

U. S. DEPARTMENT OF LABOR
BUREAU OF LABOR STATISTICS

ROYAL MEEKER, Commissioner

BULLETIN OF THE UNITED STATES } . . . { WHOLE
BUREAU OF LABOR STATISTICS } . . . { NUMBER 219

INDUSTRIAL ACCIDENTS AND HYGIENE SERIES: NO. 14

INDUSTRIAL POISONS USED
OR PRODUCED IN THE MAN-
UFACTURE OF EXPLOSIVES

ALICE HAMILTON, M. A., M. D.



MAY, 1917

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

CONTENTS.

	Page.
Introduction	5-13
Physiological action of poisons	14-57
Nitration	14
Nitrogen oxide poisoning—"Fume sickness"	14-23
Nitric acid	23, 24
Sulphuric acid fumes (sulphur dioxide)	24
Mixed acids	24
Benzol and toluol, or methyl benzol	25-27
Phenol, or carbohc acid	27-29
Nitro and amido derivatives of the benzene series	29-48
Picric acid	33-35
Trinitrotoluol, or toluol or triton or trotyl or TNT	35-45
Nitronaphthalenes	45
Nitrobenzol	45, 46
Nitrochlorbenzol and dinitrochlorbenzol	46
Anilin	46, 47
Diphenylamin	47
Dimethylanilin	47
Tetranitranilin	47, 48
Tetrañitromethylanilin or tetryl	48
Nitroglycerin	48-50
Mercury	50
Fulminate of mercury	50, 51
Ethyl nitrite	52
Ammonia gas	52
Ammonium nitrate	52, 53
Amyl acetate	53
Acetone	53
Chlorine gas	53, 54
Alcohol and ether	54-57
Influence of alcohol on poisoning from volatile compounds	57-59
Manufacture of poisons	59-92
Nitric acid	59, 60
Sulphuric acid	61, 62
Acid recovery	62
Nitrocellulose	62-70
Centrifugal or mechanical nitration	63-66
Pot nitration or direct dipping	66-69
Displacement process	69, 70
Smokeless powder and military gun cotton	70-72
Picric acid	72-76
Phenol	76-79
Nitroglycerin	79, 80
Trinitrotoluol	80-84

	Page.
Manufacture of poisons—Continued.	
Filling shells with trinitrotoluol	84-88
Nitronaphthalenes	88
Nitrobenzol and anilin	88, 89
Tetryl	89, 90
Diphenylamin	90
Fulminate of mercury	90-92
Ammonium nitrate	92
Prevention of industrial poisoning in the manufacture of explosives	92-98
Records from three model plants	97, 98
Treatment	99-102
Appendix A.—Safety standards of industrial board, Pennsylvania Department of Labor and Industry	103-115
Appendix B.—Rules and regulations suggested for safety in the manufacture of benzene derivatives and explosives, Massachusetts State Board of Labor and Industries	116-120
Appendix C.—TNT manufacture in Great Britain—precautionary measures .	121-130
Appendix D.—Tentative safety standards of the State of Pennsylvania for the manufacture of nitro and amido compounds	131-138

BULLETIN OF THE U. S. BUREAU OF LABOR STATISTICS.

WHOLE NO. 219.

WASHINGTON.

MAY, 1917.

INDUSTRIAL POISONS USED OR PRODUCED IN THE MANUFACTURE OF EXPLOSIVES.¹

BY ALICE HAMILTON, M. A., M. D.

INTRODUCTION.

The European war has made the munitions industry a very important one in the United States. Up to the outbreak of the war the manufacture of explosives in this country was largely limited to what is known as peace explosives, for mining and construction operations and for agriculture, but the demand from Europe for war-time explosives met with a quick response. Works were erected to manufacture guncotton, picric acid, trinitrotoluol, and other high explosives, and for filling shells with such charges. From time to time we are told that the rush of contracts is over, but there is still much of this work done for exportation. Nor is it to be regarded as a temporary industry, one that may be ignored as of little risk to the health of the workers, because it will come to an end with the present war. Even if the demand for munitions should cease with the declaration of peace there is every probability that these factories will still be utilized, if not for the manufacture of high explosives, then for the making of closely allied products. Formerly we imported benzol and toluol from Germany; now, because they are indispensable for the production of explosives, we have learned to distill them, and certainly we shall continue to do so and to apply them to many uses for which formerly they were too expensive. Carboic acid was imported. It is now made here in great quantities and will continue to be. Plants built and equipped to make guncotton may be used to make celluloid and picture films. It is probable that some of these newer explosives may take the place of nitroglycerin for blasting and excavating. So it would be a great mistake to look upon the industry as accidental and transient. It is a permanent addition to American industrial life and deserves careful scrutiny lest the dangers due to its hasty beginning and rapid growth become fastened upon it.

¹The technical parts of this report have been submitted to several experts in the chemistry and manufacture of explosives.

We have manufactured nitroglycerin for many years, and, to a small extent, fulminate of mercury, guncotton, smokeless powder; even trinitrotoluol in one plant, but it was only in a few long-established works that the dangers involved in the industry were well understood, and there were only a few doctors connected with these companies who knew anything about the industrial poisons that were encountered in the different processes. When the new plants sprang up after the war began they were, many of them, experimental in every sense of the word. Speed was the essential consideration—to fill the contract within the specified time limit. Everything else was of minor importance. Even some of the old-established companies erected new plants in great haste and put up with conditions far worse than they ever had permitted before the war. On the other hand, new companies that had been fortunate enough to secure the services of men experienced in the manufacture did, in rare instances, produce model plants.

Haste has been the chief evil in this industry since the outbreak of the war. Contracts were accepted that had to be filled within a certain time; construction was started, but lagged because of shortage of labor and delay in the delivery of machinery, and naturally everything that was needed for the protection of the workmen was postponed in favor of what was essential for production. Men were found working in buildings half finished. Fumes were heavy, because exhausts had not yet been installed. One factory, which is said to represent an investment of several million dollars, operated for 17 months with practically no exhausts to carry off very dangerous fumes, with no medical care for the men, and without any provision for personal cleanliness. In the heat of last July and August the workmen would leave the plant covered with the poisonous dust in which they had been working, and, with unwashed hands, would collect in the shade of a railway bridge to eat their lunch.

Another "war bride" plant was in process of construction but was already employing several hundred men. It was out in the country, and attempted to house some of its workmen near the plant in some old farmhouses, renting the beds to both day and night shifts. The men were working regularly 12 hours out of the 24, but occasionally they were induced to increase it to 14 hours. Much of this time was spent in an atmosphere full of nitrous fumes or of picric acid dust, for there had been no time to complete any effective system for the prevention of these dangers. There were no lavatories, and a visit to the lunch room built by the company showed a crowd of men, with unwashed hands, eating their noon meal, and a fine coating of yellow picric acid dust was smeared over the lunch counter.

There is no way of knowing how much illness and death resulted from the mad rush during the first months of the war, before the

factories were in a position to carry on the work properly, to get out the product.

Another thing that led to sickness in this work was its unfamiliarity. It involved new problems in engineering that had to be solved by men with little or no experience with these substances and reactions. So many of the more serious cases were engineers and chemists who took risks to which they would not subject others, and suffered in consequence. Undoubtedly also the newness of the substances employed and of their by-products was responsible for many accidents. It is plain that in some plants the occurrence of a serious case of poisoning was the first thing that aroused the management to the fact that a certain process was really dangerous. Naturally in a factory making explosives the danger of explosion is so great that it first attracts attention, and the danger of poisoning, less spectacular, but perhaps just as great, is not recognized till something startling happens.

Still another evidence of the newness and unfamiliarity of this industry is seen in the large number of cases of poisoning that occurred through some accident, something not inherent in the process. Repairing stills or retorts which have been filled with poisonous fluids is a fruitful source of serious poisoning. Others are leaking pipes which let fumes escape, or violent decomposition with the production of poisonous vapors, or a too rapid reaction producing a "boil-over." Such accidents tend to become rarer all the time, but they were frequent in the early months when the industry was still in the experimental stage.

If chemists and engineers were faced with a new problem, this was even more true of the physicians living in the neighborhood of explosives works. Such occurrences as cyanosis and syncope from nitrobenzol fumes, of toxic hepatitis from trinitrotoluol, of edema of the lungs from nitrous fumes, were totally new experiences to the ordinary physician, and there was very little in the medical literature to help him. If his practice was near the factory he was at least able to connect the illness with the occupation, and by careful observation he could build up for himself a picture of that form of industrial poisoning; but if, as is often the case, the workmen were drawn from many scattered towns, the physicians in those towns had no reason to suspect that the symptoms complained of by their patients were occupational in origin. This makes it extremely difficult to trace cases of poisoning in this industry, and it also explains why men who were suffering from symptoms that should have been regarded as grave were allowed to go back to work in a poisoned atmosphere till they were so ill they gave up of their own accord. Several of the histories we secured of deaths from occupational poisoning show that if the condition had been recognized in the early stages the victim might have been saved.

All these features of the industry are improving, but unevenly and incompletely. There are fewer accidents to machinery, fewer unexpected reactions; the services of physicians are usually provided, and these physicians are far better fitted to cope with the problems than they were at first; there are more experienced workmen, which means less blundering. On the other hand, labor is still hard to get, and foremen are therefore often unwilling to shift or discharge a workman who shows suspicious signs and who should be relieved of work exposing him to poisons. There is still a great labor turnover; still many men entering the industry utterly ignorant of any danger except that of explosion, and the shortage of labor often leads a shortsighted management to refrain from giving proper instructions to these men for fear of frightening them away. Labor shortage also leads to the evil against which the British committee on the health of munition workers has spoken so emphatically—working overtime. Fatigue quickens and strengthens the effect of poisons of all kinds.

For all these reasons it seems timely to set forth in detail the conditions in this industry as they existed in the spring, summer, and fall of 1916, recognizing the fact that during the months that have elapsed since November, 1916, improvements may have taken place in some of these plants and that some of the worst have either been destroyed or shut down. The conditions described are still to be found in this industry in the United States, and some of the dangers are inherent in the industry and will always have to be guarded against. The poisons whose physiological effects will be described are those that will always be encountered in this work, and it is most important that superintendents and physicians learn to recognize their action and learn how other more experienced countries have guarded their workers against them.

Description of the industry.—The making of black powder, ordinary gunpowder, does not carry with it any danger of occupational poisoning, and it is not included in this study. The explosives that do involve in their manufacture several poisonous substances are the following:

	Plants.
Nitrocellulose, or nitrocotton, including pyroxylin and military guncotton	13
Smokeless powder, including nitroglycerin powders	10
Picric acid and ammonium picrate	11
Nitroglycerin and dynamite	7
Trinitrotoluol, or TNT or triton (made in 4, handled in 4)	8
Fulminate of mercury (made in 2, handled in 3)	3
Tetranitraniline, or TNA	1
Tetranitromethylanilin, or tetryl	2
Nitronaphthalenes	1
Ammonium nitrate (made in 4, handled in 8)	8

Dangerous substances are also used in the production of these explosives, and they are included in the study. They comprise the following list:

	Plants.
Nitric acid (made)-----	15
Sulphuric acid (made)-----	5
Benzol and toluol (made)-----	3
Nitrobenzol (made)-----	1
Anilin oil (made)-----	1
Chlorbenzol and dinitrochlorbenzol (made)-----	1
Phenol or carbolic acid (made in 7, handled in 11)-----	11
Sulphuric ether (made in 5, handled in 10)-----	10
Mercuric nitrate (made)-----	2
Amyl acetate (made in 1, handled in 2)-----	2

Other compounds with toxic properties more or less pronounced are used in making explosives, but were not manufactured in any of the plants visited:

	Plants.
Ammonia -----	3
Caustic soda or sodium hydrate-----	6
Chile saltpeter or sodium nitrate-----	15
Acetone -----	4

Finally, there are certain poisons that are evolved in the course of chemical reactions, as by-products, or in intermediate stages in the making of explosive compounds. Some of these are the most important poisons encountered in the explosives industry:

- Oxides of nitrogen or nitrous fumes. In all processes of nitration.
- Sulphur dioxide. In making carbolic acid.
- Chlorine gas. In making nitric acid.
- Ethyl nitrite. In making mercury fulminate.

These compounds vary greatly in their toxicity, some of them producing only disagreeable skin eruptions, others being rapidly fatal after a short exposure.

Distribution of the industry.—Much of the work for export is done on the Atlantic seaboard, New Jersey leading among the States. The factories that were visited in the course of this investigation are situated in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and Indiana. There are 41, employing a total force of about 90,000 workers, but the number of those whose work brings them in contact with poisons is only about 30,000, and this study was confined to such processes as involve exposure to poisons. We did not take account of accidents from explosions, nor of acid burns, only of occupational sickness. Visits were made during the early spring, the heat of midsummer, the late fall, and early winter, so that it was possible to estimate the difference in conditions caused by variations in temperature and atmosphere

Character of employees.—Thirty thousand persons are needed to make up the force employed at any time in work exposing them to poisons, but a much larger number of people is so exposed during the year, for the labor turnover is extraordinarily great in this industry, and greatest in just those departments where poisonous fumes and dusts exist. In one very admirably managed plant it was necessary to employ about 4,000 men during 13 months to keep up a force of 200. In another on one day in April, when nothing exceptional had happened, 249 men quit or were discharged, and 225 new men were taken on. The physician in charge of a plant employing 3,800 men showed his record of physical examinations of men applying for employment and needed in the plant. In four months he had examined no less than 4,307 men.

The great majority of those employed in these processes in American factories are men. Very few women or girls are found employed in work exposing them to poisonous gases or dusts. In places where percussion caps are made large numbers of women come in contact with fulminate of mercury, but that is among the least dangerous poisons on our list and rarely causes any trouble more serious than an itching eruption on face and hands. One plant which fills high-explosive shells employs women in work necessitating the handling of trinitrotoluol, tetranitranilin, and tetryl, all dangerous poisons. Here there have been serious cases of occupational disease among the women, but in none of the other places where similar work is done are women employed. The absence of boys also is very noteworthy.

The nationality of the force varies according to the locality. In a large works in Virginia many Americans were found doing the skilled and semiskilled work, while in the unskilled occupations there were Roumanians and Syrians and Greeks. In New Jersey there are many Negroes, especially in the newer plants, where they sometimes do all the dangerous work except the supervision. Since many of the companies manufacturing for export to the allies have to refuse men who come from the territory of the Central Powers, the demand for Negroes is unusually great, and there is also an unusual number of Russians and Italians employed.

Wages and housing.—It is probably fair to say that, on the whole, wages are high and living conditions poor in many of these places. Necessarily the new plants have had to be built at a distance from centers of population—even from villages—because of the dread of explosions. Consequently the force has had to be housed in whatever quarters could be hastily secured; in old farmhouses transformed into barracks; in shacks built to last only a few months; even in tents. These provisions have never been adequate, and men have traveled miles every day to reach the plant from their lodgings in

the nearest town. Even there accommodations were insufficient and rooms have been rented to more than one shift of men. In one charming old town, with every appearance of comfort and prosperity, three shifts of men were found sleeping in the lodging houses, the men renting beds for eight hours and then giving them up to the next shift.

In contrast to such a condition are the model villages erected near some of the big powder plants, especially those owned by the old established companies. Here the housing may be excellent, the sanitation beyond reproach, the sanitary control adequate. Yet even in these places, the provision for the foreign workman who has no family with him, or for Negroes, may be quite different. Overcrowded barracks with three-decked cots, with far too little air space, and with no water supply except from hydrants out of doors, are put up for these men by the very companies that furnish such healthful accommodations for their white American employees.

Hours of work.—Three shifts of eight hours each are the rule in this industry, two shifts the exception. Four plants work the men in two shifts and one of these has even urged them to work overtime for 14 or 16 hours when labor was scarce. It is sometimes hard to prevent men who are on eight-hour shifts from working two shifts and making double pay, and, of course, if the foreman is short of help he will wink at this, but it means that the man is incurring a grave risk of poisoning.

Amount of industrial poisoning discovered in this inquiry.—It is impossible to give accurate figures as to the amount of sickness and death caused by work in this industry since the war broke out, for the information can not be secured. Many cases were never recognized, many others were seen by company physicians or insurance physicians, who are unwilling to give any information or tell anything about them. In each of the better factories there is usually a physician employed by the company who sees all but a few of the cases of sickness in the force. He may be unwilling to give information that might seem damaging to his employers, or he may not be able to give it because he has kept no records and has only a general impression, no detailed knowledge. He can strengthen the impression already gained that there is poisoning in connection with certain kinds of work, but he can not add specific cases to the list. Then there are factories, some of them employing hundreds of men, where there is either no medical care or it is so inadequate as to be of little use. In such a factory the general carelessness and indifference to the welfare of the men are so great that nobody can be found who is in a position to give trustworthy information about sickness in the working force. If the men fall ill they quit work and go to some

doctor in a neighboring town who may know nothing about the sort of work they have been doing and therefore never thinks of reporting the case as one of occupational poisoning. One physician writes as follows, concerning a shell plant where several deaths had recently occurred and where it was impossible to obtain any medical records: "It has been reported to me that a still larger number of deaths have occurred. The workers are drawn for temporary employment from localities all around here and from a considerable distance away. It must be very difficult to diagnose these cases which occur sporadically in a town at a distance from the plant. Medical and funeral expenses are met by the company, and those who act for the company give to the family or patient some diagnosis which is insufficient to serve as a ground for legal action."

One or two instances will show that the list of cases of poisoning in this industry which we have been able to compile does not at all represent the real number, or, in fact, more than a small proportion of it. In one plant, where unusually careful supervision of the men's health is maintained, the cases of so-called "fume sickness" were said to number almost 500 during five months' time; but it was not possible to discover how many had occurred during the other seven months of the year, nor was it possible to obtain as detailed a statement as that from any of the other cotton-nitrating plants.

One instance will illustrate the striking difference between two factories carrying on the same sort of work, and it will also serve to show how incomplete is the list of cases of occupational poisoning which we have been able to secure. Two factories fill shells with trinitrotoluol. One had a physician in charge who was willing to show his complete records, covering some 300 cases of poisoning from this substance, with two deaths. This would make a mortality of about 1 in 150 cases. The second had just put a doctor in charge, who either would not or could not give any information about poisoning in the plant, but from other sources we secured the records of five deaths from trinitrotoluol. Now, if the same rate of mortality obtained in this factory as in the first, we should add 750 cases to our list, and very likely that would be no exaggeration; but since it has seemed safer not to include any cases except those reported by physicians, we have been able to charge only five to the account of this second plant.

Of course this brings about a very contradictory result, for, to judge by our records, the best managed factories have the largest number of cases; the worst have few or none.

This is the list of industrial poisonings that occurred in 28 plants in the space of about a year. Thirteen plants could not be included for lack of information:

CASES OF INDUSTRIAL POISONING IN 28 PLANTS IN ONE YEAR.

Poison.	Number of cases.			Fatal cases.		
	Men.	Women.	Total.	Men.	Women.	Total.
Nitrogen oxides and nitric acid.....	1,389	.....	1,389	28	.....	28
Trinitrotoluol.....	659	43	702	11	2	13
Picric acid.....	7	.....	7	.....	.....	.....
Nitrobenzol and nitrotoluol.....	12	.....	12	1	.....	1
Benzene and toluol.....	14	.....	14	7	.....	7
Sulphuric ether.....	52	.....	52	1	.....	1
Anilin.....	205	.....	205	.....	.....	.....
Phenol.....	2	.....	2	1	.....	1
Sulphuric acid.....	4	.....	4	1	.....	1
Mixed acids.....	2	.....	2	1	.....	1
Chlorine gas.....	3	.....	3	.....	.....	.....
Ammonia gas.....	1	.....	1	.....	.....	.....
Mercury.....	1	.....	1	.....	.....	.....
Fulminate of mercury.....	79	32	111	.....	.....	.....
Nitronaphthalene.....	2	.....	2	.....	.....	.....
Total.....	2,432	75	2,507	51	2	53

Though all of these were serious enough to come under the observation of a physician, they vary in severity from a case of rapidly fatal congestion of the lungs caused by nitrous fumes to a case of eczema from filling caps with fulminate. There were nine other fatal cases, all men, six from triton and three from nitrous fumes, which were reported to us either by men who were not physicians or at second hand by physicians who had only heard of the occurrences and had not themselves seen the men. It has seemed best not to include these in our enumeration, although some of them had every mark of authenticity.

Those listed under the head of fulminate were all mild and of slight importance. Those under anilin were more serious, but far less so than most of the cases on the list. Subtracting these 316, there are left about 2,200 cases of occupational poisoning, either serious at the time or likely to become so. The 702 who had triton poisoning were not all very ill, but experience has shown that in this form of poisoning an apparently slight case may suddenly change to a severe or fatal form. The same thing is true in nitrous fume poisoning. All the benzol cases, those from picric acid, from phenol, from mineral acids, and from nitrobenzol, were serious if not fatal in character.

In this report the physiological effects of the various poisons will be described first, and then the processes of manufacture in which they are encountered.

PHYSIOLOGICAL ACTION OF POISONS.

NITRATION.

The process of nitration is essential for all the products which are covered by this investigation. In making of explosives it is necessary to provide oxygen in some easily available form to cause combustion of the substances which make up the explosive, and this is usually done by treating them with nitric acid in such a way that the group NO_2 enters into combination, the oxygen of which is readily given up. Because all these explosives are nitrated compounds the most common form of poisoning in the industry is that from nitrogen oxide fumes—usually called nitrous fumes—which are given off more or less in all nitration processes. The higher the nitration the greater the danger from fumes, unless great precautions are taken. The 1,300 to 1,400 men on our list who suffered from these fumes were employed in making nitrocellulose, or nitrocotton, picric acid or trinitrophenol, the nitrotoluols, nitrobenzols, nitronaphthalenes, nitroglycerin, and the nitric acid needed for these processes.

NITROGEN OXIDE POISONING—"FUME SICKNESS."

In the making of explosives a mixed acid is used for nitration, one ingredient of which is sulphuric acid and the other nitric acid 100 per cent strong. When it is remembered that the "strong" or "fuming" nitric acid of the chemical laboratory is only about 70 per cent pure it can readily be seen how great is the danger from fumes in connection with this work. When the mixed acid is exposed to the air, or when it is being mixed with the substances to be nitrated, a rapid decomposition sets up at once, with the evolution of the lower oxides of nitrogen, which rapidly take up oxygen from the air and change to the higher oxides. The lower oxides are pale or colorless; the higher are of a deep orange color. It is almost always easy to discover the site of a nitric acid or a nitrating plant by the yellow color which tints the sky over it and which often is deep and dense enough to be seen for several miles. Sometimes decomposition takes place suddenly and violently enough to reduce the nitric acid to a finely atomized spray, and this is caught and mingled with the oxide fumes.

These gases, known usually as nitrous fumes, are very irritating to one who is unaccustomed to them, but the workmen soon establish a good deal of tolerance, and the visitor to the factory may be choked and tearful and speechless in an atmosphere which seems to be causing no discomfort to the men who work there. If something goes wrong and there is an unusual production of fumes the air becomes unbearable even to the workmen, and unless they run to the fresh air

they may become badly poisoned. Unfortunately the immediate effect of breathing these fumes is often not painful enough to give the men sufficient warning of danger. Many men have stayed in the poisoned atmosphere long enough to cause damage to the throat or lungs, and yet at the time they did not realize that anything more serious was happening than a "choking" from the gas.

Autopsies on fatal cases usually reveal quite extensive changes, especially in the lungs. The order in which these changes take place has been described by several experimenters. Kockel¹ found in rabbits which had been exposed to nitrous fumes a general thrombosis in the capillaries of the lungs,² hyaline thrombi of degenerated red blood cells. The alveoli were filled with plugs of epithelial cells, leucocytes, and fibrin. If the animal lived for several days there were areas of pneumonia and between them the tissue was emphysematous in patches. Hiltmann³ killed a guinea pig after only six minutes' exposure to intense fumes. There was general emphysema and hyperæmia of the lungs, but the epithelium of the air cells was intact. He does not believe that the effect is that of a caustic primarily, for in another animal that lived three hours and a half he found this same condition of intact lining epithelium. The lungs were distended, hyperæmic, showing patches of emphysema and of atelectasis. The framework was swollen and soaked with yellowish fluid. All abdominal organs were congested.

Hudson believes the injury done by inhalation of nitrous fumes to be due not to absorption in the blood but to a local corrosive action, very like that of a burn on the skin. Congestion is followed in typical cases by pulmonary edema, the rapidity and intensity of which are in direct proportion to the concentration of the gases and the depth to which they have been inhaled. He experimented on dogs, limiting the action of the gas to the left lung by clamping off the right bronchus, and in this way he succeeded in producing a typical pulmonary edema on the left side, with a normal right lung, thus demonstrating clearly the local irritative action of the nitrous fumes.⁴

Loeschke (quoted by Hiltmann) finds also this locally caustic effect, leading to a sloughing of the cells lining the alveoli of the lungs and setting up inflammation in the lung tissues, which terminates in edema. He insists further that there is an action like that of all nitrites on the vasomotor system, shown in a general dilatation of the blood vessels and also a solution of red blood corpuscles. Spleen, kidneys, and liver must eliminate the products of this breakdown of

¹ Quoted in Hiltmann. *Vierteljahrresschrift fur gerichtliche medicin*, 1915, p. 1.

² Hudson has repeated Kockel's experiments and in a personal communication states that he has not been able to verify the occurrence of these capillary thrombi.

³ *Vierteljahrresschrift fur gerichtliche medicin*, 1915.

⁴ W. G. Hudson: *Further Studies on Acid Fume Poisoning*. F. I. du Pont de Nemours Powder Co., Wilmington, Del.

red cells and show the damage caused by this effort at elimination. He finds methæmoglobin in the blood.

Whatever the difference of opinion as to the nature of the early action of these fumes, there is no doubt as to the rapidly increasing congestion of throat, trachea, and bronchioles, followed by swelling, then by the pouring out of exudate. Acute swelling of the bronchioles and acute hyperæmia have been known to cause death in a workman, who for less than half an hour had been pumping nitric acid from one receptacle to another—(Rambousek). Usually, however, edema is the cause of the death that occurs quickly after exposure to the fumes.

Haldane¹ found that exposure to 0.05 per cent of nitrogen oxide fumes for half an hour would kill mice, death coming on after 24 hours.

Taking the purely local effects of the nitrous gases first, instances were found of inflammation of the mouth, nasal passages, and throat. One physician reported four cases of inflammation and ulceration of the mucous membrane of the mouth, another an inflammation of the nares so severe as to force the man to give up work. The effect of the fumes on the teeth is notorious, for acid acts directly on the enamel.

The effect on the throat may show itself in inflammation of the larynx, sometimes severe enough to be alarming. Seven such cases were found, in two of which edema of the larynx developed, necessitating in one case the introduction of a laryngeal tube to prevent suffocation. This man had inhaled rather concentrated fumes during the morning, and the severe trouble in his throat did not come on until the evening. Several physicians have said that men who have weak throats can not stand work in nitrous fumes.

