate of 1.1 in the second period, and an average rate of 0.5 per thousand man years of operations for the whole thirty-seven months.

TABLE 8.—*Occupational Illness and Medical Transfers Other Than Caused by TNT, Tetryl and Nitrogen Oxides in GOCO TNT Manufacturing Works*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total Experience
Number of employees in production (in thousands)	45.5	45.2	42.6	38.2	25.1	25.5	27.5	26.1	25.1	36.4										
Number of months in period	11	3	3	5	3	3	3	3	3	37										
Number of 1,000 man years' operations	41.7	11.3	10.7	16.0	6.3	6.4	6.9	6.5	6.3	112.1	41.7	11.3	10.7	16.0	6.3	6.4	6.9	6.5	6.3	112.1
Number of Cases of Illness Resulting in Loss of Time:																				
Systemic Poisoning:																				
DNT	12	6	0	0	0	1	1	0	0	21										
Acids	0	0	1	4	2	0	0	0	0	7										
Aniline	1	0	0	0	0	0	0	0	0	1										
Lead	0	1	0	0	1	0	0	0	0	2										
Other	0	4	1	7	1	0	0	0	0	13										
Total	14	11	2	11	4	1	1	0	0	44	0.3	1.0	0.2	0.7	0.6	0.2	0.1	0.0	0.0	0.4
Dermatitis, miscellaneous	2	1	1	1	0	1	0	1	2	9	0.1	0.1	0.1	0.1	0.0	0.2	0.0	0.2	0.3	0.1
Total cases resulting in lost time	16	12	3	12	4	2	1	1	2	53	0.4	1.1	0.3	0.8	0.6	0.3	0.1	0.2	0.3	0.5
Number of Cases of Mild Illness:																				
Systemic Effects																				
DNT	258	30	5	0	4	6	10	2	1	316										
Acids	2	0	22	295	181	118	49	20	18	705										
Aniline	0	0	0	0	5	6	3	1	2	17										
Ammonia	5	0	9	4	4	2	0	0	0	24										
Other	13	29	1	96	1	19	26	28	0	223	7	6	3	25	31	24	24	5	3	12
Total	278	69	37	395	195	151	98	51	21	1,295										
Dermatitis:																				
DNT	7	0	4	2	1	0	1	0	22	37										
Acids	10	2	156	269	206	184	92	41	100	1,060										
Composition B (RDX)	0	0	125	178	107	96	125	1	0	632										
PETN	0	2	0	0	0	12	14	17	19	65										
Solvents	14	6	1	2	2	2	3	0	1	27										
Cutting oil	0	12	4	1	0	5	0	0	0	22										
Other	50	102	71	41	18	43	46	41	41	453										
Total	81	126	361	477	335	341	286	100	193	2,300	2	11	34	30	53	53	41	15	30	20
Total cases of mild illness	359	195	398	872	530	492	384	151	213	3,594	9	17	37	55	84	77	65	23	34	32
Number of Medical Transfers:																				
Systemic Effects:																				
DNT	...	9	6	5	3	4	9	0	11	47										
PETN	...	0	0	0	0	9	7	6	2	24										
Other	...	27	3	25	0	0	0	2	0	57										
Total	†	36	9	30	3	13	16	8	13	128	†	3	1	2	1	2	2	1	2	2
Dermatitis, miscellaneous	†	18	9	180	13	4	57	23	23	327	†	2	1	11	2	1	8	4	4	5
Total transfers	†	54	18	210	16	17	73	31	36	455	†	5	2	13	3	3	11	5	6	6†

* From beginning of operations.
† Transfers not reported for first period.

The cases of systemic illness involving loss of time reported here resulted from exposure to dinitrotoluene, acids, lead, aniline, ether, nitroglycerine, carbon monoxide, ammonia and solvents, and the cases of dermatitis were attributed to acids, dinitrotoluene, ammonium nitrate, solvents and powder uniforms.

Cases of Mild Dermatitis and Other Effects.—There were 3,594 cases of mild dermatitis and other effects reported, 1,295 of systemic effects and 2,299 of dermatitis, resulting in an over-all rate of 32 cases of mild illness per thousand man years of operations—12 of systemic effects and 20 of dermatitis. Owing to changes in production there was considerable fluctuation in the relative importance of the various exposures in different report periods. The rates for cases of mild dermatitis and systemic effects rose from 9 per thousand man years in the first period to a high of 84 in the fifth period and then dropped off to an average of 29 for the last two periods. It will be noted from table 8 that the magnitude of change was greater for cases of systemic effects than for cases of dermatitis, as the rates by periods rose from 7 to 34 and declined to 3 for the last period.

The mild systemic effects resulted chiefly from exposure to dinitrotoluene, acids (other than nitrogen oxides), aniline, ammonia, solvents, carbon monoxide and lead. The cases of dermatitis were attributed principally to dinitrotoluene, acids, composition B (RDX), pentaerythritoltetranitrate, solvents, cutting oils, sulfur, smokeless powder, alkalis, sellite (sodium sulfite), soap compounds and protective gloves and uniforms.

Medical Transfers.—The proportion of employees so affected by these various toxic exposures as to require a change of jobs was relatively small, being less than one fifth of the affected groups described previously. There were no significant variations except peak rates of 13 and 11 in the fourth and seventh periods as compared with an over-all rate of 6 cases per thousand man years of operations. The principal causes of systemic effects were exposures to dinitrotoluene and pentaerythritoltetranitrate, while the chief cause of dermatitis leading to transfers was exposure to RDX.

C. IN SMOKELESS POWDER WORKS

In smokeless powder works, the most serious health hazard was exposure to the oxides of nitrogen as described previously. Table 9 shows occupational diseases resulting from other exposures and represents the experience of 61,500 man years of operations, that is, an average of 19,400 production employees over thirty-eight months of operations. It will be noted that while the number of cases of illness resulting in loss of time was negligible, there was a sizeable number of cases of mild illness and a fair number of medical transfers, and that