If the fumes have penetrated to the bronchial tubes and the lungs, the first effect is an instinctive effort to shut out and to get rid of the irritant. There is a strangling, spasmodic cough and the breath is drawn in with an effort. The men say they feel a burning and smarting in the chest and they can not breathe, because their lungs are shrunk or "tied up in a knot"; they have nothing to breathe with. To an observer the attack resembles one of bronchial asthma and doubtless the pathology is the same in those cases that respond readily to fresh air and the administration of the usual first-aid treatment—a few drops of chloroform in hot water and aromatic spirits of ammonia. This relieves the spasm of the tubes and also acts as a stimulant. If no real damage has been done to bronchi or lungs, the man may go back to work after an hour or so and be apparently none the worse.

¹ Quoted by Irvine: *British Medical Journal*, 1916, p. 163.

These mild cases are so frequent in hot heavy weather that they attract little attention. In the summer of 1916, when the weather was very hot, one guncotton plant where 300 men are engaged in nitrating, used to have about 20 men every 24 hours who had to go to the doctor with "fume sickness," but could return to work that same day or night. One carefully managed factory, where records are kept of all cases of sickness, had an average of 57 cases of nitrous fumes poisoning in an average force of 600 men during each month from June to September.

When enough gases have been inhaled to injure the tubes and lung tissue, the man may for the moment seem to have no more than a mild case of the usual fume sickness, but in a few hours serious symptoms come on. This late appearance of the results of the injury is characteristic not only of nitrous fumes poisoning, but of that which follows inhaling ammonia gas, chlorine, and bromine, as is seen in the numerous reports of gas poisoning in the trenches during the present war.

The damage done may result in a bronchitis, with fever, necessitating care in a hospital or at home for several days. Or it may result in pneumonia. According to Hudson¹ this is a lobar pneumonia, not lobular as one would expect. It follows the usual type, only that it is likely to be less severe, unless some lesion of the lungs was present before the accident. For this reason and because Negroes are more subject to pulmonary tuberculosis than are whites, the largest explosives company prefers not to employ Negroes in the nitration department. Unfortunately there are a number of plants where only Negroes are to be found in these departments.

Pneumonia is probably a much more frequent result of the action of these fumes than is generally admitted by the physicians in the employ of nitration works. There are undoubtedly many cases of pneumonia from this source that are never listed as occupational. A public hospital in the neighborhood of a large guncotton factory has on its books many cases of bronchitis and pneumonia, but we could not establish any causal relation between the exposure to nitrous fumes and the inflammatory process, because we could not persuade the company physicians to admit that such conditions were ever caused by nitrous fumes. They were willing to recognize the occupational character of the asthmatic attacks, and also of the fatal edema, but not of any condition between these two extremes. Obviously it is simply a question of intensity. Fumes not concentrated enough to set up a fatal congestion and edema may be strong enough to cause inflammation, or in other words, bronchitis or pneumonia.

¹ Medical Record, 1917, vol. 91, p. 89.

As a matter of fact there is much experimental as well as clinical evidence to prove that these results follow nitrous fumes inhalation. Hudson has produced pneumonia in animals. The valuable study of nitrous fumes poisoning published by Hall and Cooper¹ contains several histories of pneumonia. These two Denver physicians were able to follow the subsequent histories of 18 firemen and 2 printers who were poisoned by fumes from a broken carboy of nitric acid in a printing shop. The mistake was made of throwing on sawdust and using chemical-fire extinguishers instead of drowning the acid in water, and the fumes that developed were severe enough to affect 20 men, 4 of whom died. The autopsy performed on one of the victims, who died on the day after the accident, showed the changes typical of rapid nitrous fumes poisoning, a congested, edematous condition in the lungs, which were heavy and bled freely on section. The bronchioles were full of bloody fluid and there were solid areas around them. Another fatal case did not die until a month after the accident. Here the autopsy showed broncho-pneumonia with almost complete solidification in places. Some of these solid areas showed coagulation necrosis, the alveoli full of necrosed cells; others showed the beginning of fibrous change.

Loeschke also describes a typically rapid case, dying on the second day of the immediate effects, and another who developed pneumonia and lived eight days.

One or two instances from the histories collected by us will illustrate this point. The first was a man employed in a guncotton plant. He sickened on the 14th of the month and died on the 19th. At the beginning he complained of constant epigastric distress, with attacks of pain, much eructation of gas, and occasional vomiting. On the second day moist râles were heard over the anterior chest, and he expectorated frothy, bloody sputum. On the fifth day his heart action was weak and very irregular. Areas of consolidation in the lungs had developed. His pulse became thready, and he was sent to the hospital, where he died the same day. Another case was that of a young man of only 20 years who was hurt at the time an explosion of nitrous gases occurred and could not escape, but had to be dragged out of the shed through a window. He had been exposed for some minutes to heavy fumes before they got him out, but he recovered fairly promptly from the first effects. The next day he suffered from headache but nothing else, and did not develop a cough until the fourth day. The symptoms in his lungs increased very rapidly. He was transferred to a hospital in a neighboring town where the physicians thought it was a case of unusually rapid acute-miliary tuberculosis. But when the man died at the end of two

¹ Journal American Medical Association, 1905, vol. 45, p. 396.

weeks the autopsy showed gangrene of the lungs, undoubtedly a result of the original injury caused by the acid fumes.

When the physician is able to follow the case over a long period of time he sometimes finds that an apparent recovery is followed by a relapse with symptoms like those of the original attack. Hall and Cooper state that one-third of their cases suffered relapse, usually within three weeks of the accident. Of the four fatal cases two did not die from the early effects of the fumes, but from pneumonia developing 22 and 30 days after. The conspicuousness of this accident and the fact that the men were firemen attracted special attention to them, and their histories were followed up more closely than is the case with munition workers. By the time the latter have developed the late form of poisoning, they have very likely entered on other employment and the physician who treats them does not connect their illness with an exposure to fumes some weeks before.

This late development of pneumonia is mentioned by Orth as sometimes an important medico-legal point in a doubtful case.¹ Fraenkel described a terminal bronchiolitis obliterans in a man who had been exposed to nitrogen-oxid fumes, had suffered from acute congestion, then apparently recovered, and a fortnight later began to experience symptoms of the disease from which he died on the sixth day. Autopsy showed no pneumonia, but a closure of the bronchioles by proliferated connective tissue, and a general thrombosis of the smaller blood vessels.²

The duration of ill health after a single severe poisoning was found by Hall and Cooper to be fairly long. Nine months after the accident 11 of the 16 men who survived had not yet regained their usual health. They complained of shortness of breath, cough, pain in the chest and loins, stomach troubles, and nervousness. Loss of weight was general, ranging from 20 to 40 pounds.

The typical form in which severe and fatal nitrous fumes poisoning appears is not a pneumonia; it is the congestion and edema which have been already referred to, but which are important enough to require detailed description. There are many references even in the ante bellum medical literature to this peculiarly distressing kind of poisoning. The earliest case in German literature seems to be that described in 1884 by Pott.³ A heap of artificial manure, containing Chile saltpeter (sodium nitrate), caught fire, and no less than 30 workmen who tried to put out the fire were injured by the fumes. Two of them died. In English reports we read of nitrous fumes poisoning from incomplete detonation of explosives in mining, especially on the Rand.⁴ This same cause lies behind the wholesale poisoning

¹ Deutsche medizinische Wochenschrift, 1916, vol. 42, p. 208.

² Spezielle Pathologie und Therapie der Lungenkrankheiten.

³ Deutsche medizinische Wochenschrift, 1884, nrs. 29 and 30.

⁴ Irvine, in British Medical Journal, 1916, p. 163.

which has occurred on battleships when smokeless powders have accidentally exploded in a closed space without sufficient oxygen.¹

The history of a typical case of this sort is as follows: The man has a choking spell, perhaps no severer than he has had on other occasions. He recovers and goes home, feeling fairly well and not apprehensive of any serious effects. Some hours later, perhaps after he has gone to bed, he begins to "choke up," to cough, and be short of breath. Sometimes he has cramps in the abdomen and vomiting. One man who had been working in a picric-acid department where the fumes were thick was carried into a doctor's office unconscious, livid, and gasping, with persistent vomiting and involuntary defecation. Usually, however, even if there is an involvement of the intestinal tract, the symptoms in the lungs overshadow everything else. There is an increasing air hunger; the man lies motionless, propped up on pillows, his face livid, his eyes full of fear, unable to speak or move, needing all his strength to labor for breath. At first his cough is dry. Then he begins to expectorate a sticky, frothy fluid which may be bloodstained. As the dyspnoea increases his whole body may become livid. He gradually loses consciousness, and just before death there may be convulsions. An autopsy shows intense congestion of the finer bronchioles and air vesicles, which last are filled with an exudation of serum. It is said that the man is actually drowned in his own fluids.

Usually such cases follow some accident which has released an unusual quantity of the poisonous gases. One man, for instance, fell asleep in a nitrating shed, and when a fire occurred he was not discovered and dragged out until he had breathed enough fume to kill him. In another instance a plumber was sent for to install in a picric-acid plant a fan to carry off the nitrous fumes. To do this he had to stand on a platform above the nitration pots. As work went on all the time the fumes were very thick. He was "choked up" and had to go out of doors to get his breath. The superintendent advised him to give up for the day, but he insisted on going back and finishing. Again he was overcome by the fumes and was sent home. He did not seem very ill and fell asleep, but during the night he awoke with the sense of strangling, and he died in the morning of suffocation.

In many instances it is harder to explain these fatal cases, for they follow upon no accident, no unusually severe exposure. The physician in charge of a large guncotton factory said that he always made a close inquiry into every serious and fatal case of fume poisoning, and usually he would find that the man had apparently breathed no more fumes than he had often breathed before. The most puz-

¹ Ohnesorg, in U. S. Naval Medical Bulletin, October, 1916, p. 625.

zling cases in his experience were old hands, who succumbed to what seemed to be no more excessive poisoning than they had repeatedly been exposed to without apparent injury.

On the other hand, another physician of considerable experience in nitrocellulose manufacture maintains that there can be no question of varying degrees of susceptibility to caustic fumes any more than to burning from fire, and that occurrences which seem to point to such a difference between workmen simply mean that the onlookers underestimated the degree of exposure.

Hudson's explanation, based on long experience, is that these nitrous fumes are not of uniform composition. When they contain a larger percentage of the immediately irritating compounds, the workman notices the effect at once and believes he is inhaling very dense fumes. But the most harmful constituents are not at once irritating; they do not produce their effect till after entering the lungs and reacting with the water of the tissues.

Of course it is hard to estimate just how dense are the fumes to which a man has been exposed, but in some cases where a large number of men were subject to the same amount of gases there certainly appeared to be a difference in their reaction to the poison.

We have the record of a man who died after four hours' work on a night shift with some sixty men in the same nitrating shed. None of the others suffered appreciably from the fumes that night. It does not seem possible, in view of the arrangements in this shed, that he could have inhaled much more gas than did the men working on each side of him.

One very hot night in the summer of 1916 the cotton in the waste acid from the nitrators in a guncotton factory took fire and two workmen inhaled a good deal of fume. Both were overcome and rendered unconscious. One of them was back at work the next night and the other was laid up for a week with bronchitis. A man in a picric-acid plant was exposed to the fumes from a single "boil over." He developed a serious form of congestion and edema of the lungs, very nearly fatal, while no other workman in the place was seriously affected.

Czaplewski reports eight cases of men poisoned by nitrous fumes, one of whom died on the second day, one on the ninth, five were ill for a week, and one was back at work the day after the accident. He says that some who were in the poisoned atmosphere only 20 minutes suffered as much as others who were exposed to it for two hours.

The men who are employed by long-established and careful companies are instructed to take short, shallow breaths in the presence of these fumes so as to save as much as possible of the lung tissue

from the effects till they can escape to the open air. But new men employed in plants where no instruction is given are likely to follow their natural impulse and hold the breath as long as possible, then take a deep gasping inspiration, and hold it again till forced to take another. A man who does this may drive the fumes into the whole area of the lungs. If even a small portion of the lung tissue is left unaffected he may recover, provided he is given oxygen until the inflammation has had time to subside, but records were obtained of 16 cases in which the congestion and edema were fatal.

There is also a less well recognized form of nitrogen oxide fumes poisoning which is so rapidly fatal that only slight anatomical changes are found after death. The poison in these cases seems to act directly on the respiratory center. This is probably the explanation for those cases of sudden death after very short exposure to fumes when an autopsy reveals no damage to the lungs sufficient to account for death. Five instances were reported of men who had worked only a short time in nitration, two of them less than one eight-hour shift, and who had been suddenly overcome and died before medical care could be given. One was a foreigner who applied for work in a picric-acid plant where the fumes are unusually dense and where very little attention is paid to the safety of the men. He was taken on for the 4 o'clock shift and set to work in the nitrating shed. At about midnight he was found lying unconscious in the yard. An ambulance was sent for, but he died before the hospital could be reached. It has been impossible to secure a copy of the coroner's post-mortem report. The man was a foreigner, with no relatives here, and the case was never followed up. Apparently he was well when the foreman set him to work in the afternoon.

Another case was that of a Negro who was found dead in his bunk the morning after he had worked in the nitrating shed of another very bad picric-acid works. He had certainly not suffered from dyspnoea during the night, for he slept in the same room with many other men, in a company barracks, and they would have heard him call for help. The physician who reported this case had not been present at the autopsy, but the coroner described the findings to him and consulted him as to what to put on the certificate. There was some hyperæmia of the brain, meninges, and lungs, but not excessive anywhere. The heart was negative, the blood dark and fluid. They agreed to call it "heat prostration," since they had found no changes sufficient to cause death. After telling of this case the physician went on to discuss two other obscure cases of sudden death from the same nitrating sheds. None of the physicians who knew of these occurrences were aware that nitrogen oxide fumes were very dense in this factory, nor would they have known what to expect from such a condition.

Some light is thrown on these cases of death without marked anatomical lesions by the report of an autopsy performed by Dr. G. A. Apfelbach, of the Illinois State Factory Inspection Department, for Dr. E. E. Evans, coroner of Lake County, Ind., on the body of an exceptionally big and muscular man, who had been a hard drinker, and just before applying for work at the guncotton plant had had a heavy drinking bout. He had gone on with the night shift, and during that time the nitrous fumes were not bad enough to make any of the other men apply for treatment at the company dispensary. He had worked only four hours in the nitrating room when he began to suffer from the fumes and went out, saying, "This smoke is too much for me." Almost at once he lost consciousness and died in about 30 minutes. Dr. Apfelbach found the larynx, trachea, and bronchi hyperæmic, the lungs congested, the alveoli containing frothy fluid. The heart was absolutely negative, as were also stomach, intestines, kidneys, and brain; but the spleen and liver were congested, and the blood was dark and fluid. A tubeful of blood was taken to Dr. McNally, chemist to the coroner's office of Cook County, and he found a small quantity of nitric oxide, but no methæmoglobin. Death must have been caused by the action of the poison on the lower centers, especially the respiratory center.

Nitration of cotton to make nitrocellulose, and of phenol to make picric acid, are attended with the greatest danger from fumes of the oxides; nitration of glycerin to make nitroglycerin, with the least danger. Between these two extremes come the manufacture of nitric acid and the nitration of toluol, benzol, naphthalene, anilin, chlorbenzol, dimethylanilin.

NITRIC ACID.

Most explosives factories manufacture their own nitric acid, and all recover it from waste even if they do not manufacture it to begin with. Nitric acid is made by the action of sulphuric acid on sodium nitrate (Chile saltpeter). The oxide fumes that come off are collected in water. It is the escape of such fumes that constitutes the great danger in a nitric-acid building, aside from the danger of burns from contact with the acid. The symptoms caused by inhaling these fumes have already been described.¹

Leakages in pipes or in the doors of the stills may allow the escape of nitrous fumes, but the greatest danger comes from the stoppage of a pipe followed by bursting and the pouring out of the acid. Some of the worst cases of lung congestion, or edema, on our lists have followed accidents of this sort. If it takes place out of doors the danger is not so great. At the time of a visit to

¹ See page 14.

a guncotton plant an accident of this sort occurred. The supply pipe from the acid tank broke, and though the fumes that rose formed a dense orange cloud that quite hid the tank and pipe and spread every moment farther over the yard, the workmen, by keeping carefully to the windward of it, were able to drag a hose near enough to deluge the spilled acid and make it possible for a pipe fitter to get where he could stop the flow. Inside a building such an accident usually results in at least one serious case of poisoning.

SULPHURIC ACID FUMES (SULPHUR DIOXIDE).

The fumes from sulphuric acid that are to be dreaded are sulphur dioxide, given off in large quantities at a certain stage in the production of sulphuric acid and also at one stage in the production of phenol. The ordinary fumes from roasting sulphur flowers or iron pyrites consist of the trioxide, and are irritating but not dangerous, as is the dioxide.

Lehmann and Ogata¹ showed that SO₂ has serious effects on a person unaccustomed to it if it is present in even as small quantity as 3 or 4 parts to 100,000 parts of air. It causes inflammation of the bronchioles, bloody expectoration, congestion and inflammation of the lungs.

Three cases of poisoning from the fumes in making sulphuric acid were found in the records of a hospital not far from one of these plants. The men had been sent in "choked up" and had then developed acute bronchitis, necessitating a stay in the hospital of five to seven days. They all had fever, from 102 to 103° F.

One rapidly fatal case of sulphuric-acid fumes poisoning was reported by a company physician, but he gave no details of the occurrence.

The effects of sulphur-dioxide fumes are very like those of nitrogen-oxide fumes, but far fewer men are exposed to them and rarely is anyone exposed to very large quantities.

MIXED ACIDS.

Mixed nitric and sulphuric acids were responsible for severe poisoning of two men. One opened a drum of the mixed acids and in some way breathed in enough fumes to cause pneumonia, and he was in a hospital for three months. The other entered a tank which had contained mixed acids and which it was his task to repair. The tank was supposed to be quite empty and the man refused to wear a helmet, but there was enough of the acid left at the bottom to cause his death.

¹ Quoted in Rambousek: *Gewerbliche Vergiftungen*. Leipzig, 1911.

BENZOL AND TOLUOL, OR METHYL BENZOL.

A great deal of benzol is used in the manufacture of phenol (C_6H_5HO), a smaller amount in the manufacture of nitrobenzol as a step in the production of anilin for explosives, and a great deal of toluol is used in making the nitrotoluols, of which trinitrotoluol is the most important. Benzol and toluol are treated together here, because their effects on the body are very similar. Lehmann¹ and his colleagues and Chassevent and Garnier² consider toluol and xylol more toxic than pure benzol, but Rambousek³ thinks the reverse is true, and so do Agasse-Lafont and Heim.⁴

The symptoms that follow inhalation of benzol or toluol fumes or absorption through the skin differ according to the degree of exposure and the susceptibility of the individual, for men vary decidedly in this regard. There are always, however, in mild as in severe cases, the symptoms of intoxication by a substance with a specific action on the central nervous system: Dizziness; confusion; transient excitement, followed quickly by stupor; twitchings, then exhaustion; loss of consciousness, with respirations at first rapid, then slow; pulse rapid; temperature low. Rambousek says that toluol produces narcosis more slowly than does benzol, and there is less tendency to convulsions. Lehmann finds narcosis comes on more quickly under toluol and recovery is slower.

In mild cases there is a condition like early alcoholic intoxication, with excitement and irritability, headache, and dizziness. Later there is a feeling of general illness, loss of appetite, and nausea. Very little attention is paid to instances as slight as this, and we never had any such reported to us. All our cases of benzol poisoning were severe, dangerous to life, and all had come on after unusual exposure and with great rapidity.

The characteristic post-mortem findings after benzol or toluol poisoning are: Congestion of the abdominal organs and multiple capillary hemorrhages into serous and mucous membranes and into the subcutaneous tissues, probably because of the action of the poison in dissolving the endothelial walls of the small vessels, or its action in dissolving the body fats, allowing the lodging of fat emboli in the small vessels and thus causing their rupture. Sometimes hemorrhages from the nose, lungs, uterus, and gums occur during life if the poisoning is slower and the body may be covered with purpuric spots. The blood in these slow cases shows a marked diminution of white blood corpuscles, which may amount to an almost complete disappearance of these corpuscles if the poisoning is very severe.

¹ Archives für Hygiene, 1911, vol. 74, p. 1.

² Archives International de Pharmacodynamie et de Therapie, 1905, vol. 14, p. 93.

³ Concordia, 1910, p. 448.

⁴ Recherches sur l'Hygiene du Travail Industriel. Paris, 1912, p. 83.

In the making of explosives 14 serious cases of benzol poisoning were reported, with 7 deaths. The first 2 were steam fitters employed to repair the pipes inside a benzol still. The manhole through which they had entered was just large enough to allow them to crawl through. As usual in such work, the still had been not only emptied but washed out and was supposed to be free from appreciable quantities of benzol. One of the men suddenly became excited and irrational, singing and shouting. It was realized that he must be removed from the still as quickly as possible, but this was a difficult thing to do through the narrow opening, since he was not rational enough to help. It took about 10 minutes to get him out, and during much of that time the manhole was completely closed by his body. The second workman who had been helping lift him out was then found to be lying unconscious on the floor of the still. Even more difficulty was encountered in taking him out, for he was quite helpless, and it was about 20 minutes before he was brought into the open aid dead.¹

The third and fourth cases had almost the same history. They, too, were working inside a still which was supposed to be free from any dangerous quantity of benzol; they began to suffer from the effects, were dragged out in a state of coma, one was saved by vigorous measures, but the other died in spite of all efforts to revive him by the administration of oxygen and stimulants. Curiously enough, he was the one who had been in the still the shorter time. Two more deaths caused by repair work in a benzol still were reported, but without details.

Another death from benzol was startlingly sudden. There was trouble with the valve of a still and a man went up to the top of the still to see what was wrong. There was a bad leak there and he fell in a faint at once, and by the time two others could come to his rescue, which was said to be only two or three minutes, he was dead. So strong were the fumes that both men who went to help him were themselves overcome and one of them was unconscious for several hours.

The sixth and seventh fatal cases were men working in the sulphonating department of a phenol plant, in a room where benzol is sulphonated and the product run into the liming vat. Fumes of benzol were decidedly strong in this room at the time it was inspected, about a month before the occurrence of these two cases. For the details we are indebted to Dr. H. S. Martland, pathologist to the Newark City Hospital, who, together with Dr. George Warren, county physician of Essex County, made the autopsies, a condensed version of which follows: P. worked from August 7 till the 17th, the

¹ Reported by Dr. T. F. Harrington, deputy commissioner Massachusetts Board of Labor and Industries.

day of his death, in the sulphonating department of the plant. His task was to dump sacks of slaked lime into the liming vat under the sulphonator. There are in this room several possibilities for the escape of benzol fumes: From the benzol supply pump, from the sulphonating kettle, and from the liming vat when the charge from the sulphonator contains unchanged benzol, and this meets the hot liquid in the liming vat and is volatilized. P. was found dead in this room. Two days later M. was found in moribund condition in the same room near the benzol pump, of which he had charge. He died the same day. He had been employed on August 4 and had worked at the pump up to the time of his death, on the 19th.

P.'s post-mortem record is as follows—all normal findings being omitted for the sake of brevity:

Cyanosis of the mucous membranes and finger tips; cyanosis of the liver, spleen, and kidneys; dilatation of the right heart with dark blood; pleural ecchymoses and small areas of acute interstitial emphysema in the lungs.

The findings in M.'s case are similar, but more typical and pronounced. Cyanosis of mouth, of lips, and of finger tips; small amount of frothy fluid escaping from mouth; cyanosis of brain, heart, liver, and kidneys. On section of the lungs a decided odor of benzol was given off. Petechial hemorrhages in pleuræ and pericardium; small areas of interstitial emphysema in the lungs; reddened and irritated bronchi. There was an abnormal quantity of phenol in the urine, no benzol.

PHENOL, OR CARBOLIC ACID.

Up to the outbreak of the war all the carbolie acid used in this country was imported, but the manufacture soon began and now there are more than a dozen plants engaged in it, several of them very large and important. Much of this carbolie acid is used for the production of an explosive, picric acid.

Carbolie acid is a well-known poison, used often with suicidal intent, but the industrial form of poisoning differs from that which follows the drinking of the acid because industrial poisoning takes place through the skin or through the lungs. In the early days of antiseptic surgery there were many cases of poisoning resembling industrial poisoning, for it was customary to use a carbolie-acid solution to irrigate wounds, as a dressing for wounds, as a disinfectant for the surgeon's hands, and even in the form of a spray to disinfect the air while the operation was going on. Many instances are recorded of severe poisoning and even death caused by the washing out of a large wound with carbolie solution or the leaving on too long of a dressing saturated with it. Oliver describes a case of coma following the application of a 1 in 20 solution to a large surface. There

were also cases of chronic poisoning among surgeons who were obliged to work in an atmosphere filled with minute particles of the carbolic solution. The symptoms of this form of poisoning are therefore well known.

Phenol, or its salt, sodium phenolate, is a corrosive poison, which coagulates the albumen of the skin, but not as strongly as do the mineral acids. Even after this corrosive effect, absorption takes place through the skin as long as the phenol remains in contact with it, so it is of the greatest importance to wash off the splashed surface as quickly as possible.

The local effect of carbolic acid may be quite serious. Harrington¹ has collected records of over a hundred cases of gangrene which were caused by bandaging fingers and hands with dilute carbolic acid. Alcohol is the recognized antidote for carbolic acid burns, and in all plants manufacturing this compound, alcohol is kept in a more or less easily accessible place for this purpose.

When absorbed into the blood through the skin—and this may take place even through unbroken skin—it causes quickening of pulse and respirations, then slowing; depression and weakness, dizziness, roaring in the ears, confusion, then collapse with cold perspiration, irregular pulse, respiratory failure, and death.²

A very serious case of this sort was reported by the Massachusetts Board of Labor and Industry. The young man was a chemist, 22 years old, employed in a plant making trinitrotoluol and picric acid. He had been employed there for five months. On a Sunday afternoon he went into the toluol nitrating department and in the picric-acid nitrating department, but as far as could be learned he was not affected by fumes in either place. At about 5.50 p. m., when leaving the phenol building, he stepped into a "sump" of phenol waste in the yard that he mistook for a board, and immersed his right leg in the solution up as high as the knee. He ran back and undressed and washed and soaked his foot and leg in distilled water. It was said that while he wrung out his trousers he continually licked his fingers to make sure that it really was carbolic acid. Very shortly after he began to complain of ringing in his ears, dizziness, difficulty in breathing. The skin of the leg had turned white, but there was no burn. He dressed the leg and left the building at 6.20 to go to the laboratory for alcohol to put on it. As he went out, the men noticed that he seemed dazed, confused, excited, almost hysterical. Evidently he never reached the laboratory, for he was found the next morning on the road, dead. The autopsy showed the leg from foot

¹ American Journal of Medical Sciences, vol. 120, p. 1.

² Cushny: Textbook of Pharmacology and Therapeutics. Philadelphia. 4th edition, 1906, p. 124.

to knee discolored, green and black. The diagnosis of phenol poisoning seems unavoidable in this case.

Chronic phenol poisoning is described by Kobert¹ as a form of marasmus (extreme malnutrition). There are digestive disturbances, complete loss of appetite or even loathing for food, headache, skin lesions, pallor, loss of weight and increasing weakness, and a chronic nephritis from which death finally results.

NITRO AND AMIDO DERIVATIVES OF THE BENZENE SERIES.

Several compounds belonging to these two groups play a more or less important part in the explosives industry, as, for instance, the following:

Nitrophenols, nitrobenzols, nitrotoluols, nitronaphthalenes, nitrochlorbenzols, amidobenzol or anilin, diamidobenzol or diphenylamin, tetranitranilin, tetranitromethylanilin.

It is possible to deal with the amido and nitro compounds together, as is indeed done by most authorities, although some distinguish between nitro and amido, claiming that the latter are chiefly characterized by methæmoglobin production, the former by a solvent action on the red corpuscles.² Roth³ and Rambousek⁴ both find methæmoglobin formed by nitrobenzol absorption, as well as by anilin.

The characteristic form of poisoning to which these compounds give rise depends on changes in the blood and a direct action on the central nervous system. The blood changes have been described by many observers. Roth gives those following acute poisoning with nitrobenzol as follows: On the first day the blood was chocolate colored, the serum a deep yellow, but there was no methæmoglobin; the color was caused by bile pigments. When, however, the red cells were dissolved in water, methæmoglobin appeared. The urine was dark, urobilin was present, but neither bile pigments nor hæmoglobin. On the second day there was no longer methæmoglobin and the chocolate color was gone, but changes had begun in the red corpuscles, which increased for some six days, variations in size, microcytes and megalocytes, loss of color from loss of hæmoglobin. In severer cases, the serum may be chocolate colored also and show methæmoglobin.⁵

Price-Jones and Boycott, experimenting with anilin in animals, found that the blood became chocolate colored and a spectroscopic band appeared which almost, but not quite, corresponded with the methæmoglobin band. There was an early leucocytosis of 30,000 to

¹ Die Intoxikationen. Stuttgart. 1906. p. 21.

² Curschmann: Transactions of International Congress of Industrial Hygiene. Brussels, 1910.

³ Zentralblatt für innere Medizin, 1913, vol. 34, p. 417.

⁴ Gewerbliche Vergiftungen. Leipsic.

⁵ Price-Jones and Boycott: Guy's Hospital Reports, 1909, vol. 63, p. 309.

40,000, and a rapid and extensive destruction of reds, the hæmoglobin falling by some 50 per cent. Nucleated reds and basophilic and polychromatophilic reds showed the effort at regeneration by the blood-building organs.

This destruction of blood elements is accompanied by elimination of the blood coloring matter, which is carried on by the liver and kidneys. When the poisoning is prolonged, degenerative changes appear in these organs, fatty degeneration of the parenchymatous cells, sometimes death of the cells and a consequent shrinking of the organ. In 1906 a case of slow dinitrobenzol poisoning occurred in England, the man dying from toxic hepatitis, and after death the liver was found in a condition like that of acute yellow atrophy. The same effect has been repeatedly found in cases of trinitrotoluol poisoning, which have been so frequent since the war. Always such cases develop rather slowly.

These nitro and amido aromatic compounds are not, however, purely blood poisons. There is in addition a direct effect on the central nervous system, and in the case of some of these compounds it is this latter which causes the most marked symptoms and is responsible for death. Heubner¹ says that the nitro and amido derivatives of the benzene series cause collapse and narcosis more intensely and more rapidly than do the alcohols, for they act more decidedly on the lower centers, the vasomotor, respiratory, heat-regulating centers. This effect is quite independent of the formation of methæmoglobin and can be produced in rabbits before methæmoglobin appears. We have histories of several cases of rapidly developing poisoning after unusually great exposure in which the nervous symptoms were striking and death occurred from respiratory paralysis.

The symptoms of poisoning which have been described in connection with exposure to anilin, dinitrobenzol, the nitrochlorbenzols, and trinitrotoluol, especially, more rarely in connection with picric acid and the nitronaphthalenes, depend largely on the formation of methæmoglobin. The replacement of hæmoglobin with its easily released oxygen by methæmoglobin with its oxygen firmly bound, interferes with the normal exchange of gases and results in a state of internal suffocation, starvation for oxygen in the presence of plenty of air. The outward signs of this lack of oxygen are seen in the bluish tint of lips and tongue and sometimes of the face, a color which may appear before the man has noticed any disturbance in health. Experimenters who have applied these compounds to the skin have developed this cyanosis sometimes without any subjective symptoms—(White and Hay.² Hudson.³)

¹ *Zentralblatt für Gewerbehygiene*, 1914, vol. 2, p. 409.

² *London Lancet*, 1901, vol. 2, p. 582.

³ Hudson: Personal communication.

The first disturbance the workman notices is a flushing of the face and sense of fullness in the head, which develops into a throbbing frontal headache. He has no appetite, indeed he may be nauseated. Some men at this stage feel pains in the abdomen, or in the chest, extending around to the back. If the man does not at once seek the open air and remain away from work till he has recovered he grows worse, his head becomes confused, he is dizzy, feels weakness in the legs, and is unable to walk or even stand. The flushed face becomes blue and livid, he begins to feel air hunger, struggles for breath, his pulse is small and rapid, his respirations at first rapid become slow, his temperature is lowered. Unconsciousness may come on suddenly while he is at work, but more often after he has left it, perhaps on the way home or several hours later. In severe cases the dyspnoea increases, the pulse becomes imperceptible, and convulsions may precede death.

If the patient is bled, the blood is thicker than normal and chocolate colored. The temperature is subnormal in these acute cases at first, but later on there may be a rise of temperature to 102° F.—(Hudson.) This is explained as being caused by the liberation of hæmatin in the blood, just as is true in malaria, for fever may be experimentally produced by intravenous injection of hæmatin.

The urine in these cases is darker in color. Brat¹ believes that the presence of a strongly levorotatory substance in the urine is one of the earliest signs of poisoning from anilin. Curschmann² found hydrobilirubin in nitrobenzol poisoning. Mohr,³ whose cases were poisoned by chlorbenzol and dinitrochlorbenzol, found hæmatoporphyrin and hydrobilirubin, the urine being burgundy red in color.

As to the early diagnosis of poisoning from these compounds, there are different opinions. Curschmann emphasizes the rise in blood pressure in anilin poisoning and this, together with a loss of hæmoglobin of over 25 per cent, and a slow pulse, indicates threatened acute poisoning. Accompanying these is a peculiar color of the skin, slightly jaundiced and at the same time grayish. Malden⁴ believes that basophilic granulation of the red cells is the earliest observable sign of poisoning.

Hudson finds a difference in the blood changes set up by a nitro derivative such as nitrobenzol, and those following absorption of an amido compound such as anilin. Nitro aromatic bodies cause pronounced and characteristic changes which can be depended on for diagnostic purposes. The leucocytosis described by the above experimenters is not to be depended on, but it is followed by a decided

¹ *Deutsche medicinische Wochenschrift*, 1901, nrs. 19 and 20.

² *Op. cit.*

³ *Deutsche medicinische Wochenschrift*, 1902, vol. 28, p. 73.

⁴ *Journal of Hygiene*, 1907, vol. 7, p. 672.

lymphocytosis, which is very characteristic and constant. Along with it appear the changes in size and in staining of the red corpuscles that show degeneration. When, therefore, the lymphocytes are found to be running above 30 per cent, with a corresponding fall in the polynuclears, it is evidence that the poison is affecting the worker even though he may have no feeling of illness. Anilin, on the other hand, does not seem to produce a lymphocytosis, and the changes on the reds seem to be more transient than in nitro poisoning.

Curschmann says that the toxicity of these compounds increases with the degree of nitration, except when the lower nitrated products are more volatile than the higher, as is the case with mononitrochlorbenzol which is more poisonous than trinitrochlorbenzol. Dinitrobenzol is much more toxic than the mononitrite, but the latter renders the former more dangerous, because it dissolves it and thus makes it more easily absorbed by the skin.—(White and Hay.) The more volatile bodies, such as anilin, are more rapidly and acutely poisonous than are the nonvolatile and sparingly soluble compounds, such as trinitrophenol (picric acid) or even trinitrotoluol.

Chronic poisoning by these bodies causes blood changes, degeneration of organs, nervous derangements. The number of red cells may increase, but there is a low color index; loss of hæmoglobin; degeneration and imperfect regeneration of red cells; pallor and grayish or bluish tint in lips, tongue, and even face. There is shortness of breath on exertion, digestive disorders, headache, muscular twitchings, disturbances of vision. Liver enlargement and tenderness may be followed by hardness and shrinking. Ascites may follow this stage.

Absorption takes place through the skin, the respiratory tract, and the stomach, and according to most observers the channels of entry are important in the above order. Hudson finds that any volatile compound is far more toxic in vapor form than when given by the mouth. A 5 or 10 grain dose of trinitrotoluol will hardly make a rabbit seriously sick, but a much smaller amount given in vapor will kill it. British factory inspectors believe that skin absorption is most important in dinitrobenzol and trinitrotoluol poisoning and American anilin manufacturers hold the same view with regard to anilin.

The local effect on the skin is much more pronounced in some of these compounds than in others. A more or less deep yellow staining of the skin is caused by handling picric acid (trinitrophenol), the nitrotoluols, tetranitranilin, and tetryl (tetranitromethylanilin). This yellow color is so conspicuous as sometimes to confuse the uninformed and lead to a diagnosis of jaundice. As a matter of fact it may sometimes mask a true jaundice, which can be de-

tected only in the sclerotic coat of the eye, if the man's skin is dyed yellow. There is evidence to show that this staining of the skin is not always merely a mechanical effect of the contact with one of these dyes, but may be a deposit in the lower layer of the skin from the blood stream. Prosser White¹ experimented on himself with trinitrotoluol, which he applied to the skin of the arm, and a yellow stain appeared in his nails, showing absorption and deposit of the dye.²

Dermatitis of varying severity is caused by most of the members of this group. Dinitrochlorbenzol is thought to be the worst, for even the vapor will set up an inflammation of the skin. Tetryl is more irritating than picric acid, and this last than anilin.

In taking up these compounds individually, we give them in the order of their importance in this industry.

PICRIC ACID.

The nitration of phenol to form trinitrophenol, or picric acid, is one of the most dangerous processes in the making of explosives because it is very productive of nitrous fumes and much of the nitration is carried on in unprotected receptacles (see page 14). A disproportionately large number of the cases of nitrogen fume poisoning on our lists occurred in the manufacture of picric acid. This is the most serious danger to be apprehended, but it must not be forgotten that phenol is itself a poison as is also picric acid.

The commonest form of poisoning from the finished product, picric acid, is the so-called "itch," a dermatitis of varying manifestations and degrees of severity, accompanied by burning and itching. It is usually limited to the exposed parts of the body, but it may become general, especially in summer heat and in plants where no shower baths are provided for the men who have to pack the finished product. The dustier this is the more trouble from skin affections, although even when it is dried down to less than 1 per cent of moisture it is still possible to do away with "itch" cases, if the management takes pains to do it. There is one admirably managed plant in which the physician had barely half a dozen cases of itch in the course of the previous year.

Besides this purely local form, there is a systemic picric-acid poisoning, with symptoms of the same character as those produced by other nitro aromatic compounds, but since picric acid is a solid

¹ London Lancet, 1916, vol. 1, p. 400.

² Recent foreign literature on malingering in the army proves that one of these compounds, picric acid, is deposited in the skin when taken internally. Soldiers wishing to obtain sick leave swallow a small dose of picric acid and have an attack of illness very much like acute jaundice: abdominal pains, vomiting, diarrhea, and then a yellowing of skin and sclera. The only distinction between this and true jaundice is the absence of clay-colored stools.

and not volatile, these symptoms come on more slowly and with less violence than those caused by the nitrobenzols. Kobert, in 1906, knew of only three deaths from picric acid, but many cases of non-fatal poisoning, with characteristic symptoms.

Two rather unusual cases of this kind were reported by the Massachusetts deputy commissioner of labor, Dr. T. F. Harrington, at the recent meeting of the American Public Health Association. The men were, as is usual in these instances of serious poisoning, engaged in repair work and therefore exposed to more poison than would be the case with ordinary workmen.

The superintendent of a plant making picric acid, a man 25 years old, was engaged on Sunday in repairing leaky ducts in the building in which nitration was carried on. Two days later he developed marked muscular weakness, irregular, weak pulse, pallor with cyanosis and slight yellowishness of the skin, palpitation of the heart, headache, vertigo. He was absent from work three weeks. The workman who helped him on that Sunday, a carpenter 44 years old, had been employed in the nitration building for three weeks. Five days after the repair job he reported that he had been unable to eat anything since that Sunday, he had nausea, headache, vertigo, mental confusion, cough, and difficulty in breathing on the least exertion, loss of muscular power. He was away from work for two weeks.

One fatal case was reported from a place where picric acid was made, but the man was supposed to have also been exposed to nitrobenzol fumes. He died in convulsions after he reached home, and the autopsy record, which is very brief, states that the organs were congested with dark blood and the circulating blood was chocolate colored. Since both picric acid and nitrobenzol are nitro derivatives of the benzene group, they are both capable of causing this condition of the blood, but the severe and rapid course of the poisoning is more suggestive of nitrobenzol than of picric acid.

There is not much information to be obtained from company physicians about chronic picric-acid poisoning. One of them, who is in charge of the medical work in a large plant making picric acid and drying it before packing, described two varieties of symptoms among picric-acid workers, which are the same as those long familiar to French physicians, for this explosive has been for many years in use in France.¹ The most usual symptoms are acute gastroenteritis, abdominal cramps, vomiting, diarrhea, bitter taste. The less usual symptoms are those in which the nose and throat and bronchial tubes are affected, an irritative catarrh. He had never seen serious trouble of either kind, but another doctor practicing in the neighborhood of a very badly managed picric-acid plant, said he had had cases of gas-

¹ Cheron, in *Journal de Therapie*, 1880, p. 121. Quoted by Kobert, *loc. cit.*, p. 805.

tritis among the men quite serious enough to force them to quit work. They lost weight and strength.

TRINITROTOLUOL, OR TOLUOL OR TRITON OR TROTYL OR TNT.

Next to the oxides of nitrogen, this substance has been responsible for more cases of poisoning than any other in the explosives industry, and the poisoning caused by trinitrotoluol is serious enough to give it an important place quite apart from the number of its victims.

This substance was almost unknown before the war. It had been manufactured to a very small extent in Great Britain, but no ill effects had been observed from handling it and it was manifestly less poisonous than the fairly familiar dinitrobenzol. The British entered on the manufacture of triton on a large scale, with no expectation of the disastrous results that have followed. At the present time they are fully alive to the dangers of work in such plants and have issued special rules to cover them, for they have found that trinitrotoluol is poisonous "to at least a minority of workers coming into contact with it." From time to time cases of fatal toxic jaundice in triton workers have been reported by the medical journals, and, according to an article in the *Lancet* for December 16, 1916, no less than 50 such fatalities have occurred since the war broke out. The record for the nine months ending September, 1916, was 95 cases of toxic jaundice, with 28 deaths.

There was almost complete ignorance of the effects of this poison in the United States when the manufacture began on a large scale, and it was not till serious illness had appeared among the men and women employed in handling it that information concerning causes and remedies began to spread. We have now a few autopsy reports of fatal cases, and in the towns where the workmen live there are now physicians who have made a study of the poison and are familiar with its manifestations.

The danger of nitrous fumes is present in the manufacture of triton but not to a great extent. Nitration of toluol is carried on in closed retorts, and the escape of fumes is not incident to the process. If it occurs it is the result of some accident, of a "boil-over" because of too rapid nitration, or of a leak in the acid supply. The typical danger in this work is not nitrous fumes poisoning, but the effect of the trinitrotoluol itself. This is not usually a rapidly developing form of poisoning, not like dinitrobenzol for instance. In exceptional cases there may be a sudden collapse, perhaps after only a few hours' work on a hot day, but in most cases the symptoms come on gradually after an exposure of weeks or even of months.

The inhaling of TNT dust produces burning in the throat and nose, with abundant secretion, like a severe cold in the head, and with

a sense of tightness in the chest. An obstinate cough is complained of by many as one of the earliest symptoms. But much more distressing and more common are symptoms referable to the gastrointestinal tract. Indeed, some experienced foremen think that a distaste for food is the earliest and most frequent symptom of triton poisoning. It may be that part of this distaste comes from the bitter taste in the mouth which is experienced very soon, even by visitors to the works. So general is the intestinal type of poisoning that when a physician tells us he has seen only the cyanotic form in his plant, we are forced to conclude that he is not recognizing the real nature of the illness among his men.

A description of mild, acute poisoning was given by a man employed in a shell-filling plant. He first noticed a bitter taste in the mouth, and at times the bitterness was intense, like quinine, and with it he would be somewhat nauseated. Occasionally he vomited frothy, yellow fluid. Headache was severe at times. All these symptoms came on soon after he began work and then gradually passed away and when he told of them he had apparently reached a stage of immunity.

Another man, a mixer and kettle tender in a shell-filling factory, had slightly more serious symptoms. His skin showed the peculiar color that one soon comes to look for among triton workers, a mixture of lividity and jaundice, both slight, but perceptible, the yellow in the eyes especially, the lividity in the lips, and the skin a dirty, grayish yellow. He said he had lost his appetite, was constipated, felt stupid and drowsy, and had great difficulty in driving himself to work. His stomach was "heavy" and he had the train of symptoms which people try to describe under the term "biliousness."

A third man had to quit work because of ill health. He was employed on one of the machines for boring detonator holes in shells, and the shield which was supposed to protect his machine and prevent dust from escaping was broken and of no real use. After about three weeks he began to have headache and an obstinate cough, with expectoration of yellowish mucus which stained water yellow. During the sixth month of his employment he was in a room where TNT is melted in great, half-open kettles, and there is a good deal of fume rising from them. He was then quite ill, and thought that his suffering was due directly to the fumes from these pots, so that whenever he could he would step out into the open air to revive. He had pain about the navel and in the joints, and for the first time in his life suffered from attacks of vomiting, being nauseated most of the time. His joints were swollen when he finished the day's work, but the swelling would subside during the night. Headaches increased in severity and he grew weak, so that he would drag himself home in

the evening and climb the stairs with difficulty. He lost 9 pounds in weight before he quit work.

Sometimes the first effect of the TNT is to increase appetite and produce the appearance of improved health, but this soon passes away. In the typical gastrointestinal form—and this includes the majority of all cases of TNT poisoning—there is griping abdominal pain, referred to the waist line, constipation with flatulence, bitter regurgitation, vomiting, sometimes diarrhea. Trinitrotoluol may be recovered unchanged from the feces and it has been suggested that it may exert a directly irritant effect on the lining of stomach and intestines, just as it does on the skin and on the respiratory mucosa.¹

At the same time the changes in the blood already described as characteristic of the nitro group of poisons are taking place and the color grows more cyanotic. This cyanosis is not usually so marked as in nitrobenzol and anilin poisoning, though attacks of blueness with dizziness, staggering, and loss of consciousness may occur from TNT poisoning as well as from the two former. Even prolonged coma, or delirium and convulsions have been reported in cases of severe and rapid poisoning.

Involvement of the bladder is noted quite often by some physicians, but they find it yielding readily to ordinary treatment. Nosebleed is also not uncommon. In people with damaged lungs there is likely to be pulmonary hemorrhage. Two instances of this came to notice. One was a girl of 20 years, whose father and brother had recently died of tuberculosis after long illness. She had paraffined and scraped TNT charges for several months and had suffered from cystitis. She had several hemorrhages from the lungs and a profuse one was the immediate cause of her death, but the effect of the triton was shown by the thick, brown, chocolate-colored blood.

A similar case in a man was also reported. He acquired TNT poisoning in a shell-filling plant, but in his case also the immediate cause of death was a hemorrhage from the lungs.

The most serious form of triton poisoning is that which the British call toxic jaundice and under that name it is listed in their factory-inspection reports. The history of a woman employed in an American shell plant illustrates this condition. She was seen after she had been ill for six weeks and was well on the way to recovery. At that time her skin was yellowish and flabby, and the whites of her eyes were yellow. She was a heavy woman, something past 30 years, and had good health before going to work in this factory. Her abdomen was prominent, her ankles very dropsical, the edema extending almost up to the knees. She had been very weak but could sit up at

¹ London Lancet, Dec. 16, 1916.

that time and even walk about a little. Her history was as follows, given by herself:

She began to work the 1st of February, 1916, weighing charges of triton for shells. The stuff was floury and it was rather dusty work, but she always wore a respirator. About 8 to 10 girls did this sort of work. Some of them suffered from an eruption like that from poison ivy over arms and hands, but none of them became ill. Then she was set to paring off with scissors the charges which had been too heavy. This work also was dusty. After about five weeks in all she began to feel ill, her appetite was completely gone, and everything she ate had a disagreeable taste. She lost strength, would lie down all the time she was in the house, and had to force herself to go to work in the morning. Her hands had been dyed yellow by the powder, but now the skin all over her body turned yellow. Then very obstinate nausea and vomiting came on. She kept at work for three weeks after she first felt ill, but was obliged to give up because of the vomiting. For four weeks she retained hardly any food at all. She became dropsical and had an irritating rash all over her body, but she was never cyanosed. Her urine showed albumen and casts.

The fatal cases of toxic jaundice of which we have records had histories very like this one. In connection with 7 of the 13 deaths from triton poisoning we were told that the illness had lasted for several weeks. At the outset it was no more serious than the usual cases, but it took a rather sudden turn for the worse and then symptoms of jaundice and severe liver involvement came on rapidly. The clinical diagnosis is really one of acute yellow atrophy of the liver and the pathology is the same. The liver plays an important part in the elimination of the poison and in those cases where death does not come on with great suddenness, there is time for destructive changes in liver and kidneys, the latter showing also fatty degeneration of epithelial cells.

These are some of the histories secured of fatal cases. A girl of 19 years had been for some months dipping TNT charges for shells in liquid paraffin, and was then transferred to the office for two weeks. Her illness developed after she had left the triton department. At first she had only the usual symptoms, such as nausea and constipation, no jaundice. She even grew better. Then, 10 days after her last visit to the company physician, he was sent for and found her comatose, with pronounced general jaundice and absolute suppression of urine. She had vomited persistently. She died the next day, after 12 hours of profound coma. The physician said he had reason to believe that she had had some kidney derangement before going to work in the plant.

Two fatal cases in men also presented a picture of toxic jaundice, and the condition was diagnosed as yellow atrophy of the liver. There was intense generalized jaundice and tiny capillary hemorrhages thickly distributed over chest and abdomen just beneath the skin. The liver had perceptibly diminished in size. The symptoms preceding death were apparently identical in all respects with acute yellow atrophy of the liver, beginning with general malaise, then marked gastrointestinal disturbance, griping pains across the abdomen, increasing jaundice, fever, delirium, coma, and death.

Two deaths from TNT poisoning contracted in a shell works occurred in the spring and summer of 1916, and the autopsies were performed by Dr. H. S. Martland, pathologist to the Newark City Hospital, who reported them as follows:¹

Case 1 was a white man of 24 years, who had always been in good health. In April, 1916, he began to work for a shell-filling plant, and used to dump TNT powder into steam kettles, stirring it as it melted and then filling shells with the molten material. After seven weeks of this work he went to the factory physician because of nausea, vomiting, slight abdominal pain, and weakness. He was already jaundiced and there was tenderness in the epigastrium. He left the plant, but grew steadily worse and in two weeks was sent to a hospital, deeply jaundiced, vomiting persistently, prostrated, and slightly delirious. He died in coma five days after admission.

Three days later, after embalming, the body was examined. The anatomic changes which could be detected in spite of the action of the embalming fluid consisted in a toxic hepatitis with extensive destruction of the liver parenchyma; toxic degenerative tubular nephritis; icterus; cloudy swelling of the heart muscle; increased blood destruction in the spleen, and secondary anemia showing considerable polychromatophilia. A striking feature was the intense jaundice. The skin all over the body was a deep chrome yellow and all the viscera were bile stained.

Microscopically there was cloudy swelling of the liver cells with extreme fatty degeneration, followed by necrosis and autolysis of the liver cells leading to extensive destruction of the liver parenchyma, so that only a few areas of unchanged liver cells were seen, usually around a portal space. Lymphatic infiltration was seen around the periphery of the lobules; there was deposit of greenish, granular pigment; capillary hemorrhages; extensive regeneration and proliferation of the bile ducts.

Case 2 was of a quite different type. He was a man of 50 years, who had always been in fair health and who was employed for several months in this same plant. For the last two months before

¹ *Journal of American Medical Association*, 1917, vol. 68, p. 835. The article is condensed, only the essential details being given here.

his death his work consisted mainly in sweeping the floor of the room in which the detonator holes are bored in the TNT shells, and where, in spite of shields to prevent the dust from spreading, there is always a good deal of dust on the floor. After a few weeks he complained to the factory doctor of nosebleed, but apparently he was allowed to go on working. Later he went to the doctor because of epigastric pain, weakness in the legs, violent headache, and occasional coughing and vomiting of blood. Still the physician did not advise him to quit work and he did so of his own accord because of extreme weakness.

His family physician then found him suffering from frontal headache, loss of appetite, weakness of lower limbs, and bleeding from gums. His temperature was 102; pulse 90, weak but regular. On the third day he became delirious, and this continued for four days. It was a low, muttering delirium and gradually passed into coma, in which he died. There was extensive destruction of red corpuscles, which before death fell to less than a million, with a hæmoglobin of 30 per cent. The urine showed a trace of albumin, with hyalin and granular casts.

This autopsy was performed shortly after death, on the unembalmed body. The anatomic diagnosis was acute aplastic anemia, with hemorrhages from mucous membranes of nose, gums, and intestines; hemorrhages from serous surfaces, parietal and visceral pericardium, endocardium, and arachnoid; low-grade parenchymatous degeneration of heart muscle, liver, and kidneys; and increased iron pigment in spleen and liver. Blood smears showed a reduction in both red and white cells, with practically no evidence of effort at regeneration of these elements, such as nucleated reds, polychromatophilia, etc. There was no jaundice in this case and no evidence of toxic hepatitis, except the slight changes in the liver cells noted above. The bone marrow showed a replacement of erythropoietic tissue by fatty tissue.¹

Another instance of fatal toxic jaundice was briefly reported as follows: The kidneys were badly damaged, pale, with indistinct markings. The spleen was smooth, heart normal. The liver was atrophic and a stained section showed complete destruction of the cells surrounding the central lobular veins and a damaged condition of the peripheral cells.

Less typical and less usual is death from the immediate effects of larger doses of TNT, when the symptoms are those already described as characteristic of poisoning by the nitro derivatives of the benzene

¹ The findings in this case are singularly like those described by Selling in the well-known cases of poisoning by benzene (benzol) which he reported and which, because of the marked diminution of white blood corpuscles, afforded the suggestion for the benzene treatment of leukemia. Selling's cases also had hemorrhages from mucous and serous membranes.

series. Several cases illustrative of this class were described by Dr. T. F. Harrington, deputy commissioner of labor, Massachusetts.

The first was a man who was employed in the nitration department of a TNT plant for one month. One day on his way home, about half a mile from the plant, he was suddenly overcome and fainted. He was unconscious for nearly two days, deeply cyanosed, and he had several convulsions. He made a very slow convalescence, suffering from dyspnoea, cough, a rapid pulse, dizziness, and mental confusion.

The second was a man 42 years old, employed as a carpenter in a building where toluol is nitrated. He was made dizzy by fumes from a duct under which he was working and went outside, where he revived in a little while and was able to go back to work, but the dizziness returned almost at once and he was obliged to quit and go home. The next day he came back, but as soon as he reached the place where he had been at work he was overcome with dizziness and nausea, vomited, and had to be helped out of the building. He drove 2 miles in the open air to his home. The next day he felt chilly and suddenly grew very ill, had convulsions, and about midnight died. The autopsy showed "red cell destruction and secondary oxygen starvation, especially of brain and nervous system; general congestion of the organs."