TABLE 9.—*Occupational Illness Resulting in Lost Time and Mild Illness and Medical Transfers Not Due to the Oxides of Nitrogen in Smokeless Powder Works*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I	II	III	IV	V	VI	VII	VIII	IX		I	II	III	IV	V	VI	VII	VIII	IX	
	Through Feb. 45*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total	Through Feb. 45*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total Experience
Number of employees in production (in thousands)	16.9	18.1	19.1	19.1	14.1	18.8	23.8	25.1	27.8	19.4										
Number of months of operations	12	3	3	5	3	3	3	3	3	33										
Number of 1,000 man years' operations	16.9	4.5	4.8	8.0	3.5	4.7	5.9	6.3	6.9	61.5	16.9	4.5	4.8	8.0	3.5	4.7	5.9	6.3	6.9	61.5
Number of Cases Resulting in Lost Time:																				
Systemic poisoning, miscellaneous	0	12	0	0	0	0	0	0	1	13										
Dermatitis, miscellaneous	0	0	0	0	0	1	0	0	0	1										
Total cases resulting in lost time	0	12	0	0	0	1	0	0	1	14	0	2.7	0	0	0	0.2	0	0	0.1	0.2
Number of Cases of Mild Illness:																				
Systemic Effects:																				
DNT	309	66	66	79	2	4	12	0	2	540										
Aniline	10	66	0	0	0	7	6	4	9	96										
Nitroglycerine	10	67	0	0	0	1	0	0	0	78										
TNT	1	0	2	6	0	0	2	6	3	21										
Ether and alcohol	0	0	0	8	0	0	0	0	13	21										
Other	0	0	9	10	0	0	0	0	0	19										
Total	330	199	79	103	2	12	15	12	27	778	20	44	16	13	1	3	3	2	4	13
Dermatitis:																				
DNT	15	105	2	3	11	3	9	0	0	148										
Tetryl	0	0	0	66	28	0	10	69	58	218										
TNT	22	40	26	14	2	13	20	1	22	160										
Acid	0	0	0	44	0	2	2	9	5	63										
Other	20	135	150	0	4	118	12	25	21	479										
Total	57	280	178	119	45	130	54	104	101	1,068	3	62	37	15	13	28	9	16	15	17
Total cases of mild illness	387	479	257	221	47	142	69	116	128	1,846	23	106	53	28	13	30	12	18	19	30
Number of Medical Transfers:																				
Systemic Effects:																				
DNT	...	75	57	25	6	5	6	4	16	236										
TNT	...	0	6	0	1	0	0	1	..	8										
Aniline	...	3	0	0	0	0	0	20	..	23										
Other	...	0	26	15	0	0	0	1	2	54										
Total	†	78	129	40	7	5	6	26	18	311	†	17	27	5	2	1	1	4	3	71
Dermatitis:																				
Tetryl	...	0	0	5	6	0	2	16	16	47										
DNT	...	2	2	0	2	2	2	0	..	13										
TNT	...	0	2	0	0	0	0	0	1	4										
Other	...	0	9	5	0	2	0	1	2	21										
Total	†	2	15	10	9	5	4	19	20	85	†	1	3	1	3	1	1	3	3	21
Total transfers	†	81	144	50	16	10	12	45	38	396	†	18	30	6	5	2	2	7	6	91

* From beginning of operations.
† Transfers not reported for first period.

there was a considerable reduction in the occupational disease experience as the control program became more effective.

Cases of Illness Resulting in Loss of Time.—There were reported 14 cases of illness resulting in loss of time from miscellaneous causes, resulting in a rate of 0.2 per thousand man years of operations. In 13 of these cases the illness was systemic and was caused by exposure to aniline (12) and to fumes of ether and alcohol (1), while the case of dermatitis was caused by ammonium sulfamate. If the 23 cases of illness resulting in loss of time caused by nitrogen oxides are included, the total rate is 0.6 per thousand man years of operations. This corresponds to an accident frequency rate of 0.25 per million man hours of production, which compares very favorably with the frequency rates of 1.0 and 2.7 for the trinitrotoluene works and loading plants, respectively. It will be noted that while 12 cases of illness resulting in loss of time were reported for the second period there were only 2 cases reported for the following seven periods.

Cases of Mild Dermatitis and Other Effects.—There was a total of 1,846 cases of mild dermatitis and other effects, 778 of systemic poisoning and 1,068 of dematitis, from the various exposures shown in table 9, resulting in an over-all rate of 30 per thousand man years of operation. A high rate of 106 was reached in the second period, which declined sharply to an average of 18 for the last five periods. An especially pronounced reduction is observed in the case rates of systemic illness, which declined from 44 in the second period to an average of less than 3 for the last five periods, a reduction of over 90 per cent.

The mild systemic effects were caused chiefly by exposure to dinitrotoluene, although exposures to aniline, nitroglycerine, trinitrotoluene, ether, alcohol and acid each caused a fair number of cases. The cases of dermatitis were attributed to exposure to dinitrotoluene, tetryl, trinitrotoluene, acid, solvents, xylidine, dimethylaniline, double base powder and cutting oil.

Medical Transfers.—Medical transfers were not a serious problem in powder works, there being only 396, or 9 per thousand man years of operations. The dermatitis rate for transfers was almost constant throughout and averaged about 2 per thousand man years, whereas the systemic rate declined from 27 in the third period to an average of 2 for the last five periods. The transfers because of systemic illness were largely due to exposure to dinitrotoluene, while the transfers because of dermatitis were principally due to exposure to tetryl and dinitrotoluene.

D. IN MISCELLANEOUS CHEMICAL WORKS

An average total of 4,400 employees was engaged for an average of thirty-one months in the miscellaneous chemical works resulting in

11,400 man years of operations. Aside from the potential hazard of exposure to nitrogen oxides, which caused no illness resulting in loss of time, the occupational disease hazards were relatively slight as indicated in table 10.

Cases of Illness Resulting in Lost Time.—Only 16 cases of illness resulting in lost time were reported, 3 of systemic poisoning and 13 of dermatitis, which resulted in an over-all rate of 1.4 cases of illness resulting in lost time per thousand man years of operations. After a rate of 5 in the first period the rates for the succeeding eight periods averaged less than 1. The corresponding over-all standard frequency rate is 0.6 cases of illness resulting in lost time per million man hours of production, which compares favorably with the industrial groups described previously.

In 2 of the 3 cases of illness classified as systemic, the illness was due to the irritating effects of ammonium picrate on the upper respiratory tract, and in 1 it was due to similar effects of acids. Nine of the 13 cases of dermatitis were attributed to ammonium picrate, 2 to hexamethylene tetramine, 1 to a formate solution and 1 to solvents.

Cases of Mild Dermatitis and Other Effects.—There were 994 cases of mild dermatitis and other effects reported, 963 of dermatitis and 31 of systemic effects, resulting in an over-all rate of 87 cases per thousand man years of operations. The rates remained rather high from the third through the eighth period (164 to 149) but declined to 39 in the last period. The cases of systemic illness were attributed chiefly to exposure to carbon monoxide, while the cases of dermatitis resulted from exposure to ammonium picrate, hexamethylene tetramine, acids and solvents.

Medical Transfers.—Medical transfers were a problem of little consequence in these plants, being limited to 90 cases of dermatitis or a rate of 10 per thousand man years of operations. The chief causes were exposure to ammonium picrate, hexamethylene tetramine, acids and a formate solution.