A third case was very similar. The man was employed in the nitrating department, and on the second day he was sent to clean out the dinitrating tank. He felt the fumes very much and had to go outside often for relief. He worked from 10 in the morning till 2.30 in the afternoon, then he left and walked about a mile to the electric car and rode 5 miles to his home. Early in the evening he was seized with dizziness, spasms of the muscles; he lost consciousness and died at about 2 in the morning. The coroner's verdict was "Death from edema of the lungs, due to gas poisoning."

Triton has, in common with many compounds of this group, an irritating effect on the skin, caused more by dust than by fumes. This is at times very distressing, enough so to force the man to give up his work, for the itching is intense and prevents sleep and makes the sufferer nervous and incapable of work. Some people are extremely susceptible to this rash, others never suffer from it at all. Women seem to be less susceptible than men, but this may be simply because they dislike a disfiguring eruption more than men do, and will take more pains to prevent it. We heard of several instances of over-susceptibility to triton rash. Guards on the grounds who hardly ever enter a building may get it. Men may carry enough of the powder home on their clothes to give rash to members of the family. The wife and baby of a superintendent of a triton works had a

typical rash, so did a child who played in the home of a workman, and a woman who washed workmen's overalls.

Prosser White¹ describes the rash as beginning with a mottled erythema, usually first in between the fingers and spreading to the forearms, hands, and wrists. The backs of the hands may be swollen and hard, and the skin crack in large scales. At first there are tiny red points surrounded by an erythematous area, then vesicles form with opaque fluid, which look like grains of sago under the skin. Sometimes the condition resembles an erysipelas and the eyelids are swollen shut. The swelling and itching are often worse at night. Scaling follows, the skin of the palms coming off in large strips, while that of the arms and wrists come in flakes. There may be a similar eruption on the feet, the powder working its way in through the front of the boot and the sock. If the eruption is on a part of the body that is chafed by clothing and kept moist by perspiration, ulceration may result. Physicians say also that triton workers are very liable to festering sores; that slight injuries, instead of healing, inflame and suppurate.

Superintendents and foremen usually believe that men acquire immunity to triton, but a very observant physician who had had almost a year's experience in a large plant said very emphatically that although he had at first believed this to be true, he had been forced to the contrary opinion.

In order to detect the earliest stage of this form of poisoning, some doctors look for a bluish color in the lips and lobes of the ears; others for yellowing of the whites of the eyes; others for loss of appetite and a bitter taste. Hudson depends on blood examinations made at frequent intervals, looking for the changes described in the section on nitro and amido compounds, the lymphocytosis, and changes in the red corpuscles. This method enables him to put a man at other work during the early stage of his poisoning, long before he would think of going to the doctor with a complaint of sickness. The British authorities lay stress on the importance of such early symptoms as a persistent cough due to no known cause, unaccustomed shortness of breath, fatigue not explained by exertion, and pains coming on suddenly in the feet and legs.

In all well-managed factories the physician is permitted to order the transfer of men with suspicious symptoms and have them sent to other work. They may still be given employment in the works, provided it does not involve exposure to triton dust or fumes. One company has started vegetable gardens on the land near the works, and the physician sends men sick enough to need watching to work in these gardens, where they will be under supervision and he can be sure they are healthfully occupied. Such a change of work for

¹ London Lancet, 1916, p. 400.

suspicious cases is specially insisted upon by the British authorities, and the disastrous results of ignoring warning signs of poisoning are easily seen in some of the American cases, notably those reported by Dr. Martland.

Some physicians in this country hold that the respiratory tract is the most important channel of entry for trinitrotoluol. This is, however, not the usual view. Most men who have observed industrial poisoning from this compound believe that the skin is much more important, and that, even when a dusty atmosphere is the cause of the poisoning, it is the dust which falls on the skin rather than the dust which is inhaled and swallowed that is responsible for the trouble. British investigators seem to have proved that this latter theory is true. By examining the urine of TNT workers daily for seven weeks, they came to the conclusion that more TNT was absorbed and could be demonstrated in the urine when it had entered through the skin than when the digestive tract was the channel of entry. This is one reason why hot weather so greatly increases the incidence of poisoning.

The combined effect of heat, humidity, and fatigue is shown in the record of one triton plant during 1916. The number of cases of poisoning for June, a cool month, was 23. During this month a rush contract was made, and the men began to work overtime, their hours before this having been only eight. This was kept up during the intense heat and humidity of July and August, and in those months the number of cases rose to 55 for July and to 69 for August. In September, after the weather improved and work began to slacken, the cases of poisoning fell to 36.

Of course, all the triton poisoning in this country must have developed fairly rapidly, because this is a new industry and most of the plants have been running less than two years, while the appointing of a physician to look for cases of poisoning belongs to an even more recent date. As a matter of fact, all those whose histories were given with a fair degree of fullness had developed poisoning after a short exposure. Fifty cases from the records of one physician had all worked less than eight months. According to the British statistics, at least 83 per cent of their cases of jaundice occurred between the fifth and sixteenth week of work. "In 105 reports on toxic jaundice not one had been employed for a period less than four weeks. Only two fatal cases have been reported where duration of employment had been more than four months, although thousands of workers have worked a much longer time."¹

Only one of the nine TNT factories employs women in work which involves exposure to this compound, and in this one the number of women is small, so that it is impossible to draw any conclu-

¹ London Lancet, Dec. 16, 1916.

sions as to sex susceptibility from the facts collected. The British statistics show that incidence and fatality are little affected by sex. On the other hand, they find that youth does affect the seriousness of the poisoning. The percentage of deaths from toxic jaundice, recognized and notified as such, is 33 for all cases, but for those under 18 years of age the proportion is 8 deaths to 11 cases. Individual susceptibility plays a large part in this form of poisoning. "It would almost seem as though workers could be divided into two classes—the one (and much the larger) insusceptible and remaining so, no matter how much exposed; the other susceptible and liable to succumb, especially between the fifth and fifteenth week."

There are two advantages in American plants, as compared with the British. One is the absence of immature workers. Throughout all the plants visited in the course of this inquiry only two lads were seen working with TNT, and only about 40 women, the majority of whom were over 18 years of age. The other advantage is due to a difference in methods of handling TNT. In British medical articles dealing with TNT poisoning, processes are spoken of which are not used in American factories. There seems to be a great deal of hand sifting of TNT powder by girls, and this is excessively dusty work. It was never seen in our factories.

The one American company that manufactured triton before the war has proved that it is entirely possible to carry on the nitration of toluol without serious harm to the workmen, by the use of preventive measures, by controlling dust and fumes, and by strict supervision of the physical condition of the men. During more than six years this company has had no serious case of toxic jaundice and not one death.

In a recent article two British physicians¹ describe the forms of TNT poisoning as they have seen them in a large munition works where, apparently, many women are employed. They distinguish two large classes of cases, with subclasses under each. The first is the irritative, and under it come (*a*) respiratory cases, (*b*) gastric, and (*c*) skin cases. If persons with the irritative type of symptoms persist in work exposing them to the poison, toxæmia may appear. The second class is the toxic, divided into (*a*) digestive, with continuous "bilious attacks," nausea, vomiting, anorexia, constipation, jaundice; (*b*) circulatory, with faintness, giddiness, hot and cold flushes, pallor, slight cyanosis, palpitation, slow pulse, air hunger, swelling of hands and feet; (*c*) cerebral, with drowsiness, depression, apathy, transient loss of memory, blurred vision; in severe cases, delirium, convulsions, and coma; (*d*) special, including cases of irregular, scanty menstruation, dark and scanty urine.

¹ Agnes Livingstone-Learmouth and Barbara Cunningham, in *London Lancet*, Aug. 12, 1916, p. 261.

The toxic cases are usually slow, but may be fulminating. There seems to be no relation between the severity of the symptoms and the issue of the case, for a serious case may clear up, while one that begins with mild symptoms may develop into a dangerous one or even end in death.

NITRONAPHTHALENES.

According to Hunt and Jones¹ naphthalene causes symptoms not characteristic of the phenol series to which it belongs. In mild cases there is headache, malaise, vomiting; in severer, pains in the bladder, and urethra and kidneys. The urine is dark and contains alpha-naphthol and beta-naphthol. Death has been known to occur from nephritis. There is a specific effect on the eye, shown by degenerative changes in retina and subretinal hemorrhages, or in cataract formation.

Nitronaphthalenes are less dangerous poisons than are the nitro derivatives of benzol and toluol.² We found the nitration of naphthalene being carried on in one plant, where the work was supervised and largely performed by the chemist. The work was largely experimental at the time, and the resulting product was a mixture of mono and dinitro compounds. When only one nitration was done in the 24 hours, the chemist did not feel the effects of the fumes, but during the hot summer weather he was nitrating twice in the day and after an exposure of 10 or 12 hours to the vapors he would be nauseated, weak, suffering from headache and general exhaustion and malaise. A workman who was employed in the so-called drying house, where he had to fill cans with the finished product, had to quit because he would be overcome by the fumes, and so dizzy and confused that he would go round and round in circles, not knowing what he was doing.

One workman in a dynamite plant, who had formerly handled "dope" containing other nitro aromatic compounds, said that he had often had attacks of blueness and faintness, but after nitronaphthalene was substituted he had had no trouble of that kind.

NITROBENZOL.

The explosive nitrobenzol, well known in both Germany and Great Britain, is not manufactured in the United States except as a step in the production of anilin. Nitrobenzol, or oil of mirbane, is a dangerous poison, very volatile, easily absorbed through the skin, attacking the central nervous system and producing profound changes in the blood. These changes have been discussed above under the section on "Nitro and amido derivatives of the benzene series."

¹ Reid Hunt and Walter Jones. Peterson and Haines: Textbook of Toxicology, vol. 2, p. 587.

² White and Hay, in London Lancet, 1901, vol. 2, p. 582.

The action of nitrobenzol is very similar to that of anilin, but more rapid and intense. There are more deaths in proportion to cases of poisoning from nitrobenzol than of anilin, and while an ordinary case of anilin poisoning usually recovers and is back at work in a couple of days, a nitrobenzol case will have to be under medical care for four or five days or longer.

NITROCHLORBENZOL AND DINITROCHLORBENZOL.

These are well-known substances in Germany, where they have long been in use in the making of anilin dyes. There are many reports from that country of severe poisoning among men exposed to them, and the symptoms produced are those which were described in the section on "Nitro and amido derivatives of the benzene series." We found them in one plant only, as by-products. Here they have been known to set up troublesome eczema, severer than that produced by picric acid or tetryl, but we heard of no constitutional symptoms which were attributed to these compounds.

ANILIN.

This is made from nitrobenzol, and is used in fairly large quantities for the manufacture of diphenylamin, for the explosive tetryl (tetranitromethylanilin), and for the rarer explosive tetranitranilin, or TNA.

Anilin is poisonous in very small quantities, whether inhaled or spilled on the skin, and as it has a pleasant odor and is not at all irritating, it does not give warning of its dangerous nature. The symptoms have been described in the section on "Nitro and amido derivatives of the benzene series." It is rare to see really serious forms of anilin poisoning in the manufacture of explosives, and there is not one death from anilin poisoning on our list.

Mild cases are very common and are disagreeable enough to make the men dislike to work with anilin. One man who had been employed for 13 months in a large plant making anilin said that he was the oldest employee in length of service left in that department. About 200 men were needed for the work, but they quit so often that more than 4,000 had to be hired during the year. He himself had been "knocked out" at least 20 times, and said that his wife always told him when an attack was coming on because she would notice his bluish color. In his case, a throbbing headache was the first symptom, then dizziness. He would stagger out to the open air, but could not stand up, because his legs would not hold him. He never really lost consciousness, though he would be "queer" for a while. He thought it was beginning to affect his digestion and to make him ill-tempered and nervous.

Foremen in charge of anilin workers say that the men are more irritable, "grouchy," and lazier than men in other kinds of work. It is not safe to push them, because they will only get angry and quit, and they really are not up to a normal day's work.

In a large plant making anilin, an excellent one, where the odor of anilin was barely perceptible at the time the visit was made, the foreman and workmen said that on hot and heavy summer days as many as 6 or 7 men of the 200 employed would have to be sent to the first-aid room for treatment. These men could usually come back to work the following day.

We know little about chronic anilin poisoning in this country, since the substance is new in our industry and there has not been much time for such a condition to arise, especially as the men employed in it are a shifting class of workmen. What we should expect from the experience of other countries is a profound anemia, with all the multiform disturbances which result from it, digestive, nutritional, nervous. There is also among German anilin workers an undue number of cases of tumor of the bladder.

DIPHENYLAMIN.

This is made in one of the factories visited and is used in smokeless powder works. It is dissolved in the ether-alcohol for smokeless powder and incorporated with the nitroglycerin powders. As it is a volatile poison of the amido group of benzene derivatives, very closely allied to anilin, it may be expected to produce the same symptoms as the latter. We were unable to obtain any evidence of diphenylamin poisoning from physicians connected with smokeless powder works, but two of them stated that the symptoms experienced by men employed in pressing and cutting powder must be regarded as due to a mixed poison, since the vapors they inhale contain ether, alcohol and diphenylamin.

DIMETHYLANILIN.

Dimethylanilin is made in two factories which were visited, in neither of which had there been any ascertainable poisoning. The making of this compound by the action of anilin on methyl alcohol and its subsequent conversion to tetranitromethylanilin is attended with decided risk since all these substances are volatile poisons, but the processes are carried on in closed receptacles and actually no trouble seems to have occurred.

TETRANITRANILIN.

Tetranitranilin or TNA is little used in this country. It was found in one factory, where girls were handling it. It is a greenish yellow,

fluffy powder and the girls showed the effect of the dye on their hair and parts of their skin. They wore gloves and some wore caps to protect the hair.

TETRANITROMETHYLANILIN, OR TETRYL.

Two plants manufacture this explosive. The most usual effect among those who handle it in American factories seems, so far, to be an irritating and obstinate trade dermatitis. In one plant where tetryl and dry picric acid and the nitrochlorbenzols are all handled the physician finds that the last named are the most productive of skin inflammations, next tetryl, and last picric acid.

The British use large quantities of this detonator, and Dr. Enid Smith has recently published a report on tetryl dermatitis in a factory employing 250 women working with this substance. Almost all have at least a mild dermatitis, if it is no more than a roughening and itching of the skin of the hands. Severe cases may have edema of the whole face, the eyes swollen shut. There is also some conjunctivitis in milder cases and irritation of the nasal mucous membrane. Dr. Smith finds constitutional symptoms so slight as to be negligible. The report of the Health of Munition Workers Committee speaks of such symptoms as headache, drowsiness, loss of appetite. It is also said that tetryl dermatitis has a different distribution from that which follows triton poisoning. Tetryl dermatitis appears on the chin, around the nostrils, and on the eyelids, while triton lesions are most pronounced on hands and arms. An American physician who has had much experience with tetryl workers in this country does not confirm this statement.

Another physician, with women tetryl workers under his charge, describes the skin eruption from this substance as less irritating than that from TNT, and clearing up quickly. He finds, however, other disagreeable effects of the tetryl in a watery discharge from the nose, sneezing, and nosebleed. This same physician mentions a symptom of tetryl poisoning which is not touched on in the British literature, namely, a cessation of menstruation of one to three months' duration.

NITROGLYCERIN.

Before the outbreak of the war nitroglycerin was manufactured in large quantities for peaceful uses, and though its production has increased of late it is not a new explosive in this country in the sense in which the others are. There are several companies that have long been manufacturing it and the physicians connected with them are quite familiar with the effects of nitroglycerin absorption.

There is less danger of nitrogen oxide fume poisoning in the nitration of glycerin than in any other nitration process in this industry of making explosives. The extreme danger of explosions leads to

care in mixing the acid and glycerin and any sign of over-rapid nitration with the formation of nitrous fumes is at once checked, because it might also result in explosion. This same risk of explosion brings about a division of the work into small units with only two to four men employed in each building, always an advantage when there are processes involving poisonous substances.

Nitroglycerin is itself a poison which is absorbed through the lungs and through the unbroken skin. It has a decidedly depressing effect on the vascular system, dilating all the peripheral vessels with a consequent lowering of the blood pressure. Strangely enough there seems to be little of this effect observed in men who daily handle it and doubtless absorb appreciable quantities. They seem to become rapidly accustomed to it, and provided they do not leave the work they soon reach the point where they can absorb daily an amount from 20 to 30 times the medicinal dose, yet without any apparent effect on the heart or circulation. However, this immunity continues only while they are at work, and even then very hot weather or exposure to an unusual quantity of the nitroglycerin may bring on symptoms. One physician in charge of such workmen said he had seen an attack of heart failure follow when a man suddenly quit the work and the loss of dilator effect of the drug made itself felt.

Laws in 1910,¹ Ebright in 1914,² and Hudson in 1917,³ published articles on nitroglycerin workers in which they describe the effects of the drug on new men, but they were unable to find any evidence of chronic poisoning in old "powder men." According to Hunt and Jones,⁴ the chronic effects of nitroglycerin poisoning are seen in ulcers and eruptions of the skin. Rambousek⁵ has seen ulcers and inflammation of the roots of the nails in men who mix and sift dynamite. Oliver⁶ believes the effects are transitory and leave no permanent traces, no impairment of health.

New men suffer from nitroglycerin headache, which they describe as a peculiarly intense, throbbing pain, beginning in the forehead and spreading all over the head. Stooping, or even lying down, makes it intolerable, and there is a great deal of restlessness and insomnia, sometimes nausea and vomiting and more rarely diarrhea. Nothing relieves it but quiet and fresh air, and it lasts from one to four days. There is frequent urination, and the urine is increased in quantity and of low specific gravity. Ebright examined a man who was suffering from a typical "powder headache," but found no relaxation of the radial artery.

¹ Journal of American Medical Association, 1910, vol. 1, p. 793.

² Idem, 1914, vol. 62, p. 201.

³ Medical Record, 1917, vol. 91, p. 89.

⁴ Peterson and Haines: Textbook of Toxicology, p. 604.

⁵ Gewerbliche Vergiftungen. Leipzig, 1911.

⁶ Diseases of Occupation. London, 1916, p. 135.

After a while the tendency to these headaches disappears, and the man is immune as long as he continues at that sort of work; but if he leaves it for work in another part of the plant he must avoid the nitroglycerin houses, for even a few minutes' stay in one of them may be enough to bring on the headache. According to Ebright, some powder men put a bit of dynamite in their hatbands if there is a holiday, so that they will remain under the influence and not have to acquire immunity again. Shaking hands with a nitroglycerin worker may bring on a headache in a man who formerly suffered from them.

No evidence was found in the course of this investigation that powder men have any permanent impairment of their health. This is partly explained by the fact that they are a selected group of men, chosen for their sobriety and reliability; they work short hours and there is usually no great physical strain; and then in addition there is more or less selection as a result of the oversusceptible dropping out and seeking other work.

MERCURY.

To make fulminate of mercury, metallic mercury is treated with nitric acid and the nitrate formed. Later in the process the washings from the fulminate are collected and distilled to recover the mercury. In both these processes there is a possibility of mercurial poisoning, and one such case was reported, a man who cleaned out this "sludge" and distilled it.

Mercurial poisoning is characterized by inflammation of the gums, with swelling and bleeding, a foul breath and copious flow of saliva, the "salivation" which was so familiar a condition in the days before the discovery of quinine when mercury was the approved remedy for malaria. In severe cases the teeth drop out. At the same time there are certain characteristic nervous symptoms, especially the so-called mercurial tremor, a fine tremor in the muscles of fingers and tongue and lips. Nervous irritability, gastric disturbances, and more or less profound anemia follow, and in long protracted cases there is nephritis and paralysis.

FULMINATE OF MERCURY.

The manufacture of fulminate of mercury employs about 40 men in one plant and about 5 in another, the latter making fulminate only now and then as it is needed, the former continuously. The handling of this explosive, mixing it with other substances, making and pressing charges, loading caps and inspecting caps, etc., employs in the two munition works studied about 600 men and 1,100 women.

Mercury fulminate is not itself a dangerous poison. It produces in some people a painful and disfiguring eruption of the skin, but we were unable to learn of more serious troubles, except an in-

flammation starting in the eyelids and going on to the involvement of the coverings of the eye. A decided difference is evident in the susceptibility of individuals to this affection, perhaps due to difference in the amount or in the character of the perspiration, for it can not be explained on the ground of lack of personal cleanliness in all cases.

Severe fulminate dermatitis is usually like moist eczema—the skin reddened, swollen, and tense, later exuding serum, then scaling or forming a scab. Bad cases may have a good deal of swelling of face and eyelids and fingers. Instances are spoken of in the literature in which the whole body was involved; but on our records there is only one case that was very extensive, involving face, neck, eyelids, hands, and arms. Of course the most usual place for the rash is on hands and forearms, but if the worker touches his face or neck or eyes, as he is very likely to do in warm weather, the powder on his fingers will cause a rash to appear there also. Out of 61 cases of fulminate dermatitis, of which we have the histories, 3 involved hands only; 5, the face only; 3, the eyelids; 33, forearms and hands; and 16, the face and arms, with sometimes neck and hands as well.

A much larger proportion of men than women suffer from this eruption, probably because they do not take so much pains to avoid it. In one plant employing both men and women there were 32 cases among 1,070 women, and 36 among 505 men.

Although we heard of no typical mercurial poisoning in connection with the handling of mercury fulminate, evidence from foreign literature goes to show that this salt of mercury is capable of producing such symptoms. In the British Health of Mmunition Workers Committee report on industrial poisoning it is said that mercurialism is seldom marked, but there may be a blue line on the gums, impairment of appetite, headache, nervousness, depression. Oppenheim¹ in 1915 reviewed the literature of mercurialism among workers in fulminate, and gave a number of instances which apparently have occurred in Austria since the outbreak of the present war. Among 13 persons with fulminate dermatitis, 8 had "stomatitis mercurialis," swelling of the gums, bleeding from the gums, salivation. His earlier cases were more severe and typical, probably because the exposure to the fulminate had lasted longer. Thus a man who died of mercurialism in Prague in 1850 had filled percussion caps for 11 years. A woman reported by Teleky² in 1908 had done such work for 5 years.

It is well to bear in mind the possibility of mercurialism in fulminate workers, so that early symptoms may be recognized and the worker shifted to another occupation.

¹ *Weiner klinische Wochenschrift*, 1915, vol. 28, p. 1273.

² Quoted by Oppenheim.

ETHYL NITRITE.

This is a depressant drug, formerly much used in febrile conditions to lower the blood pressure. It is one of the constituents of the fumes that are given off in large quantities in the making of mercury fulminate by the action of ethyl alcohol on mercuric nitrate. No serious cases of trouble from these fumes were reported, although on the day we visited the plant we were told that work had had to be almost entirely suspended in that department because it was excessively hot, humid weather and the fumes lay low in the building and made the men dizzy. The headache and lassitude and feeling of weakness that accompany this dizziness pass off quickly once the men are in the fresh air.

AMMONIA GAS.

This is an irritating and corrosive gas, capable of setting up severe inflammation when inhaled. Here, too, there is the late development of the serious symptoms, and death is due to edema of the lungs as in nitrous fumes poisoning.

In making dynamite ammonium nitrate is added to the dope and it is also a constituent of certain high explosive shells. The manufacture of ammonium nitrate from aqua ammonia and nitric acid involves some risk of poisoning, through an accident to the supply. One such case was reported, a man who either spilled ammonia or tried to stop a leak and breathed so much of the gas that he had a serious attack of congestion of the lungs.

The fact that ammonia is irritating to the lungs makes it dangerous to use strong ammonia vapors as an antidote for nitrous fumes poisoning, as has sometimes been done. The trouble would only be aggravated.

AMMONIUM NITRATE.

Handling ammonium nitrate in making dynamite or other mixed explosives is probably quite devoid of danger. The compound is poisonous only in large doses. It is very similar to potassium nitrate, which is often administered as a medicine in 30-grain doses over long periods of time, only the ammonium salt is somewhat less depressant to the heart than the potassium salt. One physician practicing near a plant in which a mixed charge for shells is made, consisting of crude trinitrotoluol and ammonium nitrate, attributed the cyanosis, faintness, headache, dark-colored urine, and cystitis which he saw in his patients to the ammonium nitrate, but it is highly improbable that the latter had anything at all to do with these symptoms. They are characteristic of trinitrotoluol poisoning, and the occupation in question would be very likely to cause such poisoning

even if no ammonium were present in the mixture. A superintendent who had had some experience with this explosive mixture gave it as his opinion that ammonium nitrate, being hygroscopic, facilitated absorption through the skin, and therefore did actually favor trinitrotoluol poisoning.

AMYL ACETATE.

One of the solvents used for guncotton in making smokeless powder is amyl acetate. It is known to possess some toxic properties and is listed by Sommerfeld¹ among the industrial poisons, causing, according to this authority, nervous symptoms, headache, sense of fullness in the head, dizziness, nausea, feeling of numbness, disturbances of digestion, and palpitation of the heart. According to Lehmann,² who experimented on human beings as well as animals, only slight symptoms were set up in healthy men who were exposed for half an hour to an atmosphere containing a quantity of amyl acetate equal to 5 milligrams in 1 liter of air. They felt at first an inclination to cough, which was succeeded by irritation of the eyes and nasal mucosa and a dry, burning feeling in the throat and a slight feeling of weariness, but there was no headache and no change in the pulse.

We could not find any evidence of disturbance of health caused by amyl acetate in this industry.

ACETONE.

The same is true of acetone, which is also used as a solvent for guncotton. Acetone is on Sommerfeld's list of industrial poisons, although, according to Kobert,³ cases of poisoning from this substance have never been reported, and indeed are scarcely conceivable. In the making of smokeless powder, certainly, acetone is not regarded as poisonous. Indeed one company doctor found his men using it to wash the eye if a foreign particle got in it. Another doctor said he had found it a good antiseptic and used it for dressing injuries.

CHLORINE GAS.

Since the spring of 1915 there have been many articles in the French and English medical journals dealing with the effects of chlorine gas on men, because this is the gas ordinarily, if not always, employed by the Germans in the present war. Some army surgeons have believed that bromine gas and even nitrous fumes were used in certain instances, but the overwhelming evidence is that chlorine gas is responsible for the "gassing" in the trenches.

These fumes are more choking and blinding than are nitrous fumes. Men hold their breath and run when chlorine fumes overtake them.

¹ Bulletin No. 100, U. S. Bureau of Labor Statistics.

² Archives fuer Hygiene, 1913, vol. 78, p. 260.

³ Die Intoxikationen, p. 95.

Chlorine fumes are also more rapidly asphyxiating than nitrous fumes, but the symptoms that develop in those who survive the immediate effects are quite similar to the symptoms of nitrous fumes poisoning.¹ There is the same delay in the development of serious dyspnoea, the same increasing air hunger, the same edema of the lungs and death by internal drowning, or development of pneumonia if the poisoning is not so severe.

In the making of explosives the only place where chlorine gas is encountered is on the charging floor of a nitric-acid building, during the first few minutes of the reaction when the acid is acting on the sodium chloride which is always present in Chile saltpeter. Many men were interviewed who said they had been caught by these fumes, but never had had to breathe enough to hurt them. The superintendent of an acid plant said that on one occasion when he happened to be up at the top of the retorts he had been unable to get away quickly enough and had breathed so much chlorine that he felt the effects for several days—soreness in the chest and a painful cough.

A physician in charge of the men working in a large acid works has seen several cases of chlorine gas poisoning that presented the same symptoms as his nitrous fumes cases—asthmatic attacks, followed after some hours by bronchitis and sometimes congestion of the lungs.

ALCOHOL AND ETHER.

In making smokeless powder from nitrocotton large quantities of grain alcohol are used, first to drive out the water from the cotton and then in combination with ether as a solvent. The fumes of alcohol are quite strong in the block breaking department, where the cotton impregnated with alcohol in a hydraulic press is broken up. These fumes may sometimes be strong enough to make the men somewhat drunk, but the effect of the mixture of alcohol and ether is so much severer than the pure alcohol that the latter does not attract much attention.

A mixture of ether and alcohol is added to the dehydrated nitrocotton and the resulting colloid mass is pressed and cut into lengths. During these processes a great deal of the solvent evaporates and the men breathe it. Both these fluids have an effect on the central nervous system, for when they reach the blood stream they tend to accumulate in the brain and it is there that the largest quantity of both ether and alcohol is to be found.² This leads to

¹ See section on "Nitration," p. 14.

² Nicloux (*Comptes Rendus de la Societe de Biologie*, 1907, vol. 62, p. 68) found that the brain of an animal anaesthetized with ether contained 153 milligrams to 100 grams of tissue, the liver, 102 grams. Friedmann (*These de St. Petersburg*, 1902) found that in animals intoxicated with alcohol the brain receives most of the alcohol, then the liver. The brain seems to have a chemical affinity for alcohol.

an impairment of function of the cells of the brain, which are first overexcited and then paralyzed or narcotized. According to Kraepelin, complete mental equilibrium is not restored till 18 to 20 hours after an ordinary alcoholic intoxication. According to Cushny, administration of ether to the point of anesthesia reduces the resistance of the body to bacterial invasion and to the action of toxins.

Spencer,¹ experimenting on animals, found that slight sleepiness came on after 2 hours in an atmosphere containing 1.5 volumes of ether per 100 of air. If the quantity was raised to 2.5 volumes per 100 of air, incomplete narcosis occurred in 2 hours; 4.45 volumes would cause complete narcosis in 15 minutes, with slow respirations, and a weak, rapid pulse, while 6 volumes brought on paralysis of respiration in 10 minutes.

If the weather is hot and heavy, so that there is not much exchange of air between the building and the outside, or if the windows are all closed to keep in the heat in cold weather, there may be many cases of "ether jag" in the pressing and cutting department. New hands suffer a good deal from mild ether poisoning. They pass through all the stages of narcosis as they are known to the anesthetist, the gradually increasing confusion, excitement, which may make the man almost uncontrollable for a short time, then the gradual dulling of the senses and drowsiness, passing into stupor and unconsciousness. The physician, even if he be on the grounds, seldom sees the man in the stage of excitement; usually by the time he has reached the office he is already stupid. There is no treatment for this condition, beyond allowing him to sleep it off in fresh air. Occasionally cases are sent to hospitals, if the narcosis is unduly prolonged, and we have records of one case in which unconsciousness lasted for 24 hours. There may be heart symptoms needing medical care, for a very rapid pulse is not uncommon.

The two most serious cases of ether poisoning which came to our knowledge were lads who had recklessly exposed themselves to ether fumes for several hours. They had gone into one of the small buildings where ether is condensed from smokeless powder—"solvent-recovery houses," they are called—and had climbed up on one of the solvent-recovery bins where it was warm and comfortable. They lay down near a manhole which was supposedly well closed with a rubber gasket, but there must have been some escape of fumes, for after reading a while they both fell asleep. They were found after they had been there less than an hour and a half, and both were in an alarming condition—respiration only 6 or 8 a minute, pulse down to 30. Two hours' work with the pulmotor brought them around and they were apparently none the worse for their experience.

¹ Archives fuer experimentale Pathologie und Pharmakologie, 1894, vol. 33, p. 407.

The usual after-effects of ether anesthesia follow ether poisoning in industry. The next day the man is somewhat nauseated, has headache, can not eat, is generally wretched, and has pains in his back. Often he becomes accustomed to the fumes and does not seem to be injured in any way by repeated exposures of many hours each day.

On the other hand, there are men who can not get used to it. The physician in charge of one of the largest smokeless powder works said that he had frequent requests for transfer from the ether men, but that he always convinced himself that the man was really ailing before he would accede to his request. That same morning he had just issued a transfer to a man who had symptoms of nephritis. This is not, in his opinion, a frequent sequel of long-continued exposure to ether fumes, but it may occur, and it would be a good thing if it were possible to make an examination of the urine of all men applying for work in this department.

A case of chronic ether poisoning was reported by a physician practicing in the neighborhood of this same plant. The man had worked there for three months and was then suffering from albuminuria and puffed eyelids. He had never had these symptoms before. The physician had also had two patients with uremia, both ether workers. One of them had syphilis and his kidneys were undoubtedly already damaged when he went to work in the ether, but the other had been in perfect health. The former died of uremic convulsions.

Another form of chronic ether poisoning affects the digestion and general nutrition chiefly. A man who had been in charge of a smokeless powder works for six months gave his symptoms as follows: He lost his appetite, partly because he always had a taste of ether in his mouth. His breath smelt of it all the time. After about three months of this work he began to grow apathetic and listless. He felt tired out and was chronically constipated. He lost 20 pounds and decided to leave the place. After taking up other work he was still constipated for several months, but his appetite came back and gradually he regained his normal condition. Another man, a workman in the pressing and cutting room, had also had to leave on account of his health. He said he would feel at first very much exhilarated, "as if I were walking on air or had a million dollars," and then depression would come on, especially when he went home. He, too, found that his digestion and nutrition were seriously impaired.

Most physicians and practically all superintendents and foremen believe that if a man can become accustomed to the ether so that he no longer gets a "jag," or only rarely, he will not be injured in any way by months or even years of such work. They point to the

fact that some of the ether men actually gain in weight under the influence of the work. But there is experimental evidence which tends to disprove this optimistic belief.

At the meeting of the International Congress of Industrial Hygiene in Brussels in 1910, René Sand described a series of experiments he had made on dogs to decide the question of chronic ether poisoning. He exposed the dogs for 10 hours out of the 24 to an atmosphere charged with alcohol-ether, dropping 500 grams slowly on a sponge placed inside the little cell, which was about a cubic meter in size and furnished with three openings as big as a silver dollar to admit air. His tests covered only seven animals, so they can not be regarded as more than suggestive, but as far as they go they cast an interesting light on the effect of long-continued sojourn in an atmosphere heavy with ether-alcohol fumes.

The usual result was a typical "ether jag," which would develop on one of the first days of the experiment, with excitement followed by stupor. Then the dog seemed to grow accustomed to the effects and to behave normally, even to put on weight. If, however, when this step had been reached, the dog was killed for examination, it was found that marked changes had begun in the organs. There was a generally distributed passive congestion in lungs, liver, spleen, kidneys, meninges, sometimes accompanied by capillary hemorrhages; an early stage of sclerosis in liver and lungs; and a pronounced interstitial nephritis.

Therefore, though there has never been a thorough study of the effect on human beings of repeated exposure for 8 or 10 hours to an atmosphere contaminated by fumes of ether-alcohol, nevertheless, the assumption seems to be justified that such exposure may be productive of gradual degeneration in certain cells of the body and this even when the man is apparently in good health; also the belief seems to be justified that repeated "ether jags" are not as transient in their effects as is popularly supposed.

INFLUENCE OF ALCOHOL ON POISONING FROM VOLATILE COMPOUNDS.

Many of the toxic substances that have been described above are volatile compounds which when absorbed have a special affinity for the cells of the central nervous system. Such are the nitro derivatives of the benzene series, nitrobenzol, nitrochlorbenzol, nitrotoluol, nitrophenol (picric acid); also the amido derivatives, anilin, diphenylamin, tetranitranilin, tetranitromethylanilin. Phenol (carboic acid) is a poison of the same kind, and so is ether, though belonging to a different chemical group. Experiments show that in ether anesthesia the central nervous system contains more ether than does any other organ (see p. 54). These derivatives of the benzene

series and also ether, enter into combination with the fatty substances in the brain, cholesterin and lecithin, more readily than with the water-soluble elements of other organs.

Now, the same affinity for the central nervous system is shown by alcohol. Here also it is in the brain that the greatest part of the alcohol is found in cases of alcoholic intoxication. It is easy to see, then, that if a man has been exposed to one of the above volatile poisons so that his brain cells have been partially poisoned, it will require only a small dose of alcohol to act as the last straw and bring on an attack of narcotic poisoning. As a matter of fact, this does occur rather frequently and gives rise in some instances to puzzling medicolegal cases, in others to faulty medical diagnoses. These are cases of mixed poisoning, of which the industrial poison is probably the more dangerous and the more responsible for the disaster.

A man who had been working in trinitrotoluol was taken to a hospital delirious, and because his breath smelled of alcohol he was pronounced to be suffering from acute alcoholism, and when he died this was given as the cause of death. In another case the man was known to be poisoned with trinitrotoluol and was told by his doctor to stay in bed, but he got up and went out and drank some beer—no more than he had often taken before without getting intoxicated—but the result was an exacerbation of all the symptoms of poisoning and death from toxic jaundice. Another case was a man of 62 years who was employed in a toluol nitration works for about two weeks. One night on his way home he stopped in a saloon and drank, but how much is not known. He was found dead in his bed in the morning, and the physician who related the incident believed it to be a case of triton poisoning, aggravated by alcohol.

Ether men are said to be unduly susceptible to the effects of alcohol. Although this does not seem to have been observed by physicians who practice among them, the men themselves say that a single glass of beer or one drink of whisky may be enough to make a man dead drunk if he has just come off his shift in the pressing and cutting house. These men, if taken to jail or the workhouse, sometimes scent the whole place with ether, their breath is so heavy with it. It is quite probable that such stories are true, for if a man has absorbed ether just short of the point where it begins to produce anesthesia and then takes a dose of another poison with a similar effect, the two will act together, although to the uninformed it will seem like an ordinary case of drunkenness.

Mohr ¹ has reported several cases of severe poisoning from benzene derivatives (chlorbenzol and nitrobenzol), in each of which the excit-

¹ Deutsche Medicinische Wochenschrift, 1902, vol. 28, p. 73.

ing cause of the acute toxic attack was a moderate indulgence in alcohol. These facts should be borne in mind before the diagnosis of "acute alcoholism" or "delirium tremens" is made as to a man who has been exposed to one of these volatile poisons.

MANUFACTURE OF POISONS.

NITRIC ACID.

For all these explosives nitric acid is an essential. We found it manufactured in 15 plants and refortified in practically all. Chile saltpeter (sodium nitrate) is acted on by sulphuric acid in great egg-shaped iron retorts or stills, with the fire below. Acid and saltpeter are charged through a manhole at the top, which is then tightly closed and luted down with clay. The nitric acid, which is volatile at the temperatures employed, distills out and passes through a condenser, where it is condensed to liquid by cooling with water either in glass tubes over which water flows (the Hart condensation system) or in fire-clay vessels or in vessels made from an alloy of iron and silicon.

The greater part of the nitric acid produced is obtained from this condenser. However, a portion of the nitric acid generated is decomposed into oxides of nitrogen of lower degrees of oxidation which are not condensed at ordinary temperatures. In order to recover this portion of the product the gases, after leaving the condenser, and from which the nitric acid proper has been removed, pass into a series of absorption towers in which they flow countercurrent to a stream of water or dilute nitric acid, which is fed over the towers. In these towers the lower oxides are oxidized and combined with water to form dilute nitric acid. The residue ("salt cake" or "candy"), which is chiefly sodium bisulphate and some neutral sulphate, runs out hot into great shallow pans, which are out in the open, covered only with a roof, and there it hardens. To make it more fluid an excess of sulphuric acid is often added to the original charge in the stills, and consequently there may be very irritating fumes when it first flows out, but there is a ready escape for them because of the open construction. Up at the top of the stills, on the charging floor, the air may be badly contaminated, during the first few minutes of the reaction, by fumes of chlorin gas, given off because there is always some chloride present as an impurity in the saltpeter. In some plants this is allowed to escape; in others it passes into the condenser system. In one such building a 2-inch opening is left in the plug of the still, and here a pipe is connected for the first 10 minutes of the heating to carry the chlorin gas to the outside, after which this opening also is closed.

The only feature of the cooling and condensing systems that concerns us is their successful working, whether all the oxides of nitrogen are caught and condensed or more or less gas is allowed to escape and poison the air. Three nitric-acid plants were visited which were so free from irritating gases that one would not have suspected what was being manufactured there. But in the other 12 fumes were escaping somewhere, not always enough to constitute a grave discomfort to the men working in them, but usually quite enough to make an outsider suffer. This was under ordinary working conditions. When a leak occurred matters became bad enough to affect the workmen, too. Unfortunately leaks are not unusual in nitric-acid manufacture, for the acid eats through almost any material. Air pressure is very likely to be irregular in the glass "pulsometer" condensation tubes and result in breaks, the air stopping for a while and then starting up again with too much force. Filling carboys with the finished acid is a continual source of small amounts of fume. Another source is found in the fume pipes to carry off the gases from the condensers. These are often so low as to allow the fumes to spread over the ground and even blow back into the building.

To provide for accidental bursting of pipes or too rapid action in a still, the best managed plants have balconies running along the charging floor and many easily reached exits leading to them. They are also provided with abundant water supply, so that if acid splashes over a man he can immediately wash it off. In less well-equipped acid buildings the men are expected to use the water that runs over the condensing tubes.

The repairing and cleaning of stills may be dangerous work if the still is not first thoroughly cleaned out, but it is entirely possible to do away with the danger here and to render the work not only safe but fairly comfortable.

Valentiner's process was seen in only one plant. The chief feature of this method is that the distillation and condensation are carried on under a vacuum, the purpose being to reduce the corrosive action of the fumes upon the apparatus and to reduce the decomposition of nitric acid in the retort by reducing the temperature necessary for the distillation. Those who use it claim that it is more rapid, more easily controlled, and less subject to breakages than other systems, but since the condensing and absorbing apparatus for nitric acid must be constructed of acid-resisting material, it is evident that the maintenance of a vacuum-tight system presents great difficulties.

From our standpoint the Valentiner system has great advantages, for the vacuum makes the escape of fumes practically impossible. Certainly, at the time of inspection the building in which this process was in use was entirely free from fumes.

SULPHURIC ACID.

This is made in seven of the plants that were visited and by two processes, the older "lead-chamber" process and the newer contact process. For both, pyrites is roasted to produce sulphur dioxide, or sulphur flowers are burned, the latter being generally used in connection with the contact process. Pyrites roasting is hot and disagreeable work, but in the newer plants it has been made as tolerable as possible by good ventilation. One danger comes from the volatilization of arsenic, which is present as an impurity in all these ores, and which passes over with the sulphur oxides and must be removed in the "dust box," together with unburned pyrites and oxides of zinc and antimony. In the burning of sulphur flowers there may be neither excessive heat nor any disagreeable fumes, as was the case in one plant where a revolving furnace was used, automatically fed. At the time this place was visited the air was entirely free from fumes, as indeed were all the departments of the acid building.

In either process the sulphur dioxide must be converted into sulphur trioxide in order to form sulphuric acid. In the lead-chamber process this is accomplished by the oxidizing action of oxides of nitrogen, which are introduced, together with steam, into the so-called "lead chamber." The hot sulphur-dioxide gases from the burners pass first through a tower called the "Glover tower," over which sulphuric acid containing nitrogen oxides is circulated. The hot gases drive out the nitrogen oxides and also partially concentrate the sulphuric acid in the Glover tower, being thereby themselves cooled in the process. The mixture of sulphur dioxide and nitrogen oxides passes then to the lead chambers, where the oxidation takes place as above described, additional quantities of nitrogen oxides being supplied directly to the lead chamber.

The gases leaving the lead chamber are passed through a final scrubbing tower or series of towers known as the Gay-Lussac towers, where the valuable nitrogen oxides are removed by scrubbing with sulphuric acid before the gases are finally allowed to escape to the air.

It is in the chamber process that the escape of fumes of sulphur dioxide may be great enough to cause much discomfort and even actual harm. In one acid works the Cottrell process for condensing these fumes by electricity has been installed, apparently with excellent results.

The acid formed by the lead chamber process, which is drawn off from time to time from the bottom of the lead chamber, is dilute, and in order to make it suitable for most purposes it must be concentrated as described under the heading "Acid Recovery" (p. 62).

In the contact process the oxidation of the sulphur dioxide is accomplished by passing it, mixed with air, over a contact material

which consists of finely divided platinum or platinized asbestos. This platinum has the property of causing sulphur dioxide and oxygen to combine and form sulphur trioxide. The water necessary to form sulphuric acid with the sulphur trioxide is added in the form of dilute sulphuric acid, with which the gas issuing from the oxidizers or "converters" is scrubbed. This process results in the production of strong acid directly by absorption of the trioxide in sulphuric acid and it is possible to produce sulphuric acid containing free trioxide in solution. This is known as "fuming sulphuric acid."

ACID RECOVERY.

In almost all of the nitrating operations involved in the manufacture of explosives a spent or waste acid, consisting of a mixture of nitric and sulphuric acids, is obtained as a by-product. In order to recover the constituents of this waste acid in a valuable form the ingredients must be separated and concentrated.

The operation of separating the two acids, which is usually called denitration, is accomplished by passing the acids down a tower of acid-resisting material and introducing a current of steam at the bottom of the tower. The steam serves both to heat up the mixture and drive off the volatile nitric acid and nitrogen oxides and also to dilute the mixture, breaking up the compounds of sulphuric acid with nitrogen oxides, which are comparatively stable in the presence of concentrated sulphuric acid. With this treatment the separation is accomplished, the nitric acid and nitrogen oxides being given off at the top of the tower in gaseous form and the sulphuric acid free from nitric flowing from the bottom. The condensation and absorption of the nitric acid and nitrogen oxides are accomplished substantially as described above under nitric acid.

The diluted sulphuric acid flowing from the bottom of the denitrating tower must be concentrated to be suitable for most uses. This is done by passing the acid through a series of open pans or basins of material which will resist the action of hot sulphuric acid. These pans are usually heated from below by direct fire and the acid brought to boiling. In the first pans of the series practically nothing but water is evaporated from the boiling acid, which becomes gradually more concentrated. As the strength of the acid increases the boiling liquid gives off vapors of water and sulphuric acid mixed, which are condensed in order to avoid the loss of the acid and returned to the first part of the system.

NITROCELLULOSE.

Thirteen of the plants visited manufacture nitrocellulose and use processes more or less dangerous to the workmen. But in all of them

the work of preparing the cotton for nitration and the subsequent ridding of the nitrated cotton from acid are operations quite devoid of risk, so that not by any means all the employees in the factory are exposed to risk of poisoning. For instance, in one large plant, where some 17,000 men were employed in making nitrocellulose, only about 4,500 were in those departments where nitrous fumes may arise, the rest were not exposed at all in the course of their ordinary work.

Cotton is changed to nitrocellulose or guncotton¹ by treatment with a large quantity of mixed acids, about 1 part of cotton to 50 parts of acids. A mixture of nitric and sulphuric acids is used, the latter because the reaction between the cotton and the nitric acid results in the production of water, and strong sulphuric acid must be added to take up the water. The explosive power of the resulting guncotton depends on the percentage of nitrogen taken up. If the nitration is carried on for a longer time at a high temperature with a larger proportion of nitric acid, a nitrocellulose is formed which is not soluble, or sparingly so, in a mixture of ether and alcohol, and is classed as a high explosive. This is known as military guncotton and is also used in the mixed nitroglycerin powders such as cordite. If, on the other hand, the nitration is carried on more rapidly at a lower temperature and with a weaker nitric acid, soluble guncotton is formed, which is not classed as a high explosive, and is used not only for smokeless powder but for the manufacture of celluloid, lacquers, varnishes, artificial silk, etc.

Three methods of nitrating cotton were found in use in these factories, centrifugal nitration, pot nitration (Marshall's "direct dipping"), and the displacement process. There is a fourth method, Abel's, described by Marshall, but it seems not to be used in the United States.

CENTRIFUGAL OR MECHANICAL NITRATION.

A typical building for this sort of nitration is three stories high, the top floor being used for the mixing and digestion of cotton and acid. The mixed acid from supply tanks outside flows into the digester and is mixed with cotton already carefully purified. This is then sent down through supply pipes to the wringers, or centrifuges, on the floor below. There is rarely any trouble from nitrogen oxide fumes up here, unless there is a leak in the acid supply pipe—leaking pipes are no rarity in any form of nitration, for the strong acids eat through almost any substance—or unless the fumes on the second story can make their way up to the third. In cases of bad "fires"

¹ Guncotton is, according to Sadtler (Handbook of Industrial Chemistry. Philadelphia, 1895), the hexanitrate of cellulose, $C_{12}H_{11}O_4(NO_2)_6$, if the acid used is strong nitric acid; if weaker, it is the trinitrate or tetranitrate. Marshall gives as an approximate formula $C_6H_7(NO_2)_3O_6$ for the higher nitration product, and for the lower, $C_6H_8(NO_2)O_6$.

this does happen, and therefore it is best to have emergency exits and balconies for this story as well as for the second.

On the second floor are the wringers or centrifugals supplied from above with acid and cotton, or in some cases the acid is carried with the cotton in the wringer. The workman fills his wringer, turns the supply pipe to one side to drip over a drain, puts on the lid loosely, and starts the centrifuge. If it does not start promptly enough, or if the cotton is matted, and does not mix well, or if there is too little acid, or if anything else goes wrong, a rapid decomposition takes place and fumes of the different oxides of nitrogen begin to come off. This is known as "firing" or "fuming off." The mixed white and orange fumes may pour out with such suddenness and violence as to hurl the man back for several yards. In one very well-managed plant where the wringer men are protected by means of strong helmets made of fiber, one man had his helmet flattened against his head by the force of such an explosion. Of course, when this occurs a quantity of liquid acid is splashed about and may give rise to severe burns.

An investigator of guncotton factories soon becomes accustomed to these "fires," the clouds of angry-looking fumes pouring out, the workmen running for the exits, the choking feeling in the air, and the light, prickling, burning sensation over the face from the fine spray of acid. Indeed, it is rare that an inspection can be made of a guncotton plant without at least one fire occurring during the visit, no matter how short it is. Eight large fires, with fumes thick enough to dye the skies, and many smaller ones, took place during a three-hour visit to one plant, but even worse was a much smaller factory where three fires occurred during seven minutes' time. Nor did the men in either place seem to look upon it as anything out of the ordinary.

The rule is for the men at the wringers to make for the open air as quickly as possible and wait there till the fumes have died down and been sucked out by the exhausts. In the better constructed buildings, narrow porches with stairs leading to the ground are placed on both sides of the nitrating room, and there are many exits leading to them. In others, the arrangement is not so good; the walls of the wringer room are not free, and the men must go into the cotton rooms to escape the fumes, or perhaps into a space between buildings where fumes penetrate and do not find a ready escape. A very good arrangement was seen in a new plant in Rhode Island, where each nitrating unit, digester and wringer, is separated from the one next to it by a fire wall, so that in case of decomposition the fumes can not spread all through the building.

To an outside observer this continual "firing," with the loss of a whole wringer charge, seems very wasteful, not only of cotton but

of labor, for work must be suspended whenever it happens. It may be that such accidents are unavoidable, but it is certainly true that if awkwardness and lack of skill have anything to do with them there is plenty of it, for the labor employed is entirely unskilled and usually not even experienced, since the turnover of labor is always greatest on the nitrating area.

The fumes may clear up in about three minutes after a fire, to the point where the men can go back to work, though a person unaccustomed to them must wait at least twice as long. On hot, heavy days it may be 10 or 15 minutes before the air clears. During certain days in July and August of 1916 production in the nitrating area of one of these plants fell off about 50 per cent, simply because of the unbearable condition of the air.

It is not only while the mixture is going into the wringer that fires may occur, but during the time it is being centrifuged. If the wringing process is too much prolonged, if the right moment for stopping it is passed, the charge may fire or even explode. The danger is greater the higher the nitration of the cotton.

The next step is to wash the nitrocellulose free from residual acid. In factories of the type just described, the wringer is discharged directly through a pipe to a drowning tank on the ground floor and the washing is done under cover, so there is practically no trouble with fumes here. But if washing, or drowning, as it is called, is done by hand and in uncovered tanks there is always a great evolution of nitrous fumes, to adopt the term used in general for the mixture of higher and lower oxides of nitrogen. Such methods of drowning are seen in several plants using the centrifugal method of nitration. In some of them all the processes—mixing, digesting, centrifuging, and drowning—take place in the same room. The cotton is placed in wringers, acid is poured on by one man while another works the cotton back and forth with tongs to mix it thoroughly, then the cover is put on, digestion takes place, the cotton is dug out and thrown into a drowning tank. Such rooms are always fairly full of fumes and may be almost unendurably so, even when work is going on in the usual way without the slightest accident. Fumes rise when the cotton is being mixed with acid, and at any moment a fire may take place, and they rise when the cotton is thrown into the drowning tank. A description of one such plant will make this clear.

The nitration is carried on in a long, fairly high building, well ventilated for ordinary purposes, windows in sides and roof, wide doors at each end, yet the air is choking. There are 12 wringers, 6 along each wall, and down the middle of the room runs a long, open trough of water—the drowning tank. One man was charging a

wringer with cotton while another mixed it with the acid that ran in from a supply pipe in the wringer, using a sort of trident of aluminum. Both worked at a high speed, for this is in a sense piece work, and clouds of orange fumes rose as the acid met the cotton, in spite of the fact that there is an exhaust inside the wringer which is supposed to draw them off. The wringer was then closed and the men went outside to wait till digestion was over. They came back, opened the wringer, and began to empty it with the most feverish haste, digging out the cotton and flinging it into the drowning tank, and at every fling a cloud of fumes arose, though they tried to prevent that by submerging the cotton as quickly as they could. In their haste a good deal of the cotton was dropped on the floor and lay there giving off white acid fumes, but there was no time to pick it up. Three wringer charges were being drowned at once and the air was almost unbearable. The long tank is open and far too large for any exhaust system to be practicable. At this moment a fourth wringer took fire, and as the gases spread, the men were obliged to leave everything and run outside. We moved on to the next building, where only quite harmless processes are carried on—washing and boiling the gun cotton—but here, too, the fumes penetrated, because the two buildings are continuous. There are about 30 men working in the nitrating on each of the three shifts.

Another plant very similar to this one has a better arrangement, because the nitrating units are separated from each other. There is a drowning tank for each wringer. This makes possible the partial walling off of each unit and the installing of exhausts, not only in the wringer but at the end of the drowning tank which is nearest to the wringer and which receives the cotton from it. This exhaust carries off fumes which in the other building are allowed to escape.

POT NITRATION OR DIRECT DIPPING.