E. IN SMALL ARMS AMMUNITION PLANTS

In the plants manufacturing small arms ammunition, an average number of 85,000 employees was engaged in production over thirty-three and one-half months, resulting in 237,400 man years of operations. Although there were many potential health hazards, they were well controlled, and very little systemic poisoning was reported. On the other hand, dermatitis was an important problem in many of the operations, as shown in table 11.

Cases of Illness Resulting in Lost Time.—There were 203 cases of illness resulting in lost time reported; 197 of dermatitis and only 6

TABLE 10.—*Occupational Illness and Medical Transfers Other Than from Exposure to Nitrogen Oxides Among Production Employees in Miscellaneous GOCO Chemical Works*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I	II	III	IV	V	VI	VII	VIII	IX		I	II	III	IV	V	VI	VII	VIII	IX	
	Through Feb. 45*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total	Through Feb. 45*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total Experience
Number of employees in production (in thousands)	4.9	5.7	5.5	5.8	3.9	4.4	4.2	3.7	3.5	4.4										
Number of months in period	5	3	3	5	3	3	3	3	3	31										
Number of 1,000 man years' operations	2.0	1.4	1.4	1.6	1.0	1.1	1.1	0.9	0.9	11.4	2.0	1.4	1.4	1.6	1.0	1.1	1.1	0.9	0.9	11.4
Number of Cases of Illness Resulting in Lost Time:																				
Systemic, miscellaneous	0	0	1	0	0	0	0	0	2	3	0	0	1	0	0	0	0	0	2	0.3
Dermatitis:																				
Ammonium picrate	7	0	0	0	1	0	0	1	0	9										
Hexamethylene tetramine	1	0	0	0	0	1	0	0	0	2										
Other	1	0	0	0	1	0	0	0	0	2										
Total	9	0	0	0	2	1	0	1	0	13	5	0	0	0	2	1	0	1	0	1.1
Total cases resulting in lost time	9	0	1	0	2	1	0	1	2	16	5	0	1	0	2	1	0	1	2	1.4
Number of Cases of Mild Illness:																				
Systemic Effects:																				
Acid	0	0	2	0	0	0	0	0	0	2										
Ammonia	0	0	0	1	0	0	0	0	0	1										
Carbon monoxide	0	0	0	0	0	0	3	18	7	28										
Total	0	0	2	1	0	0	3	18	7	31	0	0	1	1	0	0	3	20	8	3
Dermatitis:																				
Ammonium picrate	0	0	181	119	11	186	181	90	0	660										
Hexamethylene tetramine	0	0	0	65	28	32	20	25	28	208										
Acids	0	0	46	10	35	0	0	0	0	91										
Other	0	2	1	0	0	0	0	1	0	4										
Total	0	2	228	187	74	167	161	116	28	963	0	1	163	117	74	152	143	129	31	84
Total cases of mild illness	0	2	230	188	74	167	164	134	35	994	0	1	164	118	74	152	149	149	39	87
Number of Medical Transfers:																				
Systemic Effects	†	0	0	0	0	0	0	0	0	0	†	0	0	0	0	0	0	0	0	0
Dermatitis:																				
Ammonium picrate	...	8	0	0	0	4	11	1	11	39										
Hexamethylene tetramine	...	0	2	1	1	5	3	1	0	23										
Acids	...	0	0	3	4	0	0	0	0	13										
Other	...	9	0	0	1	0	0	0	0	10										
Total	†	18	21	6	6	12	14	2	11	90	†	13	15	4	6	11	13	2	13	10†
Total transfers	†	18	21	6	6	12	14	2	11	90	†	13	15	4	6	11	13	2	13	10†

* From beginning of operations.
† Transfers not reported for first period.

TABLE 11.—*Occupational Illness and Medical Transfers from All Causes Among Production Employees in GOCO Small Arms Ammunition Plants*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I	II	III	IV	V	VI	VII	VIII	IX		I	II	III	IV	V	VI	VII	VIII	IX	
	Through Feb. 43*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total	Through Feb. 43*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total Experience
Number of employees in production (in thousands)	95.6	166.8	155.8	118.9	45.9	31.5	24.4	26.5	42.2	85.0										
Number of months in period	7.5	3	3	5	3	3	3	3	3	33.5										
Number of 1,000 man years' operations	59.6	41.7	38.9	49.5	11.5	7.9	8.6	9.1	10.6	237.4	59.6	41.7	38.9	49.5	11.5	7.9	8.6	9.1	10.6	237.4
Number of Cases Resulting in Lost Time:																				
Systemic poisoning, miscellaneous	3	0	2	1	0	0	0	0	0	6	0	0	0.1	0	0	0	0	0	0	0
Dermatitis:																				
Cutting oils	72	34	25	21	9	3	3	2	2	161										
TNT	3	0	0	1	0	0	0	0	0	4										
Solvents	3	5	0	1	2	0	0	0	0	11										
Other	4	6	3	2	3	1	1	1	1	21										
Total	82	45	28	25	12	4	4	3	3	197	1.4	0.8	0.7	0.5	1.1	0.5	0.5	0.3	0.3	0.8
Total cases resulting in lost time	85	45	30	26	12	4	4	3	3	208	1.4	0.8	0.8	0.5	1.1	0.5	0.5	0.3	0.3	0.9
Number of Cases of Mild Illness:																				
Systemic Effects, miscellaneous	66	122	2	14	0	1	36	0	0	253	1	3	0	0	0	0	4	0	0	1
Dermatitis:																				
Cutting oils	620	477	726	934	236	278	216	231	230	4,222										
Solvents	105	123	129	8	7	3	6	6	15	402										
TNT	35	22	20	0	6	0	0	0	0	94										
Tracer or primer	0	5	122	3	4	1	0	0	0	135										
Smokeless powder	0	1	10	1	0	0	0	0	0	12										
Other	1,022	1,009	435	1,334	204	82	26	50	43	4,206										
Total	1,780	2,196	1,508	2,270	637	400	347	287	297	9,323	30	55	39	46	55	51	40	32	28	41
Total cases of mild illness	1,857	2,430	1,505	2,284	637	401	383	287	297	10,081	31	58	39	46	55	51	44	32	28	42
Number of Medical Transfers:																				
Systemic effects, miscellaneous	....	237	42	10	0	0	0	9	12	270	†	7	1	0	0	0	0	1	1	3
Dermatitis:																				
TNT	....	15	6	10	1	0	0	0	0	32										
Solvents	....	6	9	0	2	3	7	2	3	31										
Cutting oil	....	0	9	30	0	3	6	3	10	85										
Tracer and primer	....	0	21	0	1	0	0	0	0	22										
Other	....	166	18	255	54	0	1	0	5	498										
Total	....	186	63	295	58	10	14	4	18	648	†	4	2	6	5	1	2	0	1	4
Total medical transfers	†	422	105	305	58	10	14	13	30	1,018	†	12	3	6	5	1	2	1	2	61

* From beginning of production.
† Transfers not reported for first period.

of systemic poisoning, resulting in an over-all rate of 0.9 per thousand man years of operations, or a corresponding frequency rate of 0.4 per million man hours. The lost time rates dropped rapidly from 1.4 in the first period to 0.3 in the last two periods, a decline of 79 per cent.

Of the 6 cases of systemic poisoning, 2 were attributed to trinitrotoluene, 2 to lead and 2 to cutting oil mists. The cases of dermatitis resulting in loss of time were attributed chiefly to cutting oil, with solvents, trinitrotoluene, tracer and primer mixtures, Carboloy dust, drawing solutions and smokeless powder each contributing a few cases.

Cases of Mild Dermatitis and Other Effects.—There were 10,081 cases of mild dermatitis and other effects reported, 9828 of dermatitis and 253 of systemic effects, resulting in an over-all rate of 42 per thousand man years. The rates varied from a high of 58 in the second period to an average of 30 in the last two periods, a decline of almost 50 per cent.

The systemic effects were caused by barium salts, welding fumes, trinitrotoluene, cleaning fluid, lacquer fumes and trichloroethylene. The cases of dermatitis were attributed to cutting oils, solvents, tracer and primer mixes, trinitrotoluene, smokeless powder, Carboloy, acids and alkalis, drawing solutions, paint, soap, greases, uniforms and gloves, mercury fulminate and numerous other minor exposures.

Medical Transfers.—There were 1,018 workers sufficiently affected by toxic exposures to warrant a change of work, 370 from systemic effects and 648 from dermatitis, giving an over-all transfer rate of 6 per thousand man years. The rates by periods declined from a high of 12 in the second period to an average of 2 for the last four periods, a reduction of over 80 per cent. The chief causes for the transfers for systemic effects were lead, trinitrotoluene, paint and trichloroethylene, and the causes of the dermatitis resulting in transfers were chiefly cutting oil, trinitrotoluene, solvents, tracer and primer mix, Carboloy, dinitrotoluene and solvents.

F. IN ARSENALS

In the old line army-operated arsenals, occupational disease reports covered an average of 53,000 production employees over a period of 32.7 months, or 144,400 man years of operations. The different arsenals were engaged in many varied and changing activities during the present war and so were not strictly comparable with one another or with other industrial groups. The cases of illness resulting from exposure to trinitrotoluene and tetryl have been presented in preceding sections, and the remaining cases are shown in table 12.

Cases of Illness Resulting in Loss of Time.—There were reported 87 cases of illness resulting in lost time from miscellaneous causes, 24 of systemic effects and 63 of dermatitis, resulting in a rate of 0.6 per thousand man years of operations. The over-all rate for cases of illness

TABLE 12.—*Occupational Illness and Medical Transfers from All Causes Except TNT and Tetryl Among Production Employees in Government-Operated Arsenals*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total Experience
Number of employees in operations (in thousands)	54.4	57.8	61.1	40.2	40.2	64.2	64.7	56.6	54.0	53.0										
Number of months in period	6.7	3	3	5	3	3	3	3	3	33.7										
Number of 1,000 man years' operations	30.4	14.3	13.3	16.8	10.1	16.1	16.3	14.3	13.5	144.4	30.4	14.3	13.3	16.8	10.1	16.1	16.3	14.3	13.5	144.4
Number of Cases Resulting in Lost Time:																				
Systemic Poisoning:																				
Chemical Warfare Service chemicals	5	0	2	0	0	0	0	0	0	7										
Solvents	5	0	1	0	1	0	0	0	0	7										
Miscellaneous explosives	1	0	1	0	0	0	0	0	0	2										
Lead	0	0	0	2	0	0	0	0	0	2										
Carbon monoxide	0	0	0	0	0	0	0	5	1	6										
Total	11	0	4	2	1	0	0	5	1	24	0.4	0	0.3	0.1	0.1	0	0	0.4	0.1	0.2
Dermatitis:																				
Solvents	0	6	1	3	2	1	2	0	0	15										
Cutting oil	2	6	1	4	0	0	0	0	0	13										
Other	26	0	2	0	0	5	1	0	1	35										
Total	28	12	4	7	2	6	3	0	1	63	0.9	0.8	0.3	0.4	0.2	0.4	0.3	0	0.1	0.4
Total cases resulting in lost time	39	12	8	9	3	6	3	5	2	87	1.3	0.8	0.6	0.5	0.3	0.4	0.2	0.4	0.1	0.6
Number of Cases of Mild Illness:																				
Systemic Effects:																				
Carbon monoxide	10	15	0	1	1	0	1	10	1	39										
Solvents	6	0	1	0	0	1	0	0	1	9										
DNT	13	1	2	1	0	0	1	0	0	17										
Chemcial Warfare Service chemicals	12	0	3	0	0	0	0	0	0	15										
Lead	2	0	4	5	0	0	0	0	0	14										
Other	22	0	0	0	0	4	2	2	1	31										
Total	65	16	10	10	1	5	4	12	3	125	2	1	1	1	0	0	0	1	0	1

Dermatitis:																				
Solvents	31	42	36	37	43	58	38	48	64	398										
Cutting oil	56	42	40	31	23	270	54	76	121	712										
Tetrytol	18	45	3	0	22	0	0	0	0	88										
Rouge	24	0	3	7	1	1	0	1	0	37										
Chemical Warfare Service chemicals	10	0	118	4	0	2	0	0	0	129										
Powder	0	0	10	0	2	1	0	0	0	13										
Miscellaneous explosives	3	20	0	3	0	0	0	17	0	43										
Other	45	25	17	25	4	22	44	28	21	251										
Total	186	174	222	117	96	349	186	180	206	1,665	6	13	17	7	9	22	8	13	15	13
Total cases of mild illness	253	190	222	127	94	354	140	192	209	1,791	8	13	13	8	9	22	9	14	15	13
Number of Medical Transfers:																				
Systemic Effects:																				
Solvents	...	6	3	10	2	1	0	0	0	21										
Miscellaneous explosives	...	3	6	0	0	2	2	2	0	15										
Lead	...	0	12	10	0	0	0	1	0	23										
Other	...	0	0	0	1	0	0	1	0	2										
Total	†	9	21	20	3	3	2	4	0	61	†	1	2	1	0	0	0	0	0	1
Dermatitis:																				
Solvents	...	12	3	20	6	13	5	6	6	71										
Cutting oil	...	6	13	10	1	80	35	21	23	199										
Miscellaneous explosives	...	0	0	10	2	1	1	10	1	25										
Other	...	9	15	15	31	3	2	2	4	81										
Total	†	27	36	55	40	97	43	39	39	376	†	2	3	3	4	6	3	3	3	3
Total transfers	†	36	57	75	43	100	45	43	39	437	†	2	4	4	4	6	3	3	3	4†

* From beginning of report period.
† No transfers reported first period.

resulting in lost time is 0.9 if the 15 cases of illness due to trinitrotoluene and the 30 due to tetryl previously described are included. This corresponds with a standard accident frequency rate of 0.4 per million man hours, the same as that for small arms ammunition plants. There was a pronounced decline in the prevalence of cases of illness resulting in lost time with increasing experience, the rates dropping from 1.3 to 0.1 case per thousand man years from the first to the last period, a decline of 92 per cent.