Centrifugal nitration is not adapted to produce the highly nitrated cotton of low ether-alcohol solubility, because parts of the cotton may escape the action of the acid in the relatively short time the cotton remains in the centrifuge. For the production of military guncotton and nitroglycerin powders a longer digestion is needed. This is done in zinc or steel or earthenware pots. The prepared cotton in one of these pots is mixed with the acids; then the pot is covered and set aside to digest for about 20 to 40 minutes. Then it is emptied quickly into a centrifuge wringer and cautiously freed from the excess acid, the wringing being watched carefully, for fires are very likely to occur during this process. The cotton is dug out and plunged into water. Strong nitric acid is used in this process, and it is the experience of one large plant in which both pot and mechani-

cal nitration are carried on that the pot method is the more productive of "fume sickness" among the men. A description of one such plant would read as follows:

"Pot nitration is carried on in open sheds with wide doors, and there are windows in roof and walls. The wooden floors are eaten by the acid, and this makes them rather soft and slippery. There are separate sheds for dipping (mixing), for digesting, and for wringing. In the dipping shed men were lifting zinc pots to a platform about a foot and a half higher than the floor, made of wood with strips nailed across to keep the men's feet from slipping. Here the acid from a storage tank outside is run in on the cotton and just above the opening of the acid supply pipe is an earthenware fume pipe designed to catch the fumes at the point where they form. A jet of steam in it makes a fairly strong up-draft but not strong enough to catch it all, and the management plans to slot the floor of the platform and install a down-draft through it.

"A Roumanian, a new hand, was letting the acid run into his pot and was prodding the cotton and turning it over to mix it thoroughly. Suddenly something went wrong, and orange fumes began to come off. The foreman ran forward and showed him how to manage it, for a 'fire' was imminent. When it was mixed he gave it a shove along the slippery floor, and another man covered it with a good, air-tight lid and took it to the digester shed.

"The air in the digester shed is very tolerable. After digestion the pot goes to the wringer shed, where the workman takes off the lid and, in great haste, shovels the contents into a wringer and starts it, while an overseer stands by, watch in hand, timing him, for if he lets it run too long it will 'fire.' It is all done so hastily that cotton is spilled on the floor and nobody has time to fork it up nor to put the lid on the now smoking pot, but these fumes, though choking to the unaccustomed visitor, are negligible in the eyes of the foreman who is watching for so much more dangerous ones. At any moment the wringer may 'fire' and give serious trouble.

"The fumes in the wringer shed, ordinarily, are not nearly so trying as in the dipping shed, for there acid is often spilled on the floor, sometimes a pot tips over, sometimes a supply pipe springs a leak. Really dangerous fires, however, occur more often in the wringer sheds. Precautions against these dangers are seen everywhere, in the easy escapes to the outer air, in the provision of emergency shower baths, and bubbling fountains, so that if acid splashes over a man's skin or into his eyes he can wash it off in an instant. The bubbling fountain makes an excellent eye douche."

In another plant a similar method is used, but the arrangements are not nearly so good, and consequently the fumes from the different processes are far more irritating. The dipping shed is continuous

with the digester and wringing sheds, so fumes from any part can spread all through. The lids on the pots are flat and are put on so carelessly that puffs of white fumes escape all the time digestion goes on. Here the air was so foggy with these white fumes of nitric acid and the lower oxides that one could barely see the other side of the shed. Good exhausts are provided for the wringers and the fumes are carried off unless there is a fire, but there is no exhaust for the drowning tank which stands beside it and the fumes from it are sometimes very bad. After only a few minutes' stay in this building the visitor was forced to go into the open air, for the fumes were blinding, and it was impossible to breathe even through a handkerchief.

In all these plants some precautions are taken to protect the men from acid burns and from "fume sickness," but in some naturally they are much more intelligently and generously planned than in others. It is the prevailing custom to provide the men in the nitrating area with rubber gloves and high rubber boots and often rubber aprons. Respirators also are usually provided and the men urged to wear them, but this is seldom done except perhaps for a short time during a "dress parade" before an inspector. Indeed it is doubtful if they should be worn, especially in hot weather. The pressure of the edge against the prominences of the cheek makes acid-laden perspiration collect there and leads to sores and ulcers. The sponge in the respirator would have to be washed out often to make it really useful. In those cases where a formidable amount of acid fumes must be encountered for a short time, as when a leak must be stopped, there is no doubt that a respirator with the sponge soaked in a solution of caustic alkali as strong as can be endured, or in a solution of bicarbonate of soda is the best protection possible, but for continuous use probably a thick pad of cheesecloth over nose and mouth is better. Factory inspectors of both Great Britain and Germany have for some years past advised such protection for men exposed to lead dust and fumes, on the ground that pads were more efficient worn all the time than were respirators which would inevitably be worn only part of the time. There are several patterns of such cotton pads used in British lead works and the employer is required to have them washed daily.

Nitrating buildings should always have an abundant and easily accessible water supply, for acid splashes will occur, and the only chance of averting a severe burn is to wash with plenty of water as quickly as possible. The best of these plants have shower baths installed at frequent intervals and bubbling fountains. Others have only hydrants or ordinary sinks with cold-water faucets. One manager has placed on the balcony of his nitrating building a large hogshead filled with a solution of soda ash, and the burnt man is

supposed to jump in and submerge till he is all soaked with the weak alkaline solution.

DISPLACEMENT PROCESS.

This was seen in only one factory. It seems to be the safest method of nitrating cotton, and it can be used for making military guncotton, the highly nitrated product.

Cotton is placed in large earthenware receptacles, about 42 inches in diameter, which stand in rows in a long narrow shed with a brick floor sloping to a drain. These pots are on pedestals about a foot from the floor. The cotton lies on perforated earthenware plates at the bottom of the pot and acid is run in and mixed with it. During mixing an adjustable hood is lowered and an 8-inch earthenware pipe with a down-draft is uncovered. More perforated plates are then laid on top of the mixed acid and cotton, and a film of water is carefully run over the surface, serving to hold in the acid fumes. There is then no further need for the hood, and it is raised, and the pipe covered. The cotton digests for about an hour, then a drain at the bottom of the pot is opened, and water is run in from a hose to displace the acid, washing it down the drain and overflowing to the runway in the floor.

Along the floor a cloud of white acid fumes lay up to about 3 feet, but above that the air was clear till displacement began. Then whitish clouds began to come off, but the air was never really trying even to an unaccustomed person. Some decomposition may occur in case the mixing is poorly done, the cotton matted, or so on, or there may be a break in the supply pipe. But there is said to be no danger of a real fire in this process. Certainly it was not possible to discover any serious case of "fume sickness" in connection with this plant.

In the neighborhood of these nitrating factories the wire screens of windows rot away rapidly, the woolen shirts worn by the men last fairly well, but the cotton thread in the seams rots and the shirts fall apart. The men find that their front teeth decay. One company doctor has said that he would like to reject all mouth breathers who apply for work in nitrating, because they are sure to lose their teeth.

It seems unbelievable that acid strong enough to affect the enamel of the teeth and to eat away good wire screening in a few months should be quite without effect on the mucous membrane lining the human respiratory tract, yet physicians who have charge of these plants insist that no chronic injury results to the throat or bronchi or lungs as a result of long exposure to the acid fumes. Indeed, they sometimes claim that the men are singularly free from pulmonary tuberculosis. This is, however, a common belief wherever corrosive poisons are used. The fumes are always supposed to kill the germs of

tuberculosis. Even lead workers believe that lead fumes have this effect, though statistics show exactly the contrary to be true.

It may be that the continual turnover of men in this industry is what keeps chronic effects from appearing. In one plant, one of the best, 249 of the 4,500 nitrating men quit at the end of one week, and of all the new men taken on 40 per cent were for the nitrating force, although it comprised less than one-third of the whole.

SMOKELESS POWDER AND MILITARY GUNCOTTON.

Some of the guncotton made in this country is shipped wet to Europe, to be there converted into various kinds of powders, or it may be shipped wet to another factory in this country, but as a rule the powder is made in the same plant in which the cotton was nitrated.

Nine plants were visited in which smokeless powder and mixed powders, the so-called nitroglycerin powders, are made. The various processes are carried on usually in separate buildings, and there is ample ventilation and a high standard of cleanliness, both of these necessary as measures of accident prevention, for the vapors given off are inflammable and the dust is explosive. Incidentally the danger of industrial poisoning is also lessened by these measures.

Wet guncotton comes from the washing and boiling departments which have followed the processes of nitration, and the first step is to drive out the water, then colloid the cotton by means of some solvent, and then to press and cut the rubberlike mass into appropriate shapes. After most of the water has been removed by centrifuging, the next process is dehydrating by forcing denatured alcohol in through the blocks of nitrocotton in a hydraulic press. From the press the cotton comes out in a block like a large cheese, and this is broken up by wooden hammers. A great deal of alcohol vapor is given off in block breaking, and the men may have alcohol "jags," but the effects are so much pleasanter than the effects of the ether encountered in the next step that they attract little or no attention. This block breaking is usually done in small separate buildings, and they must be kept scrupulously clean for fear of explosions.

Mixing is the next operation and the solvent used differs in different powders. What is known as smokeless powder, or pyroxylin, or pyro powder, is a product of lower nitration, described as the pentanitrate of cotton, or dekanitrocotton, containing about 11.5 to 12.5 per cent of nitrogen. It dissolves in ether-alcohol, which changes it to a colloidal state. This smokeless powder is not classed as a high explosive.

The nitroglycerin powders, cordite and others, are made from guncotton of higher nitration, a hexanitrate or endekanitrocotton,

containing about 12.5 to 13.5 per cent nitrogen. These are mixed with nitroglycerin and sometimes acetone and vaseline to form colloided strips. N. G. powders are not soluble in ether-alcohol.

For smokeless powder, pyroxylin, the fragments from the block are put into a mixer or incorporating machine, where they are finely divided. Then ether and grain alcohol are run in from a hose and thoroughly mixed with it.

Often this is done in a long narrow building with a row of mixers, each with a wide door in front of it and a window behind. The mixers are like bread-kneading machines, containing blades rotating in opposite directions. The openings are rather wide, about $1\frac{1}{2}$ by $2\frac{1}{2}$ feet, and whenever the machine is thrown open strong whiffs of ether escape. Then, when the men are emptying out the mixed cotton with long-handled hoes, the air gets very heavy with ether. To get at the last part of the charge the man always seems to have to lean far into the machine with his head inside while he digs out the cotton at the bottom. Often, too, one sees a man almost inside the mixer trying to set right something which has gone wrong with the mechanism. To the outsider, mixing seems to be attended with exposure to very unpleasantly strong ether fumes, but it is the unanimous testimony of workmen, superintendents, and company doctors that this is not the department in which ether poisoning is to be feared. The danger is in the processes of pressing and cutting. Eight times as much of the solvent, according to one superintendent, is lost in pressing and cutting as is lost in mixing.

In the mixing department it is a fairly simple matter to provide abundant natural ventilation, and on cool, windy days the air is generally fairly good. But in the following department, pressing and cutting, free ventilation is possible only in warm weather, because the temperature here must always be maintained at about 75° F. (in one place as low as 70° , in most up to 80° F.). When a visit to a smokeless-powder factory was made on a hot, humid day in summer, or on a cold fall day when the windows were shut, the report invariably read "ether fumes heavy and disagreeable," while the visits made on pleasant, fresh days in May and October found the air in these departments quite tolerable. The men themselves always say that the cases of ether poisoning are most frequent in winter when all the windows are shut, and next most frequent on heavy, windless nights in summer.

From the mixers the cotton goes to a block press—"preliminary block"—and comes out a colloid mass, looking very like some kinds of crude rubber. This is pressed through a "strainer," a series of metal screens, to remove impurities, out of which it emerges in the shape of spaghetti or macaroni. This is again pressed into the "final block," and the final block is driven through a die and comes

out in long cords of various degrees of thickness, from that of coarse spaghetti to delicate strings, all of them perforated with several tiny holes running the length of the string. These are cut into the required lengths in a machine and are taken in tightly covered boxes to the solvent recovery houses, where the remaining ether-alcohol is collected for further use.

Pressing and cutting are almost always carried on in a building with plenty of windows and wide doors that provide good natural ventilation, sufficient if only ordinary processes were going on, and a system of artificial ventilation for the days when the windows must be closed. One plant was visited which had been running all winter with no air supply except the windows, and since the heat had to be kept at 75° F., it was easy to credit the superintendent's statement that they had had endless trouble with the men and had decided not to try to get through another winter without artificial ventilation. The best method of providing this is the one that is used in several of the plants visited—heated air sent in through numerous pipes just below the ceiling and vents in the walls just at the floor level. Ether fumes are heavy and can not be got rid of by an up-draft. The suction must be down and the air given egress at the floor level.

Even in the best ventilated pressing and cutting buildings the air is always, in all weather, ether-laden. There is always more or less trouble from this source, especially among new workmen.

Solvent recovery houses give no trouble, except in case of accident, for every effort is made to recover and not to lose the ether fumes. The subsequent processes of "wet-dry" cleansing, of sorting, and of blending, while highly important, if one is studying accidents, are negligible if one is studying occupational poisoning.

For certain kinds of smokeless powder amyl acetate is the solvent used. The odor of amyl acetate was not disagreeably strong in either of the buildings in which this form of powder was being made.

There are many mixed, or nitroglycerin, or n. g., powders manufactured, but only two were seen in the course of this investigation, namely, cordite and ballistite, both made from nitroglycerin and guncotton with acetone as a solvent. Diphenylamin is sometimes added to solvent for smokeless powder and undoubtedly is responsible in part for the symptoms caused by inhaling this solvent.

PICRIC ACID ($C_6H_2(NO_2)_3HO$).

At the time this investigation was made, 10 plants were manufacturing picric acid or had been doing so up to a few weeks before.

All that has been said of the dangers of nitrogen-oxide fumes in the nitrating of cotton holds good of the nitrating of phenol

and need not be repeated here. As in the case of cotton it is the mixing and the drowning processes that give rise to the most dangerous fumes. Whether or not these fumes are actually more abundant in the manufacture of picric acid than in making nitrocellulose, certainly in the United States they are more abundantly produced in the making of picric acid. The reason may be found in the fact that no nitrocellulose factory was found which was so recklessly and crudely conducted as were certain of those making picric acid. The number of cases of fume poisoning in four guncotton plants as compared with those in four picric-acid plants were found to be as follows:¹

	Guncotton.	Picric acid.
Number employed -----	14,000 to 15,000	1,200 to 1,300
Total cases -----	97	39
Fatal cases -----	12	6

The proportion of cases among total employed is much greater among the picric-acid men, and the severity of the poisoning as indicated by proportion of fatal cases is also somewhat greater.

The methods used to change phenol to its trinitro derivative, which is known as picric acid, vary from the most primitive to the most highly developed. In two small plants the following processes were found. In the first, phenol which has been mixed with sulphuric acid² is blown to a tank in the nitrating building. Here the nitrating tanks are charged with nitric acid by pouring in the contents of carboys, and then the phenol is drawn from the storage tank into pitchers and poured into the acid, while the workman stirs the mixture. There is a great evolution of fumes, and some escape through the 2-foot opening in the lid of the nitrator. Nitration takes about 24 hours, and during this time the lid of this opening must be removed from time to time, and the mixture stirred again. There is a fume pipe from each nitrator running to the roof and with a steam jet to make an exhaust, but it is of little use while mixing is going on; the fumes are far too abundant. The men here work in 12-hour shifts.

The second plant (since closed) was in an ordinary factory building with no more than the usual window space for ventilation. In a room about 200 by 50 feet there were 30 large stone crocks for nitrating, and phenol manufacture was carried on at the other end of the room. Each crock stood in a wooden box with an air-tight cover, but there was an opening in it about a foot square through which mixing

¹ These figures are not complete, but the margin of error is probably as great on one side as on the other.

² Phenol is first sulphonated, making it water-soluble, then treated with nitric acid. The action of nitric acid on unchanged phenol would be too violent.

and stirring were done, first with wooden rods, then, after they rotted away, with glass rods. The picric acid was dipped out and poured into filters and water poured over it. The fumes in this place were very bad, and later on the management undertook an elaborate system of closed nitrators and exhausts, but the plant closed down before it was completed. Both these factories employed few men, not more than 50 or 60 in each.

Even more dangerous conditions were found in two other plants which were at the time employing about 1,100 men, and have since more than doubled that force. They use pot nitrating. The process in the two is essentially the same.

There are two long, open sheds for nitrating picric acid. One, recently built, has a fairly high roof; the second, older, is very low, and air is cut off on one side by a building. Rows of wooden tanks with wooden lids run down both sides of the shed. Inside are great earthenware pots containing sulphonated phenol, and outside are carboys of nitric acid. As the lid was raised to show the pot the opening of an exhaust pipe was also seen just above the pot. When they are ready to nitrate, a siphon is introduced into the carboy, started with water, and the acid flows down into the phenol in the pot. The lid, of course, is off while this goes on, and the exhaust does not nearly carry off the fumes, which are very dense the moment the acid reaches the phenol. All the siphons in one shed, 100 or more, are supposed to be "shot off" at the same moment and the men to run for the open. There they are supposed to wait for two hours and then go back, break up the crust of picric acid which has formed on the surface of the pot, and go out again. The men say this causes almost as bad fumes as the mixing. Of course, if anything goes wrong the man can not run out at once, and, in any case, he has five pots to "shoot" before he can go. Later on a fire may start or a leak or a stoppage may occur. Then he must venture back again into the long, low shed, now filled with heavy fumes. The workmen themselves complain more bitterly of this method of making picric acid than of any other kind of work in the manufacture of explosives, and the evils are aggravated in the two plants using this method by the fact that they were hastily constructed and had not, at the time this study was made, devised any efficient method for controlling the fumes, nor had they provided any way for the men to rid themselves of picric-acid dust at the end of their day's work. There were no facilities for washing, and in one of them, where a lunch counter was used by the men, one could see workmen eating with hands covered with the yellow dust and smears of yellow dust on the counter. This place worked the men in 12-hour shifts.

Six other plants nitrate phenol in far safer ways than this. In one the crude phenol, melted with steam, is sulphonated in tanks, heavy

iron vessels tightly covered and mechanically agitated. The phenol runs into a great square vat, lead lined, covered with heavy, removable plates, and connected with an exhaust by means of a fume pipe. There is some escape of fume from the cracks between the plates and also from the peephole, about the size of an ordinary stove lid, which is lifted from time to time to see how the reaction is progressing. The air here is usually very good, however, though there may be a violent evolution of gases, which would blow off the plates and scatter acid and spread thick fumes. The picric acid from the nitrator runs out into open earthenware pots with coarse earthenware colanders, that lie on cracked stone, and through which the waste acid filters out.

In another very well conducted plant the following method was found in use: The building is a long, low shed, quite open, with windows in roof and sides, floor clean and dry, because it is covered with a wooden platform, and all the spilled acid flows away under it. The sulphonated phenol is two-thirds nitrated in a great autoclave, then blown through a hose into earthenware nitrators, which are covered with tight, heavy lids. There is in each lid an opening just large enough for the hose, and each is connected with a main exhaust pipe running to the roof. From these the picric acid is pumped out to be washed and filtered in great tanks. There were absolutely no nitrous fumes there at the time the place was visited, and in case of a "boil over" they start a fan in the roof. This is also used in hot weather for ventilation. In winter warm air is driven in. The criticism to be made of this place is that the men work in two shifts—a day shift of 11 hours and a night shift of 13, changing every two weeks. Such long hours should not obtain in work that exposes the men to poisoning.

One very good plant uses the following method: The nitrating is carried on in a large building with a brick floor sloping to a drain. Warm air is driven in through large pipes which end about 10 feet from the floor and goes up through windows in the roof. In summer cool air is driven in. Nitration is done in tightly closed kettles, each with a fume pipe and an exhaust, and above each is a feed tank for phenol and one for acid. After nitration the product is drawn through pipes into water, boiled, and recrystallized; but at no point is it exposed to the air. From the washers it drops into a filter, is washed, and then taken to the drying house, with about 20 per cent of moisture in it. There are 24 such nitrators.

So far only the danger of nitrogen-oxide poisoning in the making of picric acid has been considered, but there are other dangers. Nitric acid is handled, and there are the same risks of pipes leaking, connections breaking, acid spattering or spilling as were described in connection with the making of guncotton. In addition to this there

is danger from the picric acid itself. Guncotton manufacture begins and ends with a harmless substance, but picric-acid manufacture begins with a poison, phenol, and ends with one. In a nitrocellulose plant less than one-third of the men employed may be exposed to the danger of poisoning; in a picric-acid plant practically all are exposed to some form of poisoning.

Usually about 10 per cent of moisture is left in the picric acid, and it is packed and shipped in this partly moist form, but occasionally it is dried, all but about two-tenths of 1 per cent of the water driven out, before packing. When this is done there is much more trouble from picric-acid itch among the packers and from irritation of nose, throat, and bronchial tubes.

The drying houses of one such place may be described as follows: "These are small separate houses, with wide shelves, glass covered, on which picric acid is spread thinly, two shelves about 3 feet wide running around three sides of the room. The men working here brush the dry picric acid off the shelves into a receptacle, which is about on a level with the lower shelf, but $2\frac{1}{2}$ feet below the upper one, so that the powder must fall down and much dust rises when this happens. The men work with long-handled brushes, using them very carefully, but even so it is impossible to avoid raising some dust. I went into one where two men were working. One was sweeping the floor. He had tied a handkerchief over his mouth and nose and wore goggles. The other man was dumping the dry powder into a screen. The air was so choking and irritating that in less than two minutes my mouth was full of the bitter taste and my eyes running and my nose and throat smarting. It was very hot weather, and the powder clung to my skin so that the next day a mild 'itch' developed over the exposed part of my throat—a burning, itching, reddened dermatitis with tiny papules, which later on scaled. There are three drying houses and a separate house for weighing where six men work, all dyed canary yellow. There are no exhausts." This plant is equipped with excellent shower baths, for strict bodily cleanliness is the only way to prevent dermatitis, which may be serious enough to incapacitate a man if he be susceptible.

PHENOL (C_6H_5HO).

In six of the factories that make picric acid the phenol needed for it is also manufactured, and in one that does not make picric, phenol is made. The methods used in these places involve the danger of benzol poisoning, of poisoning from sulphuric acid or sulphur dioxide, sometimes burns from caustic soda, as well as danger from the phenol itself.

The first step is to sulphonate pure benzol with fuming sulphuric acid to form benzol-sulphonic acid. This is done in closed cast-iron kettles, and the work may be quite safe or fumes of benzol may be allowed to escape to a dangerous extent. The vapors of the benzol are supposed to pass over to a cooler or condenser and then back to the sulphonator again. In one factory the whole sulphonating department was full of the odor of mirbane (nitrobenzol), caused by the sulphuric acid not being pure, but having had nitric acid added to keep it from freezing, which formed nitrobenzol.

The benzol-sulphonic acid is run into a liming tank, where it is cooled and neutralized or made faintly alkaline. This is a danger point and there should always be provision for carrying off the fumes. Two fatal cases of benzol poisoning occurred in the sulphonating department of a phenol plant in the fall of 1916, and their occurrence has been explained on the following ground: When there is not enough acid added to the sulphonating kettle sulphonation will be incomplete and a residue of unchanged benzol will remain. Then when this is run into the hot liming vat the free benzol will volatilize at once and poison the surrounding air. The way to avoid this danger is to stop the agitator in the sulphonator and let the charge stand till the free benzol has collected on top; then through a vent placed somewhat above the bottom of the sulphonator the charge is run into the liming vat, but the top layer of unchanged benzol is left behind, to be sulphonated with the next charge.

From the liming vat the liquid goes through filters to get rid of the sulphate of lime, and if this is done in ordinary filter presses the room is generally very wet and dirty. The clear liquid, containing the calcium salt of benzol-sulphonic acid, is led to a tub where it is treated with sodium carbonate to form the sodium salt and get rid of the remaining calcium as calcium carbonate. This is then evaporated to dryness and a fine white powder results—sodium-benzol-sulphonate. This goes to a fusion building where it is added little by little to an autoclave, in which is melted sodium hydrate—caustic soda. This is dusty work and the men doing it wear goggles and tie cloths over their faces.

The sodium phenolate is allowed to solidify in iron pans, from which it must be broken and crushed and dug out, and here, too, goggles and protection for mouth and nose are needed, for the salt is said to cause as severe burns as does pure phenol. Sulphuric acid is then added to liberate the crude phenol, and at this stage there is a copious evolution of sulphur dioxide gases, which are most irritating when no means are provided for carrying them off.

The phenol may be separated from the soda liquid, if it is given time to cool thoroughly, by gravity only, but if the work must be hur-

ried, benzol is used to extract it, and then removed by distilling and used again. This introduces a second danger of benzol poisoning.

The various dangers which may be encountered in such a plant were almost all exemplified in one large factory, visited on a hot, humid day in July.

"In the sulphonating building are not only the sulphonators, but the great open washing tanks, hot and steaming, filter presses dripping all over the floor, which is slippery from the water and powdered over with dust in dry spots, and machinery so crowded that a visitor has great difficulty dodging belts and getting about. The odor of benzol from the sulphonators is very irritating. It was admitted that the men often got 'benzol jags.' Later two men died of acute benzol poisoning in this room. (See p. 26.)

"As we left this building and came out into the open we met a blast of air from the acidulating kettles in the next building, heavy with sulphur dioxide fumes. All four in the party were 'knocked out' in a few seconds, eyes burning and tearful, so that we were almost blinded and stumbled along trying to get to clear air, but quite choked by the time we did escape from the fumes. The feeling was as of a stream of fire running down the throat and windpipe. These escaping fumes, white and thick, could be seen coming from two discharge pipes in the roof of the two-story building, and the men were doing their best to keep to the windward of them.

"Inside this building we found caustic soda piled in great uncovered heaps on a floor so wet that pools of melted soda lay in every hollow. The men go to and fro, wheeling caustic soda in open barrows, into which they have shoveled it. They are not protected in any way against caustic burns. On asking about goggles a search was instituted, and finally one pair was produced with rubber flaps. Our guide said that one of the men was under treatment at the time for a badly inflamed eye, but he was not sure the caustic was responsible."

Besides the two fatal cases of benzol poisoning mentioned, there have been three cases of acute bronchitis, with temperatures running up to about 101° and 102° F., treated in a near-by hospital. The men were said to have inhaled sulphuric fumes. No real medical care is provided in this plant, and these cases were discovered only through the records of the coroner and those of the hospital. Of course, many more must have occurred which escaped notice.

None of the five other phenol plants had nearly so many dangerous features as this one, though one of them had a very decided odor of benzol in the sulphonating room, and the air in the room where crude phenol was skimmed from open vats was far too full of phenol fumes. In another plant there were very irritating fumes of sulphur dioxide, because they were using a residue rich in sodium sulphite in place

of caustic soda for fusion. In another plant an accident occurred, which might easily give rise to serious benzol poisoning. The storage tank, into which the benzol distills in the final process, "boiled over," and benzol spread rapidly over the floor. In less than two minutes the fumes were strong enough to drive the investigator to the open air because of dizziness and inability to stand up, but in some way the spilled stuff had to be cleaned up. This was done without apparent mishap to the three workmen in the department.

The finished product, phenol, may give rise to severe burns and may also be absorbed and cause general symptoms. One fatal case of poisoning is on our records. (See p. 28.)

NITROGLYCERIN.¹

In the United States Nobel's process is used for making nitroglycerin.