The cases of systemic poisoning were due to exposure to solvents, lead, carbon monoxide, tracer powder, mustard gas and chlorine, while the cases of dermatitis were attributed to exposure to solvents, cutting oil, mustard gas, paint, ink and arsenic.

Cases of Mild Dermatitis and Other Effects.—There were 1,791 cases of mild dermatitis and other effects reported, 126 of systemic effects and 1,665 of dermatitis, giving a rate of 12 cases per thousand man years. There was slight improvement for case rates for systemic poisoning the last year, but there appeared to be little or no improvement for the cases of mild dermatitis. The systemic effects were caused chiefly by exposure to carbon monoxide, dinitrotoluene, lead, solvents, mustard gas, chlorine, nitroglycerine and incendiary mixtures, while the cases of dermatitis were attributed to exposure to cutting oil, solvents, tetrytol, rouge, creosote, mustard gas, incendiary mixtures, tear gas, smokeless and black powder, fulminate of mercury, protective oils, acids and alkalis.

Medical Transfers.—Medical transfers from these miscellaneous causes were not a serious problem, the over-all rate being 4 per thousand man years, 3 from dermatitis and 1 from systemic effects. Very few transfers were made because of systemic effects during the last five report periods, but the dermatitis transfer rates remained fairly uniform throughout excepting an elevated rate of 6 per thousand man years in the sixth period. The toxic exposures causing these transfers were essentially the same as described previously.

G. IN ORDNANCE DEPOTS

Occupational diseases were not a widespread problem in Ordnance depots, as a great majority of employees was engaged in handling finished products. There were, however, sufficient toxic exposures in maintenance shops and renovating operations to justify close supervision and control over those operations. Early in production there were a few plants loading trinitrotoluene, but this was largely discontinued. In these depots an average of 24,800 employees was engaged in operations over 32.1 months, resulting in 66,300 man years of operations.

TABLE 13.—*Occupational Illness and Medical Transfers from All Causes Among Employees in Ordnance Depots*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I	II	III	IV	V	VI	VII	VIII	IX		I	II	III	IV	V	VI	VII	VIII	IX	
	Through Feb. 43*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total	Through Feb. 43*	Mar. to May Incl.	June to Aug. Incl.	Sept. to Jan. 44 Incl.	Feb. to Apr. Incl.	May to July Incl.	Aug. to Oct. Incl.	Nov. to Jan. 45 Incl.	Feb. to Apr. Incl.	Total Experience
Number of employees in operations (in thousands)	21.6	25.7	28.9	26.7	23.3	24.2	29.4	23.6	23.0	24.8										
Number of months in period	6.1	3	3	5	3	3	3	3	3	33.1										
Number of 1,000 man years' operations	11.0	6.3	7.3	11.1	5.8	6.0	7.4	5.7	5.8	66.3	11.0	6.3	7.3	11.1	5.8	6.0	7.4	5.7	5.8	66.3
Number of Cases Resulting in Lost Time:																				
Systemic Poisoning:																				
TNT	9	0	5	0	0	0	1	0	0	15										
Nitrogen oxides	0	0	0	0	0	2	0	0	0	2										
Other	0	0	0	0	0	1	2	0	0	3										
Total	9	0	5	0	0	3	3	0	0	20	0.8	0	0.7	0	0	0.5	0.4	0	0	0.3
Dermatitis:																				
TNT	0	5	1	0	0	0	1	0	0	7										
Crate stain	0	0	0	10	1	2	1	0	0	14										
Other	0	2	0	1	2	2	0	0	0	7										
Total	0	7	1	11	3	4	2	0	0	28	0	1.1	0.1	1.0	0.5	0.7	0.3	0	0	0.4
Total cases resulting in lost time	9	7	6	11	3	7	5	0	0	48	0.8	1.1	0.8	1.0	0.5	1.2	0.7	0	0	0.7
Number of Cases of Mild Illness:																				
Systemic Effects:																				
TNT	284	6	46	0	0	9	6	1	12	363										
Solvents	0	0	2	0	0	1	6	0	0	10										
Other	0	0	2	2	0	2	0	0	0	6										
Total	284	6	50	2	0	12	12	1	12	379	26	1	7	0	0	2	2	0	2	6
Dermatitis:																				
TNT	221	0	13	0	1	0	13	13	5	277										
Solvents	15	0	6	7	6	6	4	21	13	78										
Crate stain	0	0	16	10	2	5	2	0	0	34										
Chemical Warfare Service chemicals	0	1	5	0	0	0	2	0	0	8										
Cutting oil	0	0	2	0	0	0	1	1	0	4										
Other	208	0	10	0	1	1	0	2	2	222										
Total	502	1	52	17	11	10	22	42	22	663	46	0	7	2	2	2	3	7	4	10
Total cases of mild illness	786	7	102	19	11	22	37	43	30	1,062	71	1	14	2	2	4	5	8	6	16
Number of Medical Transfers:																				
Systemic Effects:																				
TNT	...	15	60	0	0	0	1	1	12	89										
Other	...	0	3	0	0	0	0	0	1	4										
Total	†	15	63	0	0	0	1	1	13	93	†	2	9	0	0	0	0	0	2	2
Dermatitis:																				
TNT	...	9	15	0	1	0	2	1	0	28										
Crate stain	...	0	3	0	1	2	2	0	0	9										
Solvents	...	0	6	0	4	1	0	0	0	11										
Other	...	0	0	30	1	1	3	1	1	37										
Total	†	9	24	30	7	4	8	2	1	85	†	1	3	3	1	1	1	0	0	2
Total transfers	†	24	87	30	7	4	9	3	14	178	†	4	12	3	1	1	1	1	2	31

* From beginning of report period.
† Transfers not reported for first period.

Cases of Illness Resulting in Loss of Time.—There was a total of 48 cases of illness resulting in loss of time reported, 20 of systemic effects and 28 of dermatitis, resulting in an over-all rate of 0.7 per thousand man years of operations. This corresponds to a standard frequency rate of 0.3 per million man hours, which is slightly less than the frequency rates for arsenals and small arms ammunition plants of 0.4 and slightly more than the rate of 0.25 for smokeless powder works.

The cases of systemic poisoning resulting in lost time were caused by exposure to trinitrotoluene, nitrogen oxides, phosgene and carbon monoxide, while the cases of dermatitis were attributed to trinitrotoluene, pentachlorophenol, creosote and grease. No cases were reported in the last two periods, as is shown in table 13.

Cases of Mild Dermatitis and Other Effects.—There were 1,062 cases of mild dermatitis and other effects reported, 379 with systemic effects and 683 with dermatitis, resulting in an over-all rate of 16 cases per thousand man years. Most of the cases of systemic poisoning were due to exposure to trinitrotoluene and occurred early in production when several more of the depots were loading or renovating shells on a relatively small scale. The cases of dermatitis were chiefly caused by exposure to trinitrotoluene, although solvents, pentachlorophenol, cutting oil, mustard gas, creosote and acids all contributed a number of cases.

Medical Transfers.—Medical transfers were not a serious problem in the depots, as the total number was only 178, of which 93 were for systemic effects and 85 for dermatitis, with an over-all rate of 3 per thousand man years of operations. During the last five report periods the transfer rates averaged about 1 per thousand man years. The cases of systemic poisoning were practically all from exposure to trinitrotoluene, and the dermatitis cases were attributed to exposure to trinitrotoluene, solvents, pentachlorophenol, paint and grease.

H. IN PROVING GROUNDS

Reports on occupational diseases from the ordnance proving grounds covered an average of 7,200 employees in operations for thirty-eight months, or 22,600 man years of operations, as shown in table 14. Because of the nature of these operations relatively few employees were exposed to significant concentrations of toxic substances.

Cases of Illness Resulting in Lost Time.—There were 44 cases of illness resulting in lost time, 20 from systemic poisoning and 24 from dermatitis, resulting in a lost time rate of 1.9 per thousand man years of operations. The corresponding standard frequency rate is 0.8 per million man hours, which is the next highest to that of the loading plants (2.7) and of trinitrotoluene manufacturing works (1.0).

The cases of systemic poisoning were caused by exposure to carbon monoxide, gasoline, carbon tetrachloride and nitrogen oxides, while

TABLE 14.—*Occupational Illness and Medical Transfers from All Causes Among Employees in Operations at Ordnance Proving Grounds*

Report Period	Number of Cases										Rates per 1,000 Man Years of Operations									
	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total	I Through Feb. 43*	II Mar. to May Incl.	III June to Aug. Incl.	IV Sept. to Jan. 44 Incl.	V Feb. to Apr. Incl.	VI May to July Incl.	VII Aug. to Oct. Incl.	VIII Nov. to Jan. 45 Incl.	IX Feb. to Apr. Incl.	Total Experi. ences
Number of employees in production (in thousands)	9.7	9.7	5.0	5.5	6.6	5.9	5.6	5.0	5.2	7.2										
Number of months in period	12	3	3	3	3	3	3	3	3	36										
Number of 1,000 man years' operations	9.7	2.4	1.5	2.2	1.6	1.5	1.4	1.2	1.3	22.6	9.7	2.4	1.5	2.2	1.6	1.5	1.4	1.2	1.3	22.6
Number of Cases Resulting in Lost Time:																				
Systemic Poisoning:																				
Carbon monoxide	9	0	0	1	0	0	0	0	0	10										
Solvents	0	0	0	2	0	0	0	4	0	6										
Other	1	2	0	0	0	0	0	0	0	4										
Total	10	2	0	2	0	0	0	4	0	20	1.0	1.2	0	1.2	0	0	0	3.2	0	0.9
Dermatitis:																				
Solvents	7	0	0	2	0	4	1	0	1	15										
Cutting oil	1	0	0	0	0	0	0	0	0	1										
Other	3	2	0	0	1	0	0	0	1	8										
Total	11	2	0	2	1	4	1	0	2	24	1.1	1.2	0	0.9	0.6	2.7	0.7	0	1.5	1.1
Total cases resulting in lost time	21	4	0	4	1	4	1	4	2	44	2.2	2.5	0	1.9	0.6	2.7	0.7	3.2	1.5	1.9
Number of Cases of Mild Illness:																				
Systemic Effects:																				
Carbon monoxide	58	1	0	0	1	0	0	0	0	60										
Nitroglycerine	0	0	0	0	0	18	12	4	0	34										
TNT	4	0	0	0	1	0	0	0	0	5										
Other	0	1	1	0	0	0	0	8	24	36										
Total	62	2	1	0	2	18	12	12	24	129	6	1	1	0	1	12	9	10	18	0
Dermatitis:																				
Solvents	117	30	30	47	16	21	11	19	12	312										
TNT	4	0	0	2	0	2	0	0	0	8										
Miscellaneous explosives	5	0	0	0	0	0	2	0	0	7										
Other	1	6	6	5	1	0	0	1	3	23										
Total	127	45	36	54	17	23	13	20	15	350	13	19	20	22	11	15	9	17	12	15
Total cases of mild illness	184	48	37	54	19	41	25	32	39	479	19	20	21	22	12	27	18	27	30	21
Number of Medical Transfers:																				
Systemic, miscellaneous	...	0	0	0	2	2	0	2	0	6										
Dermatitis, miscellaneous	...	2	0	20	0	4	2	0	1	30										
Total	†	2	0	20	2	6	2	2	1	36	†	1	0	9	1	4	1	2	1	2†

* From beginning of report period.
† No transfers reported for first period.

the cases of dermatitis were attributed largely to solvents, cutting oil and poison ivy.

Cases of Mild Dermatitis and Other Effects.—A total of 479 cases of mild dermatitis and other effects was reported, 129 from systemic effects and 350 from dermatitis, resulting in an over-all rate of 21 cases per thousand man years of operations. The prevalence of cases of mild illness appeared rather irregular, and no definite trend is observed by report periods. The cases of systemic poisoning were caused by carbon monoxide, nitroglycerine, trinitrotoluene, nitrogen oxides, gasoline and acetylene, while the cases of dermatitis were caused principally by solvents, trinitrotoluene, poison ivy, cutting oil, smokeless powder, soap and miscellaneous explosive compounds.

Medical Transfers.—The transfer of workers to jobs free from exposure because of occupational disease at the proving grounds was a minor problem. Only 36 transfers were made, chiefly because of exposure to solvents, double base powder, trinitrotoluene and acetylene, resulting in a rate of 3 transfers per thousand man years of operations.