In the nitration of glycerin the reaction is carried on in a steel vessel provided with mechanical air agitation and cooling coils through which water or brine is circulated. Mixed nitric and sulphuric acids are used, for in this reaction as in nitrating cotton, water is liberated and sulphuric acid must be provided to take it up. The glycerin, previously warmed to reduce its viscosity, is introduced in one or more fine streams either over the surface of the acid or below it. Thorough agitation is needed to prevent overheating of any part of the charge, for this might result in violent decomposition or "firing," and for the same reason the cooling coils are provided to keep down the temperature.

If such an accident threatens, the glycerin stream is stopped, the agitator run faster, and if that does not lower the temperature, the vent at the bottom of the nitrator is opened and the whole charge run down to the drowning tank of cool water, which is always built just under the nitrator and is fitted with mechanical air agitation.

After the glycerin has all been added the charge is run into a lead separating tank, where it is allowed to stand until the acid and glycerin are separated. This tank has a glass set in the side so that the progress of separation can be observed. When separation is complete, as shown by the presence of a distinct line of demarcation, the nitroglycerin, which is the upper layer, is drawn off from a draw cock in the side of the separator to the wash tank and the waste acid is sent to the acid recovery.

At the next lower level or in the next building the separated nitroglycerin flows to washing and neutralizing tanks of lead or wood,

¹ Nitroglycerin is not a nitro compound as are guncotton and picric acid, in which H is replaced by the radical NO_2 . It is a glyceride of nitric acid. Glycerin, $\text{C}_3\text{H}_5(\text{OH})_3$ is an alcohol in which three atoms of H can be replaced by three acid radicals, producing compound ethers or glycerides. Nitroglycerin is the trinitroglyceride, $\text{C}_3\text{H}_5(\text{ONO}_2)_3$.

where it is agitated by air jets, and here, too, fumes of nitroglycerin are given off, and a fine spray of nitroglycerin-laden drops passes into the air and the contents of the tank may splash on the floor. From these tanks it flows to storage tanks. Then it is weighed and run through a hose into small cars for transporting to the "doping" house.

The most usual plan is to have the nitration, separation, washing, etc., all done in one high room with three levels, the nitrator on the highest, then the separator, and the washing on the ground level. In other plants each of these processes is carried on in a small separate building with about 300 feet between it and the next building. This is in order to reduce to a minimum the number employed in any one building, a great advantage in case of explosion. It is also an advantage as regards cases of poisoning, for it means that few men are exposed to air contaminated by fumes or droplets.

A pipe with an exhaust or a jet of compressed air is sometimes placed in the nitrating room just over the discharge from the separator to the washing tanks. Ventilation in the triple buildings is usually fairly good. In the separate ones it is abundant. All these factories must be kept scrupulously clean, and there is no dust, but the men do get more or less nitroglycerin on their persons. They use cloths to wipe up splashes and to wipe the end of the supply hose from the storage tank, and these cloths soon get saturated.

Yet nitroglycerin is certainly the least dangerous of the explosives, if one considers illness, not accident. Nitrous fumes may arise from defective supply pipes, but the process itself does not involve their production. Another great advantage is the custom of allowing as few men as possible to stay in any of the buildings. Nitroglycerin is itself a poison, but one of the least harmful encountered in the making of explosives. (See p. 48.)

Washing facilities are provided for nitroglycerin men only in the best managed plants. In many there is nothing but a cold-water hydrant or perhaps the mountain stream flowing down the valley in which the plant is built.

TRINITROTOLUOL.

There were eight factories visited in which trinitrotoluol is manufactured or made into charges for high explosive shells. A ninth had been nitrating toluol up to a short time before, when it was destroyed by an explosion, but it was still possible to obtain full information as to cases of illness that had occurred among the men working there. This report, therefore, covers five factories where toluol was nitrated and four in which it was pressed and molded into charges.

Trinitrotoluol,¹ called triton and TNT in the United States, and trotyl and TNT in England, is a comparatively new explosive in this country. It was manufactured first as an explosive in Italy, in 1907. At the outbreak of the war only one American plant was making it, but very soon additional factories were hastily erected, both for the nitration of toluol and for the preparation of high explosive charges. The processes of manufacture as well as the effects of trinitrotoluol on the workmen were unfamiliar to the men engaged in the manufacture and undoubtedly there was much illness in the beginning caused by dust and by escaping fumes. Since then there have been great improvements in the mechanical equipment of all these plants, resulting in less hand work, less fume, less leaking and boiling over, and accidents of all kinds, better provision for personal cleanliness, all of which diminish the cases of poisoning.

Exhaustion over and around planing and boring and reaming machines, exhausts over melting pots, mechanical stirrers for melting pots, bubbling fountains of drinking water, excellent wash houses, and many other good features were pointed out as newly installed improvements of which the management was justly proud, but which, of course, betrayed the fact that in the early days of the factory there were many danger spots.

The eight plants now working employ about 2,500 to 3,000 persons in occupations which bring them directly in contact with triton, in handling it, or in breathing dust or fume-laden air. Only 30 to 40 of them are women and these are all employed in one plant.

The production of trinitrotoluol from toluol is accomplished by the action of a mixture of nitric and sulphuric acids and may be done in a one-stage nitration or by two or three successive steps. In the latter case it is not necessary to wash the intermediate product, the mono and dinitrotoluol, but the mixture is simply allowed to separate in the nitrator, the acid drawn off and the fresh nitrating acid for the next stage added.

Nitration is carried out in an iron nitrator, the mixed acid being run gradually into the toluol or partly nitrated toluol, as the case may be, and the temperature being controlled by coils in the nitrator through which water or steam is passed. The nitrator is equipped with efficient mechanical agitators. Chemists say that if during the early stages of the process the acid used is too dilute, the resulting compound will be largely phenylnitromethane, $C_6H_5CH(NO_2)_3$, and it is probable that some of the illness that has occurred in the course of such work is traceable to this compound. One chemist who

¹ Toluol is methyl benzol, $C_6H_5CH_3$. In the process of nitration hydrogen atoms are replaced by the nitro radical, NO_2 . Trinitrotoluol is therefore $C_6H_2(NO_2)_3CH_3$.

was doing experimental work suffered rather severely from symptoms which he attributed to this rather than to TNT.

In all the plants visited nitration is carried on in tightly closed kettles, and drowning tanks are so placed that in case of decomposition the charge could be run into water. After nitration is complete the charge may be allowed to separate either in the nitrator or in a separate tank, the waste acid separating out on the bottom. The trinitrotoluol which is at a temperature above its melting point is run off as a liquid into the drowning tank where it is washed with successive washes in order to completely eliminate acid. Since the melting point of triton is close to 80° C. it is possible by using water above this temperature to maintain the trinitrotoluol in the molten condition and to wash it as a liquid in the same manner as nitroglycerin is washed.

After the trinitrotoluol is thoroughly neutral the molten material is run into cold water with vigorous agitation where it solidifies in a granular form.

In other plants the product from the nitrators is allowed to flow out into crystallizing tanks where the waste acid settles and the triton forms a thick crust on top. When this hot liquid runs out from the nitrator there is opportunity for fumes to escape.

In one such plant where the separating pans for the trinitrotoluol are very large—about 10 feet long, 5 feet wide, and 4 feet deep—a great hood is lowered while the mixture from the nitrators is flowing down. The pipe from the nitrator passes through an opening in the hood. This is really done more to prevent splashing than with the idea that fumes will be very bad. The solidified triton is broken up and shoveled into cars for the washers, and the portion which has splashed over the inner side of the hood must be broken off, too. This handling or collecting is work which involves risk of poisoning, especially if the product contain some of the lower nitrations.

A much better arrangement was seen in another plant where the separating pans are covered all the time, and there is a fume pipe running from each to the roof. There is no breaking and shoveling here. The solid triton is melted by driving in steam, and it runs down to the washers on the story below. This method, so much better as far as the workmen are concerned, is said not to be applicable to TNT of high grade, of 81° C. melting point, which must therefore be chipped out.

Crude triton contains more or less dinitrotoluol, and sometimes, if the toluol was not pure, dinitrobenzol as well. This last is decidedly more poisonous than any of the nitrotoluols.¹ As to the

¹ See White and Hay, in *London Lancet*, 1901, vol. 2, p. 532.

comparative poisonousness of the higher and lower nitration products of toluol, the British experience—confirmed by tests—goes to show that crude TNT containing some dinitro is no more toxic than the pure. On the other hand, American physicians who have charge of men in nitrating works maintain that more cases of poisoning develop in the dinitro department. This may be because the dinitro is more volatile than the trinitro, and because it is semiliquid at ordinary temperature and more easily absorbed by the skin.

The breaking and shoveling seems to give rise to very little dust, for the stuff is fairly moist and pasty, about like lumps of maple sugar. It may be that the illness which undoubtedly does take place here may be caused by volatilization at ordinary temperature, if there is dinitrotoluol present. Or it may be caused by handling, though there seems little need for handling. The product of first nitration, when the process is done in two stages, is at first half liquid, and though it soon solidifies there is always some oily substance left which must be removed by centrifuging. There is a good deal of trouble from fumes or a fine spray from this centrifuge, unless an exhaust suction draft is supplied to carry it off.

Washing the triton is done with hot water in great closed kettles with an opening in the top through which the men dump the fragments from the crystalizing tanks. The triton goes on to the grainers—open chasers—such as one sees used for grinding paint in oil. These should be furnished with hoods, for they are heated to drive off the water and there may be volatilization of the contents. Blending comes next, in an enormous bolting machine, which discharges either into a screen or into a bin from which it must be shoveled into the screen. Then, after passing through the screen, it is packed by hand into paper-lined barrels.

These last processes, blending, screening, and packing, are all somewhat dusty, especially as some of the stuff is always spilled on the floor and ground up by the feet of passers-by. A very fine dust can be discovered over unnoticed projecting surfaces in such rooms, even when one can not perceive dust in the air. It is generally acknowledged that there is risk of dust poisoning in this department. Sweeping with long-handled brushes goes on all day (except in the one plant where a vacuum cleaner is used), but it seems to be done cautiously and not to stir up much dust, even though it is done dry. Many of the men engaged in breaking up the TNT in the separating tanks and in screening, packing, and so on wear cloths over mouth and nose. A few further protect themselves with goggles. Rubber gloves and boots are furnished by the companies.

Sweepings, scraps carried off with the wash water, spent acid, etc., are all collected in lead tanks, there mixed with water, cooled, and the TNT crystallized out. There is usually abundance of steam

coming off from these tanks, but it is said to carry only an infinitesimal percentage of TNT.

In nitrating toluol there is the usual danger of decomposition, or a "boil-over" or leaking acid pipes, with the discharge of nitrous fumes, or even of nitrotoluol fumes from hot liquid. Out of a list of 10 cases of poisoning in plants nitrating toluol, the histories of which were given with a fair degree of fullness, there are 6 stated to have been poisoned because of an unusual exposure, something not encountered in the ordinary course of work. One, a fatal case, was a carpenter making repairs; another was an electrician, also repairing; two very severe cases, one of them fatal, came as a result of cleaning out a tank which had been full of dinitrotoluol. The fifth case, a machinist, was severely poisoned by a "boil-over" from a nitrator; and the sixth, by fumes from a leaking pipe.

One factory was visited where the processes, instead of all being carried on in the same large building, are separated in small units, with each process in a little building by itself. There are seven such units, each with a nitrating building, a washing and screening building, and a building for packing. There are several other distinctive features in this factory. The separating tanks are done away with, for separation takes place in the nitrator, which has vents at different levels so that acid and triton can be drawn off separately. The acid goes to a receiving tank, furnished with a fume pipe to the roof. The triton goes through a pipe line to an open tank in a shed, where steam is run in to remove free acid; it is then pumped to a closed tank for thorough washing, agitated by streams of air. It is crystallized in the usual way, the chaser being covered with a hood, and then screened and packed.

FILLING SHELLS WITH TRINITROTOLUOL.

In the four factories where TNT is melted, purified if necessary, molded, and filled into shells there is fully as much danger of poisoning as there is in the nitrating of toluol, if not more. Indeed, it would seem that the filling of shells, either by pressing, which is very dust productive, or by molding, which involves fumes, may be much more poisonous work than making the triton unless great precautions are used.

Charges for shells may be pressed or molded. For the former kind of shell the triton powder is weighed and then put into a hydraulic press. Although this weighing and pressing does not seem to a casual observer to be attended with much production of dust, it is said by those who know to give rise to more triton poisoning than any other work. Not only is there dust from the powder, but there is a good deal of direct contact from handling, and TNT is

absorbed through the skin perhaps more than in any other way. The men who work here have hands stained a bright yellow in spite of the fact that all wear gloves. In one plant two young lads were pressing charges, fortunately an unusual sight.

These pressed charges are trimmed on a lathe, by men, and usually in the pressing room. Then they are dipped in melted paraffin and wrapped in paper with caps, and varnished. All these last processes are, in one factory, carried on by women in rooms separate from the pressing and trimming. In the other factory men do the work. The final wrapping of paraffined charges and varnishing the outside is harmless work, because the triton is safely coated over, but the paraffining and inspecting is much more dangerous than it seems to an outsider. The inspector weighs the paraffined charge, and if she finds it too heavy she must scrape off part of the paraffin and with a knife or scissors cut away enough triton to make the weight correct. The girls who do this all wear heavy gloves and are careful about cleanliness of the person, more so than are the men, because they dislike the disfiguring dye on the skin and the still more disfiguring eruption that may come from triton dust; yet, they, too, suffer from triton poisoning as a result, apparently, of the insignificant amount of dust encountered in paraffining and inspecting.

More charges are made by molding than by pressing, because the latter is the method used by the Russians and also for the mixed shells called for in some British contracts. In the molding or pouring method there is not so much dust as in pressing, but there are more fumes. TNT melts at 80° C., and is not supposed to volatilize under 180° C., but fumes are easily perceptible around kettles not nearly at so high a temperature as that. It is also shown by experience that if melting kettles are left open and men work near them they may become poisoned. In one of these shell-filling works the poisoning caused by open kettles was evident enough to lead the management to place the large melting pot in a room quite separate from the pouring and to allow only one man to work there. In another there was a row of open kettles along the inner wall of a long shed, the outer wall of which had wide doors and windows. It had been hoped that this abundant natural ventilation would be enough to do away with any trouble from the kettles, but experience showed that it was not. The tops of the kettles were about 3 feet in diameter and they were only half covered, for one of the two half lids had to be taken off to allow the tender to watch as the kettle turned and churned up the charge of triton, and also to allow him to feed in more triton from time to time. The illness of the men here was probably caused by the fumes from these kettles and, to a certain extent, by the dust spread as the kettles were charged.

This triton dust is worse when scrap is being melted than when TNT as it comes from the nitrator is used. In any case there is some dust. One man was feeding very carefully, with a flour scoop. When the box was empty he lifted it up and knocked it against the side of the kettle to get out the last particles. He said he was following orders in using a scoop, but in his opinion it would be better to empty the whole box at once, for though it would make a great deal of dust it would not last long, while in this way it took a long time, and a little puff of dust came with each scoopful. He was suffering from a mild form of poisoning, as shown by the jaundiced tint of eyes and face and his digestive symptoms and loss of strength. The only way to prevent danger at this point is to have an exhaust within the kettle strong enough to pull in the dust and not let it escape.

Other sources of fumes are the open kettles for melting scrap and for melting out the "sink heads," for they may be left uncovered even when the molding kettles are well covered. The best managed factory which was visited has a very excellent system for preventing fumes. The five melting pots are charged and then tightly closed and not opened till another charging. A fume pipe to the roof carries off the vapors, an exhaust fan supplying the draft, and upon the charging floor the air was perfectly clear. Stirring is mechanical. Down below where the melted triton flows out there is another exhaust.

As melted triton comes out from the kettles it is received in pails or tubs and is stirred for 20 or 30 minutes till it cools to about 76° F. and begins to crystallize, when it is ready for pouring. Fumes breathed in the course of this stirring were responsible for one death from triton poisoning last summer (see p. 39). One can see delicate clouds of vapor rise while the men stir, and also if later on they stir the stuff after it is in the mold.

Molders get their supply from the tubs and spill a good deal on the floor while they do it. This hardens and has to be chopped off and swept up. As they pour the melted triton into shells some of it runs down over the outer surface and must be cleaned off by chipping with wooden sticks or bronze knives, the men blowing or brushing away the fragments. This dusty and dangerous work is made unnecessary in some plants by the simple device of covering the shell with paper held in place by an elastic band. Or a tin funnel, called a sink head, may be inserted in the neck and enough triton poured in to fill it too. It is really to press out bubbles from the liquid triton that this sink head is used, but incidentally it prevents smearing of the shell.

A third way of making changes is by pouring the melted TNT not directly into the shells, but into molds, then after hardening they are taken from the molds, bored, planed, and paraffined. The con-

sistency of such a change is about like that of hard maple sugar, and there is no light dust from it. It would seem as if the unusual amount of sickness attendant on work of this sort must come from handling the charges, from skin absorption, especially as crude triton is used and this contains some dinitrotoluol, which is more easily absorbed through the skin than is the tritnitro. There may even be some of that very poisonous compound, dinitrobenzol, if the toluol originally contained some benzol.

After the shells are filled, the danger from fumes is over and the danger from dust reappears. The solid TNT charge must be bored to allow of the insertion of a detonator, it must be "faced," i. e., the neck must be drilled down and the screw neck of the shell must be cleaned unless it has been protected during pouring by a funnel, and the outer surface must be cleaned and polished. All this is dusty and is sometimes done in quite dangerous ways. It is usual to protect the boring and planing machines to a certain extent by means of hoods with exhausts and a down draft. Sometimes the hood is double, an inner one to catch the coarse powder, an outer one to take care of the finer and fluffier powder. The dust may be carried to a dust chamber and discharged into water.

The trouble with all exhaust hoods is that they get out of order easily and then afford little or no protection. Leaky "collars," as the workmen call them, are very common, and in the rush of work many days may pass before they are repaired, and meantime the escaping dust may have caused poisoning in the man at the machine.

The best arrangement was seen in two factories, though it was in use in only one. Each drilling machine is surrounded with a half-moon shaped barricade of 6-inch concrete running up to the ceiling. The driller puts the shell in place, then immediately steps to the protected side of the screen and from there starts the machine. After the hole is drilled he stops the machine, still from his protected position. It is a moment's work to take off one shell and put another in place. The drills are along both walls of the room, and the barricades shut them off from the central passage where the men are. Dust from the boring is caught in closed receptacles. This operation makes the detonator bore, removes excess from the neck of the shell, and drills the charge down to the shoulder.

Cleaning the threads in the neck of the shell when it has not been protected during pouring is dusty work and so is cleaning out the bore for the detonator with a long, narrow brush which brings out a very fine, light dust. The factory which uses vacuum cleaning also uses suction for the removal of dust from the bored shells. Imperfect, rejected shells must be emptied out, and this may be done in very dusty ways. In one otherwise excellent plant this was the only really bad spot, the place where shells with faulty bores were bored

down and the fragments blown out with compressed air. In another factory they drop the imperfect shells into a tank of hot water and let the charge melt just enough to slip out easily, which seems a good method; at least, it is not dusty.

The British seem to have had much experience with amatol, a mixture of crude triton and ammonium nitrate. They state that "of cases showing jaundice, about 27 per cent have arisen from pure TNT, 67 per cent from amatol and 6 per cent from ammonal." Amatol has 40 to 60 per cent ammonium nitrate, ammonal has 20 per cent. However, we are not told what proportion of persons are employed in each sort of work, and it may be that most of the shells in England are filled with amatol. Prosser White, experimenting on himself, was unable to produce a characteristic dermatitis with anything but the pure TNT. With ammonium nitrate alone or with a mixture of the two he got no reaction at all.

NITRONAPHTHALENES.

Naphthalene is nitrated in one plant among those visited in the course of this inquiry. This nitration is carried on in a building that was formerly used for nitrating glycerin, in a closed nitrating kettle connected with a fume pipe and provided with the usual drowning tank for emergency use. Separation takes place in the nitrator, and the mixture of mononaphthalene and dinitronaphthalene is piped to the next building where it is first washed with cold water and then neutralized in hot alkaline water. At this point it may give off vapors and these hot tanks are consequently covered and provided with fume pipes and exhausts. The dark reddish brown liquid is piped to a drying house, where part of the liquid is got rid of, and it is filled into steel containers for shipment.

The points at which fumes escape are: In nitrating, where because the work is as yet somewhat experimental, the process must be watched continually; the second separator when the fluid is hot; and in filling receptacles. There is also the same danger of a "boil-over" as in the nitrating of toluol.

NITROBENZOL ($C_6H_5NO_2$) AND ANILIN ($C_6H_5NH_2$).

These substances are of some importance in the manufacture of explosives, for nitrobenzol is a step in the making of anilin and anilin is a step in the manufacture of diphenylamin and of two high explosives which, on account of the expense of manufacture, have so far only a limited use in this country, tetranitranilin also known as TNA and tetranitromethylanilin, or tetryl. The former is said to be manufactured in only one place in the United States and

it was found in use in only one. Tetryl was being made in two factories. Nitrobenzol, anilin, and diphenylamin were made in one.

There is not so much risk of poisoning in the nitrating of benzol as in the subsequent reduction of the nitrobenzol to anilin, because there is less opportunity for fumes to escape. Nitration is carried on in a large steel retort with a mechanical stirring device and cooling coils. The charge of benzol is run in by gravity from the weighing tank and then the mixed acids, nitric and sulphuric, are added. In some places these acids are mixed and kept in partially closed receptacles and the fumes are allowed to escape. After about four or five hours agitation in the retort nitration is complete and the nitrobenzol is washed and neutralized.

Anilin is produced by reducing this nitrobenzol by means of iron filings and hydrochloric acid. This reduction is carried out in a cast-iron reducer, the temperature being controlled by the rate of addition of the different materials and by blowing steam into the solution if necessary to hasten the reaction. The reducer is equipped with a plow which turns slowly and prevents the separated iron sludge from solidifying in the bottom of the reducer. At the temperature of operation steam is evolved from the reaction mass, which carries with it considerable quantities of anilin. These vapors pass through a condenser and are returned to the reducer.

After reduction is completed steam is turned into the reducer and the anilin, which volatilizes with the steam, is distilled out, the condensed distillate is allowed to cool and settle and anilin, being immiscible with water, separates out. There is a chance for anilin fumes to escape where the filings go in, and also from the "sludge," with the iron filings at the bottom of the reducer, for this flows out or must be shoveled out frequently. The anilin is distilled and redistilled to purify it, and from time to time samples are drawn off to be tested, by sight and smell, to see how the process is going on. Then it is drawn off into drums from the stills. In the course of much of this work anilin may spill on the floor and the men step into a pool and have their shoes wet with it. Or they may spill some on their clothing. Anilin poisoning follows skin absorption probably more promptly than absorption of fumes by breathing. Another source of poisoning is repair work, necessitating entering a reducer which has not been thoroughly cleaned out, and thorough cleaning is very difficult.

TETRYL.

The first step in the manufacture of tetryl consists in the formation of dimethylanilin by treating anilin with methyl alcohol in the presence of sulphuric or hydrochloric acid. After diges-

tion the product is washed with water to remove the excess alcohol and purified by redistillation.

The dimethylanilin is sulphonated by treatment with concentrated sulphuric acid in an iron tank equipped with stirrer. The sulphonated product is nitrated by being run into mixed acid—nitric and sulphuric acids. The tetryl or tetranitromethylanilin separates out in solid form in the nitrator.

The charge, after completion, is drowned in a large quantity of water and the separated solid product washed several times to eliminate all free acid. An enormous evolution of nitrous fumes takes place when the tetryl is drowned, orange clouds rising to the heavens and being visible for miles around. There seems to be much difficulty in preventing this, and, so far, all that is done is for the men to run outside and wait till the fumes subside.

After thorough washing, the tetryl is dried in the same way as picric acid, except that less heat is required—only 65° to 70° F. as against 70° to 80° F. for picric acid. The dust in the drying room is quite as bad.

DIPHENYLAMIN.

Diphenylamin is prepared by digesting anilin and anilin hydrochloride in an autoclave under pressure. Reaction forms hydrochloric acid, so that the autoclave used must be of material which will resist the action of hydrochloric acid at the high temperatures used.

At the end of the digestion the product is washed several times with hot dilute hydrochloric acid, the temperature used being sufficient to maintain the diphenylamin in the molten condition and permit of its more thorough washing. The hydrochloric acid dissolves the unchanged anilin from the diphenylamin. For further purification the diphenylamin, after the completion of the washing, is distilled from a still heated by direct fire.

In the one plant in which this was done the whole process took place in a closed system.

FULMINATE OF MERCURY.

The making of this very powerful explosive is attended with a constant danger of accidental explosion, and this is true to a less extent of the handling of fulminate in filling percussion caps. This leads to a strict avoidance of dust, a scrupulous cleanliness, and a separation as much as possible of different processes, all of which measures tend also to diminish the risk of occupational poisoning.

Two plants were visited in which fulminate is made. In one, the smaller, all the preparation of the compound is done out of doors, at a distance from the buildings. They select a day when the wind is favorable, so that fumes will not sweep over the grounds, and erect a very simple equipment. The mercuric nitrate which has been made by mixing metallic mercury and nitric acid and letting the mixture stand for 24 hours, is poured over alcohol in large glass "balloons." Immediately there is an evolution of dense fumes, first white, then reddish, which fill all the upper part of the flask. As they subside, crystals of fulminate of mercury can be seen to have formed along the sides, and the balloon is emptied into a muslin-covered box which stands in a trough, and water is run in from a hose to wash off every trace of acid. At this point there is always some fume given off. The washed crystals are collected and carried off to be stored.

In the larger of these two plants all the processes are carried on inside. The room in which mercury is nitrated is separate from the fulminate room, and the latter is very high and roomy and well ventilated. Every effort is made to collect all the by-products by means of exhausts placed at the point where alcohol is added to the nitrate and where the balloons are emptied, yet on a hot day the fumes in this building may be heavy enough to make work almost impossible. These fumes are very difficult to analyze, and their make-up is uncertain, but one of the constituents is certainly ethyl nitrite, formerly much used in the treatment of fevers under the name of sweet spirits of niter. When condensed the liquid can be used again with the addition of fresh alcohol.

There is some danger of mercury poisoning in the making of the nitrate. Tiny globules of mercury were scattered all over the nitrating apparatus in one of these plants. Even greater is the danger in recovering mercury from the water used to wash the balloons. This liquor yields a "sludge" or "mud," which may contain as much as 30 pounds of mercury in 140 pounds, and when it is distilled the mercury is volatilized, but, of course, every effort is made to prevent it from escaping.

Fulminate is made into charges for percussion caps, either in dry or moist form, the latter being decidedly preferable from our point of view, since there is no dust. When it is handled dry, excessive precautions are needed to prevent explosions, and there is very little actual contact with the powder, except in the initial weighing and the mixing with potassium chlorate. Both these processes are carried on in separate rooms and by one man only. Other processes—weighing charges, loading, and pressing—are so arranged that a man standing behind a heavy steel or a thick concrete barricade can con-

trol the mechanism by means of a lever, guiding himself by watching a mirror fixed above the machine. The substances added to the fulminate to make up the charge are none of them harmful, consisting of chlorate of potash, antimony sulphide, ground glass, sometimes sulphur.