I. IN BAG LOADING PLANTS

An average of 9,100 employees was engaged in operations in bag loading plants for a period of forty-three months, resulting in 32,500 man years of operations. There were practically no uncontrolled health hazards associated with these operations, and consequently very few occupational diseases were reported. There was only 1 case of illness resulting in lost time reported, a worker with cutting oil dermatitis, which results in a rate of 0.03 per thousand man years or an accident frequency rate of 0.01, by far the lowest for all industries. Nine cases of mild illness were reported, 8 of dermatitis attributed to black powder, and 1 of dermatitis thought to be due to handling powder bags. Six medical transfers resulted from exposure to black powder. The lack of any poisoning or dermatitis from handling large quantities of finished single base smokeless powder strongly indicates that this compound is not a significant health hazard.

VIII. SUPPLEMENTAL REPORT COVERING OCCUPATIONAL DISEASE EXPERIENCE FOR PERIOD X, MAY THROUGH JULY 1945

Since the preceding sections were written and the graphs and tables were prepared for the first nine report periods, occupational disease data have been received for the tenth period including the months of May, June and July 1945. Shortly thereafter, on Aug. 14, 1945, the surrender of Japan was announced, and the manufacture of explosives was largely discontinued. It is not believed that the short remaining

experience during the first two weeks in August would appreciably affect the report and no cases of serious illness have been reported for this period. Accordingly, the addition of the data for the tenth period as a supplement to this report will present the complete experience with occupational diseases for government-owned ordnance explosives establishments during production in World War II.

TABLE 15.—*All Cases of Occupational Disease in All Assigned Government-Owned Plants for Report Period IX and X and for All Ten Periods*

Report Period	Number of Cases			Rates per 1,000 Man Years of Operations		
	X (Last)	IX (Preceding)	Total (10 Periods)	X (Last)	IX (Preceding)	Total (10 Periods)
Number of Employees in Operations:						
Bomb and shell loading plants	51,000					
TNT manufacturing works	28,700					
Powder works	33,400					
Arsenals	45,600					
Miscellaneous chemical works	2,500					
Small arms ammunition	35,600					
Ordnance depots	18,800					
Proving grounds	5,800					
Bag loading plants	7,000					
Total	211,400	262,900	909,000			
Number of months of operations	2	2	87.5			
Number of 1,000 man years' operations	53	66	968	53	66	968
Number of deaths	1	0	28	0.02	0.00	0.03
Number of Cases Resulting in Lost Time:						
Systemic poisoning	31	35	754	0.6	0.5	0.8
Dermatitis	43	82	1,531	0.8	1.2	1.6
Total	74	117	2,285	1.4	1.8	2.4
Number of Cases of Mild Illness:						
Systemic effects	1,066	1,226	23,417	20	19	24
Dermatitis	2,120	2,592	73,118	40	39	76
Total	3,186	3,818	96,535	60	58	100
Number of Medical Transfers:						
Systemic effects	834	909	9,965	18	14	14
Dermatitis	260	608	12,190	5	9	17
Total	1,194	1,517	22,155*	23	23	31*

* Transfers not reported for first period.

The additional experience for the tenth report period is discussed briefly under the same general headings as for the preceding periods, comparisons are shown and the new over-all totals are presented.

All Occupational Diseases in All Plants.—Table 15 presents the data for the tenth period showing all occupational diseases for all assigned plants. It will be noted that the rates for the tenth period are extremely close to those of the ninth period. There is a slight improvement in cases of illness resulting in lost time, a very slight increase in cases of mild or nondisabling illness, and the medical transfer rate remains the same as in the ninth period. The over-all picture suggests that the occupational disease rates have become stabilized at a low level. Com-

parison of the total rates for all ten periods in table 15 with the total rates for all nine periods in table 2 shows the same over-all rate for cases of illness resulting in lost time and a very slight improvement for cases of mild illness and medical transfers. One death from trinitrotoluene poisoning occurred in a loading plant during the tenth period, bringing the total number of occupational disease fatalities to 28, less than 3 fatalities per hundred thousand production employees per year.

Cases of Illness Resulting in Lost Time.—There were 74 cases of illness resulting in lost time reported in the tenth period, 31 from systemic poisoning and 43 from dermatitis, making a rate of 1.4 cases of illness resulting in lost time per thousand man years of operations. This compares favorably with the rate of 1.8 per thousand man years for the ninth period and with the over-all rate of 2.4 for all ten periods covering an average of 37.6 months of production for 309,000 employees. Fifty-three of the cases of illness resulting in lost time occurred in the loading plants, 38 from exposure to trinitrotoluene, 13 from tetryl, and 2 from solvents. Nine cases of illness resulting in lost time occurred in the trinitrotoluene manufacturing works, 4 from exposure to trinitrotoluene, 1 from nitrogen oxides, and 4 from synthetic rubber gloves. Six cases of illness resulting in lost time were reported from the small arms ammunition plants from exposure to cutting oil. There were also reported 1 case from exposure to nitrogen oxides in the powder works, and 3 cases in the arsenals and 2 in the depots from exposures to solvents and to miscellaneous substances.

Cases of Mild Dermatitis and Other Effects.—There were 1,066 cases of mild systemic effects and 2,120 cases of mild dermatitis reported for the tenth period, resulting in a rate of 60 cases of mild illness per thousand man years of operations as compared with rates of 60 and 58 for the eighth and ninth periods and an over-all rate of 100 for all ten periods. This appears to be a well stabilized rate for the last three periods after a rapid decline from a high of 124 in the first period—a reduction of more than half. A review of the cases by cause and by industrial groups indicates the same trends as described previously.

It is again emphasized that the great majority of these cases were relatively insignificant from a medical viewpoint and would not be reported and tabulated under most reporting procedures. They are shown here merely to indicate the extent of the problem of occupational diseases and as an additional index of the success of control measures.

Cases Resulting in Medical Transfers.—Almost 1,200 patients presented sufficient signs or symptoms of toxic exposures in the tenth period to warrant their transfer to another job, giving a rate of 23 transfers per thousand man years of operations. This is the same rate as that for the ninth period, but the proportion of cases of systemic

illness and of dermatitis has changed as will be noted in table 15. As the rate of transfers because of dermatitis was reduced by about 75 per cent during the last five periods, the rate of transfers for systemic effects approximately doubled during the last two periods. This increase is accounted for by three loading plants and does not represent the industry as a whole. It will be noted, however, that the total transfer rate averaged only 22 per thousand man years for the last four quarterly periods, about half of the peak rate of 44 in the third period despite a tremendous increase in production. This decline represents a very large saving in production costs and man hours.

A review of the individual plant reports for the tenth period indicates the same general causes for transfers and the same trends as reported in preceding sections.

SUMMARY AND CONCLUSIONS

This report shows the results of an extensive industrial health and hygiene program on the incidence of occupational diseases in one hundred and one government-owned ordnance explosives establishments with an average of 309,000 operating employees who had potential exposure to many toxic materials. The ten report periods cover an average of more than thirty-seven months of operations during World War II for plants that produced 95 per cent of all military explosives in the United States.

The coordinated resources of the Ordnance Department, the Medical Department and the United States Public Health Service were fully utilized in this effort to prevent occupational illness and to bolster the production of ammunition by keeping workers fit and on the job. Semi-annual to annual industrial hygiene surveys were made of all plants presenting significant health hazards by teams of trained physicians, engineers and chemists, and resulting recommendations for improving medical services and controlling health hazards were followed up and enforced through operational channels. Research was done on the toxicology of explosives, and meetings were held with plant physicians and engineers to bring together all new information and experience. Special technical consultations and studies were available to the plants as new problems arose, and correspondence on technical matters was maintained. Circulars were distributed to the plants giving timely information on subjects concerning health and hygiene.

In these 968,000 man years of operations there were only 28 fatalities because of occupational disease, 22 from trinitrotoluene, 3 from nitrogen oxides, 2 from carbon tetrachloride and 1 from ethyl ether—a rate of less than 3 fatalities per hundred thousand workers per year. Of these 28 fatalities only 6 occurred in the last eighteen months of the war. The fatality rate is but a small fraction of that shown by

incomplete reports for limited explosives production during World War I.

During World War II there were only 2.4 cases of occupational illness and dermatitis sufficiently severe to cause loss of time from work per thousand man years of production. The quarterly rates were reduced from a peak of 3.8 in the spring of 1943 to an average of 1.4 for the last year of operations, a decrease of 63 per cent, despite a great increase in production. Dermatitis accounted for two thirds of these cases of illness resulting in lost time which leaves the more serious general or systemic type of poisoning with an over-all rate of less than 1 (0.8) case per thousand man years of production.

Trinitrotoluene poisoning among the 76,000 operating employees in shell and bomb loading plants was by far the principal health problem in the nine industrial groups here presented and accounted for 19 of the total fatalities, but only 5 of these occurred in the last eighteen months of production as compared with 14 in the preceding twenty months. Among an average of 16,700 employees actually exposed to significant concentrations of trinitrotoluene in these plants, the case rates for illness resulting in loss of time fell from a peak of 29 per thousand man years of exposure in the spring of 1943 to an average of less than 8 for the last 6 quarterly report periods, a reduction of over 70 per cent despite a great increase in production.

In the trinitrotoluene manufacturing works, among an average of 5,600 employees exposed to trinitrotoluene in forty months of operations, there was only one fatality due to trinitrotoluene, and the rates of cases of illness due to trinitrotoluene which resulted in loss of time declined from a peak of 12.7 per thousand man years of exposure in the first report period to an average of less than 2 during the last seven report periods, a reduction of 85 per cent.

Similar improvement was noted in the control of disability caused by exposure to tetryl and nitrogen oxides. In the three industrial groups, loading plants, manufacturing works and arsenals, offering significant exposures to tetryl among an average of 163,000 employees, the case rate of illness resulting in loss of time dropped from 1.5 in the first report period to an average of 0.6 for the last six report periods, a reduction of more than 65 per cent. Exposure to the oxides of nitrogen was a potential hazard to the 59,500 operating employees in the powder works, trinitrotoluene works and miscellaneous chemical works. Three fatalities resulted in a rate of less than 2 deaths per hundred thousand man years of operations, and none occurred in the last five quarterly report periods. Less than 1 case (0.8) of disabling illness occurred per thousand man years of operation, and the lost time rates declined from a peak of 1.9 in the second report period to an average of 0.15 per thousand man years in the last six report periods, a reduction of over 90 per cent.

Cases of mild or nondisabling occupational diseases were reported along with the cases of illness resulting in lost time. These were usually of little significance from a medical viewpoint but served as an additional index as to the scope of the problems involved and the success of the control program. The trend and distribution of cases of mild dermatitis and other effects resulting from different exposures were very similar in pattern to those of the cases of illness resulting in lost time. Among all operating employees in all plants, the case rate for mild dermatitis and other effects from all exposures dropped rapidly from a peak of 124 per thousand man years of operations in the first report period to an average of 59 for the last three periods, a reduction of more than half. With regard to the more serious exposures, the reduction in cases of mild illness from trinitrotoluene, tetryl and nitrogen oxides was even greater, as shown in the sections describing these effects.

Workers showing some signs or symptoms of toxic exposures were transferred to other jobs by the plant medical departments as a precaution against disabling illness until the exposures could be controlled more effectively. These cases were largely of little significance, but better control of the exposures and personal hygiene reduced the need for medical transfers, resulting in more efficient production and a considerable saving in costs.

The rate of medical transfers for all exposures in all plants dropped from a peak of 44 per thousand man years of operations in the third report period to an average of 22.5 for the last four report periods, a reduction of almost half—and despite a great increase in production. It is believed that from an economic viewpoint alone this reduction in the need for transferring workers away from their jobs more than justified the whole industrial hygiene program.

So far as is known, this is the first large scale demonstration of what a vigorous industrial health and hygiene program can accomplish by preventing illness and conserving man power in a large industry presenting exposures to many poisonous compounds. During more than thirty-seven months in World War II, despite the difficulties associated with rapidly increasing production of explosives, unskilled labor, a fairly high labor turnover and frequent changes of production processes and schedules, a considerable reduction was effected in the prevalence of fatal, disabling and nondisabling illness from occupational disease and in the transfer of workers away from their regular jobs because of occupational diseases.

Also, despite the magnitude of explosives production, the total of 22 fatalities due to trinitrotoluene reported here is but a small fraction of the 475 fatalities reported from trinitrotoluene and related compounds during limited production in World War I. From all available evidence

it is believed that the results of this industrial hygiene program in World War II compare favorably with those of the Ordnance safety program. The Chief of Ordnance has reported that during World War I facilities of the United States which produced 40 per cent of military explosives used by the Allies reported a ratio of 230 fatalities per billion pounds (per four hundred and fifty million Kg.) of explosives manufactured. In this war the government-owned, contractor-operated plants producing 95 per cent of all United States military explosives have suffered only 5 fatalities per billion pounds of explosives produced.

Full acknowledgment is made to the many agencies and persons who made this industrial hygiene program possible. Among others are the Director of Safety and his staff of the Safety and Security Division of the Ordnance Department for their keen appreciation of industrial hygiene problems and their hearty cooperation; the directors and personnel of the Occupational Health Division of The Surgeon General's Office and the Division of Industrial Hygiene of the United States Public Health Service for the many, painstaking plant surveys and studies; the Industrial Hygiene Research Laboratory of the National Institute of Health for valuable toxicologic research both in the laboratory and in the plants; the state industrial hygiene divisions for their services to privately owned plants, and all the plant medical, engineering and safety departments for their invaluable and conscientious work in maintaining the highest possible health and hygiene standards.

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