The factories manufacturing small arms commonly fill their own caps, but do not manufacture the fulminate. Many men and women are employed here in work which exposes them somewhat to the action of fulminate-laden dust, though here, too, there is enough risk of explosion to lead to avoidance of unnecessary dust and to a certain amount of segregation of some processes. There is a fairly large amount of fulminate dermatitis among the workers who do the loading and pressing and inspect the primed shells, but no more serious troubles so far as we were able to discover.

AMMONIUM NITRATE.

The authorities on explosives describe many different ammonium nitrate explosives, but in the course of this investigation we found it in use only as a constituent of dynamite and of a mixed charge for high explosive shells.

It is made by the action of ammonia on nitric acid and as a usual thing most of the processes are carried on in the open under a shed that allows free escape for the disagreeable fumes of ammonia and pyridin bodies, fumes that are very heavy at certain stages of the reaction. If the work were carried on indoors some harm might result from them, but in all the five plants where ammonium nitrate was being manufactured there was abundant provision for the escape of the gases. Once neutralization is complete there is no fear of fumes, and the subsequent crystallization may be carried on indoors in great open chasers.

The real danger to be looked for in making ammonium nitrate is an accident either to the supply of aqua ammonia or to the supply of nitric acid, for these are both powerful, fuming poisons.

PREVENTION OF INDUSTRIAL POISONING IN THE MANUFACTURE OF EXPLOSIVES.

Fumes.—Since all the dangerous fumes evolved in the course of the processes described above are heavier than air, it follows that an efficient system of fume removal must be based on a supply of air from above and a vent at the floor level. The air driven in should be heated in winter and cooled in summer. Two of the large companies have very excellent systems of this kind in factories making smokeless powder, carbolic acid, and trinitrotoluol. Hudson warns against sending the air in jets or spurts, for that stirs up dust.

and vapors. He also calls attention to the unusual difficulty of supplying artificial ventilation in this industry, since the type of fan ordinarily used for suction is of metal and may produce, by friction, sparks which might cause explosions.

Hoods should be placed over all vapor-producing fluids at every point where vapors may rise and as close to the point of origin as possible. Many hoods are installed in explosive works that are of little if any value, because the draft is not strong enough to carry off fumes. Of course, a strong lid over a fuming liquid will usually hold in the vapors, but such lids almost always have an opening large enough to serve as a peep hole, at least, if not for feeding or stirring, and this also makes a strong draft necessary if the vapors are not to escape.

The superintendents of the newer plants usually have respirators provided for men working where there are poisonous vapors, and some foremen take much trouble to persuade the men to wear them. The British Government advises against respirators for this purpose, saying that they are useless and should never be depended on; they can not keep out gases. Esch,¹ the German authority, says the same thing. "Such a mask would be really effective only if it could be so charged with a chemical as to remove the noxious gas from the inspired air. This is very difficult of practical application; only a small amount of the protective chemical substance could be used and saturation would soon occur. Furthermore, most chemical reactions would proceed too slowly to catch the gas passing by with the speed of forced respirations. Finally there is, as a matter of fact, no really effective chemical neutralization known. Solutions of soda combine with nitrous oxide only ineffectively; possibly a spray of soda solution might be more effective."

This spray has been used in pot nitrating sheds with apparent success, a solution of ammonium carbonate being atomized and sprayed into the air. In these sheds the crystals of ammonium nitrate resulting from the reaction with the nitrogen oxides could be seen on the walls and roof.

Cheesecloth pads of many thicknesses tied over mouth and nose undoubtedly save the men employed in nitrating from much discomfort in the ordinary course of work. But for accidents accompanied by the evolution of large quantities of nitrous fumes, air helmets must be provided and their use insisted upon. They should also be supplied and used whenever repair must be made necessitating entrance into a still or tank which has held a volatile poison, even if the tank has been well washed out.

¹ Veröffentlichungen aus dem Gebiete des Marine-Sanitätswesens, February, 1915. Abstracted by K. Ohnesorg, Surgeon U. S. A., U. S. Naval Medical Bulletin, 1916, No. 4, Vol. X, p. 625.

A mask which serves to protect against drops of acid that might cause severe burns has been devised by the du Pont Co. It is made of fiber, with eyepieces of cellulose acetate, and it is fastened to a cap which the man wears in such a way that he can throw it back easily out of the way when he does not need it, and yet it is there for instant use at any time.

Dust.—Respirators will keep out dust as they will not gases, yet there are objections to their use for this purpose also. If a respirator is dense enough to really shut out the dust, the effort to get enough air to breathe will be so great as to constitute a real strain on the man's heart, especially if he is doing hard work. The British Government recommends the use of respirators in triton works, but Livingstone-Learmouth and Cunningham¹ found them practically useless if not harmful. The powdered triton is likely to collect along the edge, where the skin is moist from pressure, and set up a bad rash. They also suggest that the danger of poisoning may be increased by the heat and moisture generated by the respirator. The one death from triton poisoning among the women under their charge was in a woman who had always worn a respirator.

Dust must be prevented, not caught in respirators after it is formed. The chief sources of dangerous dust are in feeding melting pots with powdered explosives, in cleaning out crystallizing tanks, in planing and boring explosive shells, in packing dried explosives, and in sweeping floors. For the first, a strong draft inside the protective hood is the proper method of prevention; for the second, melting out instead of breaking and shoveling; for the third, well-fitting shields leading to a dust-collecting system, preferably a wet chamber; and, for the fourth, careful handling and the provision of exhausts. Sweeping is always done carefully in explosives works because of the recognized danger of explosion, yet there is danger of dust inhalation in some of them, especially where triton is handled. Unfortunately, vacuum cleaning can not be used for most of these dusts because of their instability or tendency to form dangerously explosive compounds with metals with which they come in contact.

The one factory which has installed a vacuum cleaner and is using it with success is engaged in filling shells with triton and collects the dust made by boring and trimming the shells. When it is impossible to do away with poisonous dust, the rule must be to make the exposure as slight as possible, to work the men on short shifts, alternating with safe employment, and to have specially careful medical supervision for them.

Men working in poisonous dust must be further protected by full suits of overalls, such as are worn by men in some of the western lead smelters when cleaning out flues filled with lead and arsenic dust.

¹ London Lancet, Aug. 12, 1916.

The sleeves are long and are close at the wrist, fitting under the cuff of the glove. The neck is high, and a washable cap pulls down to meet a thick pad of cheese cloth which covers all the face except the eyes. Especial attention should be paid to the shoes, which should not be low, and there should be no possibility of the powder working its way in through eyelet holes, for this has resulted in distressing eruptions on the feet. The British authorities advise the provision of fresh socks every day. American nitric acid and nitration works supply rubber gloves, aprons, and boots, and sometimes woolen shirts as well. Overalls are rarely supplied to any class of workmen.

Ample washing facilities are an essential in this industry, and are very generally supplied. For men doing dusty work, shower baths also are necessary. Many employers complain that the men will not avail themselves of these baths, though they are provided in all the better plants. It is very plain that there are foremen who can make their men bathe, so it must be something in the construction or management of the baths that makes other foremen find it impossible. As a matter of fact, whenever one looks closely into the matter one finds that there is some ground for it when the men obstinately refuse to use shower baths after a patient effort has been made to persuade them to do so. Sometimes the hot and cold water are not properly blended and the men have been startled by a shower of scalding or of freezing cold water. Sometimes the room is not heated and they have to stand on cold cement instead of wooden slats. And then it is well to remember that Latin and Slavic workmen are not accustomed as boys to go in swimming together and they will resent a lack of privacy which to an Anglo-Saxon is a matter of course. These men may refuse to use excellent showers simply because they are not screened off. Curtains of heavy duck between the baths remove this objection.

Lunching in rooms where poisons are handled is not at all a rarity in American explosive works. It should be forbidden always, and a lunch room provided, unless, as is very unusual, the plant is near a cheap restaurant. The best plan is to have the locker room at the entrance, where the men check in and out. Here the man should be made to leave his dinner pail with his street clothes. Then next to this should be the lavatory. As he comes for his dinner pail he must pass through the lavatory, and here a superannuated or crippled employee may be stationed to see to it that each man washes his hands and face before leaving the room. After that it is immaterial whether he uses the lunch room or stays out of doors; he is at any rate free from poisonous dust.

It seems to be customary in British munition works to provide a cup of milk or cocoa for the workers when they arrive in the morn-

ing, because the risk of poisoning is lessened by the presence of food in the stomach. The workers often come from a long way off, and the women especially are likely to take only a scanty breakfast. This is also true of many of the foreign workmen in American plants. They still take only the continental breakfast of bread and coffee, and sometimes no milk in the coffee. The British works also have "canteens" provided in many instances, with hot food served at noon and at midnight, and sold at cost.

Another point emphasized by the health of munition workers' committee is the injuriousness of overwork—of excessive fatigue. In connection with the manufacture of triton, they advise that no overtime be allowed, the period of exposure be as short as possible, and if practicable safe work be alternated with dangerous. "In some large factories where the number of workers and the nature of the processes carried on has permitted of systematic alternation of work on TNT with other work away from it, no cases of toxic jaundice have been reported. And in others, where on occurrence of cases alternation has been arranged, the number notified has fallen."

Medical care is an absolute necessity in this industry, and is so regarded by all but a few careless, indifferent companies. In most works making explosives there are physicians regularly employed to treat cases of occupational sickness among the employees, but the amount of care given varies a good deal and so does the amount of authority delegated to the physician. Sometimes the doctor comes only when summoned. This means that he sees the cases of sickness after they have developed to the point of definite symptoms, or to the point of attracting the attention of the foreman. The proper system is to have a regular medical inspection of all the workers employed in contact with poisons, an inspection that need not take much time and need not interrupt work at all, unless a suspicious case needs closer examination.

The doctor should be allowed full freedom to order the removal from dangerous work of any employee who, in his opinion, shows signs of absorption of poison. From the histories of many cases reported to us from TNT works especially, it is very evident that if the early symptoms of ill health had been heeded, the worker might have been saved a severe and in some cases fatal poisoning.

As a usual thing there is not much, if any, instruction given the men in this industry as to how to protect themselves against the dangers of sickness. Indeed in some plants no instruction at all seems to be given, perhaps for fear of frightening away the men at a time when labor is scarce. Men working in a large triton-shell plant said they had never even been told the stuff was poisonous. On the

other hand, a great guncotton plant has a regular system of instruction for the force, taking the men according to departments and giving them lectures in English and in their own languages, explaining the dangers peculiar to the departments in which they work. So far as possible, these talks are illustrated by stereopticon pictures. The effect is shown by their report of fume sickness for five months. The first month there were 266 cases among 660 men; the fifth month, 24 cases among 621 men.

The measures of protection for workers in poisonous fumes and dusts are well summed up in the British directions for the manufacture of TNT.

“Apart from the removal of fumes and dust, to employ workers over 18 years of age; to make suitable canteen provision so that workers can obtain good food on factory premises; to eliminate those showing early signs by frequent medical examination; and to alternate the work or reduce the length of the shift, if practicable.”

In the Royal Arsenal the prophylactic measures adopted are as follows:

Only persons in good health, and, as far as practicable, between the ages of 20 and 50 are employed on TNT.

All workers are inspected by a medical officer once a week.

Special clothing is provided, also veils, respirators, and gauntlet-gloves.

Employment is alternated fortnightly.

Mechanical devices are adopted for preventing dust and getting rid of fumes.

Workers are warned against sleeping in the clothing worn at the factory and advised to have a complete change of clothing on reaching home.

Facilities are provided for obtaining suitable and sufficient food at proper intervals. Milk is supplied free on the arrival of the workers.

Washing of hands and face is insisted upon before meals and before leaving the factory. Neutral soap and individual towels are provided.

RECORDS FROM THREE MODEL PLANTS.

In the course of this investigation ample evidence was found of the success of efforts at the prevention of occupational poisoning in several plants, but the improvement could not be shown statistically for lack of records. Recently, however, detailed reports have been received from three plants which do give just such information. These factories are engaged in making anilin, in nitrating toluol, and

in filling shells with trinitrotoluol by the pouring method. We reproduce these figures in order to show how the number of cases of poisoning may be lessened by proper precautions and also how low may be the rate of sickness from these poisons in a well regulated plant.

The period covered is from July 1, 1916, to December 31, 1916. The cases listed here would in some factories escape mention because many of them were very slight. A "major case" is one which necessitated absence from work for one-half day or over; a "minor case," one with a disability of less than one-half day.

CASES OF POISONING IN THREE MODEL PLANTS.

ANILIN POISONING (MAJOR CASES).

Month.	Average number working per day.	Number of cases of poisoning.	Total hours of disability.
July.....	90	12	206
August.....	75	2	16
September.....	89	3	32
October.....	90	3	88
November.....	90	6	65
December.....	90	4	56

TRINITROTOLUOL POISONING WHILE POURING LIQUID INTO SHELLS (MAJOR CASES).

August.....	55	2	40
October.....	50	3	32
December.....	50	1	96

TRINITROTOLUOL POISONING FROM ABSORPTION DUE TO DRILLING SHELLS (MAJOR CASES).

July.....	40	11	134
August.....	50	7	90
September.....	55	1	16
October.....	55	1	8
December ¹	30	5	193

¹ It is suspected that the high rate of disability in December was due to the physical condition of one of the patients from use of alcoholic stimulants.

TRINITROTOLUOL POISONING IN INHALING TOLUOL (MINOR CASES).¹

Month.	Average number exposed.	Number of cases.
July.....	338	7
August.....	309	9
September.....	296	1
October.....	281	1
November.....	256	.....
December.....	194	.....

¹ There were no major cases.

TREATMENT.

Nitrous fumes poisoning.—For the asthma-like attacks the usual treatment is that recommended by Hudson of the Du Pont Co., namely 15 drops of chloroform shaken up with a tablespoonful of aromatic spirits of ammonia in three-quarters of a glass of water, to be sipped by degrees during an hour's time. This does not exert any effect on the lung tissue, does not prevent the development of edema; it simply relieves the spasm and the abdominal pain. Inhalation of the vapors from this mixture may give relief, but Dr. Hudson warns against strong ammonia vapors as quite capable in themselves of causing edema.

An instance of death following the combined effect of nitrous oxide fumes and strong ammonia is related in the London Lancet (1902, vol. 2, p. 1397). A man was making a slow recovery from nitrous oxide anesthesia, and strong ammonia was held to his nose. He died, and acute congestion of all the air passages was found.

Substitutes for chloroform are found in chlorodyne, small doses of opiates, bromides. Several physicians have declared that they did not use the chloroform treatment except when a man had become accustomed to it in another place and demanded it.

A spray of some soothing liquid, such as albolene with menthol or thymol, is said to relieve the spasmodic cough. For the pain in the abdomen Loeper recommends large doses of bicarbonate of soda or cocaine or stovaine. The British committee's report lays stress on the relief afforded by vomiting, and when this does not occur spontaneously they give lukewarm salt water till the effect is secured.

Fresh air, quiet, and rest are advised even after a mild attack of fume poisoning. The diet should be simple, and laxatives should be given.

Many experiments have been made to find a method of treatment which will help to ward off the development of the dreaded dropsy of the lungs. Esch¹ claims to have found that sodium thiosulphate has such an effect by virtue of its reducing power. Esch recommends a hypodermic dose of a tenth to a fifth of a gram of thiosulphate or a much larger dose by mouth, since it is quite harmless. In addition inhalations of ammonia should be administered. The thiosulphate is said to be antagonistic to picric acid and the nitriles, as well as to possess this reducing power.

In case of unconsciousness from nitrous fumes artificial respiration should be given, preferably with oxygen; the man should be kept warm; heart stimulants given if necessary; and as soon as pos-

¹ Veröffentlichungen aus dem Gebiete des Marine-Sanitätswesens, Feb., 1915. Abstracted by K. Ohnesorg, Surgeon U. S. A., U. S. Naval Medical Bulletin, 1916, No. 4, Vol. X, p. 625.

sible fluids given in large quantities. The British authorities recommend milk; Esch, alkali waters with strong coffee.

When edema develops absolute rest must be insisted on, so as to make as little demand as possible on the lungs. Oxygen may serve to keep a man alive till the dropsical fluid begins to be absorbed (Hudson). Counterirritation in the form of mustard plasters is recommended by one American physician. Venesection and normal salt infusion is advocated by Hudson and by Esch. Zadek¹ used intravenous injections of sodium bicarbonate solution.

British and French medical journals during the last two years have contained many articles on the treatment of "trench gassing," poisoning by chlorine gas, in which the later lesions are much the same as in nitrous-fume poisoning, though the immediate asphyxiating effects are much more intense. Edema of the lungs develops after a varying interval, as in nitrous-fume poisoning, and the suggestions as to treatment of this condition would apply also to edema from nitrous fumes.

Bramwell² uses large linseed poultices over the whole back. He finds that anemic men do not suffer as severely as the plethoric and believes that bleeding would help. Gardner³ gives emetics to help in the expulsion of the fluid, but even better is to place the man on an inclined plane at about 30°, with the neck on an upright piece and the head falling back over it to a padded rest. Massage of the chest given in this position results in the expulsion of much fluid from the lungs. The treatment may be given for 10 minutes at a time.

Symes⁴ experimented on animals and found chloroform of no use in relieving the bronchial spasm, but burning stramonium leaves, with perhaps lobelia mixed, gave decided relief. The pupils must be watched for the danger of overdose. Opium fumes also were of use. There is a controversy among British physicians as to the value of injections of atropin for chlorine gassing.

Nitro and amido compounds.—Curschmann says there are two remedial measures for poisoning by nitrobenzol and anilin, removal from the source of the poison, and administration of oxygen. Although animal experiments give one no reason to believe that the amount of oxygen in the blood can be artificially increased, nevertheless empirically oxygen does seem to work, perhaps by increasing the depth of the inspirations. He quotes Brat as finding the alkalinity of the blood lessened by the formation of methæmoglobin, and therefore advising venesection. Curschmann sees no benefit in the

¹ Deutsche medizinische Wochenschrift, 1916, vol. 42, p. 208.

² British Medical Journal, 1915, Vol. II, p. 460.

³ London Lancet, 1915, Vol. II, p. 78.

⁴ British Medical Journal, 1915, Vol. II, p. 12.

use of excitants such as camphor and musk, recommended by many German physicians. He would give cool baths and abundant milk.

Many American physicians use oxygen in cases of cyanosis from these poisons, but others have seen no benefit from it and consider it an illogical form of treatment, because the methæmoglobin can not be driven out from its combination by forcing in oxygen. They prefer to use stimulants, of which camphor seems the most valuable. Anilin on the surface of the body should be washed off with soap or with a weak solution of acetic acid or vinegar, not for the reason often held, that it serves to form acetanilid and prevent absorption, but simply because water will not remove anilin unless it is acidulated.

Clements (quoted by Hudson) uses effervescing phosphate of soda for the nausea, and aromatic ammonia as a stimulant. He then encourages elimination by a brisk purge, usually calomel followed by a saline. For diuresis, he recommends large quantities of warm milk.

Trinitrotoluol.—Systemic symptoms. In cases without jaundice the British authorities recommend removal from contact with the poison, rest in bed for a day or two, a light diet of milk, fruit, and green vegetables; demulcent drinks, such as barley water, tea, and coffee; the bowels kept open by cascara sagrada or other vegetable laxatives; and a mixture of sodium sulphate, potassium citrate, and sodium bicarbonate to be given as routine treatment.

If jaundice develops, rest in bed from the first is essential; milk, at first in small quantities, slowly increasing to four pints a day. The bowels must be kept loose, preferably by *mistura alba*, repeatedly given to maintain its action, if necessary. Alkali-producing drugs, such as citrates and bicarbonates, are given to counteract the tendency to acid intoxication. Rectal and intravenous saline injections have a definite place in the treatment of severe cases.

Dermatitis.—There are many remedies recommended for this form of triton poisoning.

As a preventive the British committee recommends a mixture of 2 parts of castor oil to 1 of lanolin, rubbed into the skin after washing at the end of work.

The English dermatologist, Prosser White,¹ uses for the early itching stage a mixture containing camphor, carbolic acid, hydrarg. perchlorat, picric acid, and alcohol. This is to be painted on by the physician. For home treatment he gives a mixture containing 2 parts of the above to 4 parts of *lotio calam. comp. and pulv. acaciæ*. Then for a soothing ointment, to be applied at night when

¹ London Lancet, 1916, Vol. I, p. 400.

a bandage can be worn: Acid oleic, 9 parts and zinc oxid 1 part, stand two hours. Emplastrum plumbi 10 parts, parenol solid, 25 parts, parenol liquid, 13 parts, hydrarg. ammon. 3 parts.

Two English physicians who are in charge of the force in a triton works say that any simple emollient will serve the purpose. They use zinc and bismuth ointments, lotions of tragacanth and glycerin, or boro-calamine lotion.¹

Among American physicians alkaline washes seem to be popular, especially wet dressings of a saturated solution of bicarbonate of soda. One physician with a wide experience uses for moist eczema a teaspoonful of lysol in a pint of water; and for the dry, an ointment with phenol, calomel, zinc oxide, starch, and petrolatum. Another prescribes a wash of magnesium carbonate suspended in water, and then a mixture of alcohol and glycerin.

Fulminate of mercury.—At the United States arsenal at Frankford, the men who handle fulminate are given carbolized vaseline to rub on the skin after washing. For fulminate itch, an ointment is made of balsam of Peru, with zinc oxide ointment, and a little carbolic acid.

Picric acid.—Crédé's ointment has been recommended for severe picric-acid itch, and for the milder forms, a lotion of equal parts tincture of belladonna and tincture of aconite. Another treatment is carron oil applied after a full bath.

Tetryl dermatitis.—Dr. Enid Smith,² who has had charge of 250 women handling tetryl in an English munition works, advises the following measures: Each woman hardens her hands before going to work by washing in "methylated spirit" 20 parts, to 80 parts of water, and dusts the face with a powder of zinc oxide 1 part to 3 parts of starch. She is warned not to touch the face after this. On leaving work she washes with bran or with olive-oil soap. The working clothes must be soaked in cold water and kerosene and rinsed before boiling to get rid of the tetryl dust. If a severe dermatitis occurs, the face should be steamed, then wet cloths applied to allay the irritation, and then calamine lotion or ointment of zinc oxide with lanoline and castor oil. No lead lotion must be used as lead has a dangerous affinity for tetryl.

¹ Livingstone-Learmouth and Cunningham, London Lancet, 1916, Vol. II, p. 261.

² British Medical Journal, 1916, Vol. I, p. 618.

APPENDIX A.

SAFETY STANDARDS OF THE INDUSTRIAL BOARD, PENNSYLVANIA DEPARTMENT OF LABOR AND INDUSTRY. PLANTS MANUFACTURING OR USING EXPLOSIVES. OPERATIVE ON AND AFTER APRIL 1, 1917.

PETITIONS.

The following safety standards have been adopted by the Industrial Board, subject to the provisions of the Law (Act 267, section 15, P. L. 1913) which provides that persons affected may petition the Board for changes in the regulations. Upon the receipt of such petition, it will be reviewed by the Board and if considered necessary a public hearing will be called in regard thereto.

PENALTIES.

Every person or persons who violate any of the provisions of Act 267 of June 2, 1913, or any of the rules or regulations of the Industrial Board, or who resist or interfere with any officer or agents of the Department of Labor and Industry in the performance of his duties in accordance with the said rules and regulations, shall be deemed guilty of a misdemeanor and shall upon conviction thereof, be punished by a fine of not more than one hundred dollars, or by imprisonment not exceeding one month, or both, at the discretion of the court.

EXPLOSIVES.

The word "SHALL" where used is to be understood as mandatory and "SHOULD" as advisory.

Caution:—Employees shall not remove or make ineffective any safeguards while same are in use, except for the purpose of making repairs, and such safeguards so removed shall be replaced.

The provisions of all safety standards issued by the Industrial Board shall apply in all matters not specifically covered herein.

Section 1. Places Covered.—This code shall govern the operation of all buildings, factories, establishments, or other places where people are employed, wherein explosives are manufactured, used, handled, stored, or in which they are produced as the result of manufacturing processes.

Sec. 2. Materials Covered.—The following materials are classed as explosives by the Industrial Board: Black powder (all varieties), dry guncotton, nitroglycerin, dynamite, chlorates, fulminates, fireworks and any other of their compounds or mixtures or any other substances which are subject to explosion by the aid of shock, friction, spark or heat. Smokeless powder, wet guncotton and wet nitrostarch, while not properly classed with the above as explosives, are also included in these regulations.

EXPLOSIVE VAPORS.

Sec. 3. Construction of Buildings, Except Experimental and Testing Laboratories.—All rooms or portions of explosives plants in which there are used, generated or found, explosive vapors and wherein persons are employed shall be separated from other rooms or portions of plants by fire resisting walls or

partitions, pierced with such openings only as are necessary except when such rooms or portions of plants consist of separate buildings. In such places where the material which is being used or which produces the explosive vapors does not exceed ten gallons in quantity and is confined in approved safety cans it will be necessary only to prohibit the use of naked flames, to post approved danger signs and to observe safe practices. Materials which give off explosive vapors shall not be stored in workrooms wherein people are employed, unless such materials are stored in closed containers properly vented. Where practical, safety cans should be used.

Where materials giving off explosive vapors are stored in separated or underground storage systems outside of buildings they may be distributed by approved types of pipe lines throughout buildings where persons are employed.

The openings which are necessary in the above mentioned fire resisting walls shall be provided with an approved type of fire resisting door and these doors shall be kept closed at all times except when in use to permit passage from one room or portion of a plant to the other. On all such doors shall be posted an approved danger sign, warning against the carrying of matches or an open light and prohibiting the entrance of any but authorized employees or others designated by the manager or superintendent.

Sec. 4. Number of Employees.—The number of employees in such rooms or portions of a plant shall be kept to the minimum compatible with the process of manufacture. This can be obtained by building additional fire resisting portions or by the addition of small unit buildings.

Sec. 5. Lighting.—No open or naked lights such as lanterns, stoves, torches, etc., shall be allowed in such rooms or portions of plants, except for necessary repairs under proper supervision. Watchmen or others using portable lights shall be supplied with vapor proof lights.

Such rooms or portions of plants shall be lighted (if artificial light is needed) by means of an electric system installed in conduit or in lead encased cables, with vapor proof keyless lamps. All switches or fuses shall be located on the outside of such rooms or buildings in a protected place. This installation must conform to the Underwriters' Standards. It would be preferable and desirable if all lights could be projected by reflectors into rooms from the outside through properly located windows. The employment of electric motors other than those of a sparkless induction type, in the above rooms is forbidden.

Sec. 6. Ventilation.—If the amount of gases or vapors produced in such rooms or buildings is deemed sufficient by the Commissioner of Labor and Industry, or his authorized representative, to be a menace to the safety or to the health of employees working herein, an efficient exhaust system, plans of which must be approved by the Department of Labor and Industry, shall be installed in such rooms and kept operating at all times when persons are employed therein.

During necessary repairs which might cause a spark, all other operations shall cease, and such repairs shall be made only after adequate ventilation has been established to free the room or portion of the plant from explosive gas or vapor.

Sec. 7. Prevention of Explosions.—Oil lanterns, open lights, and any method of work which might generate a spark are prohibited in the vicinity of acid containers, except when necessary to apply heat for thawing purposes which shall be done under proper supervision. The opening of drums by means of an iron chisel and hammer is prohibited. Suitable wrenches shall be provided.

Localities where such material is stored shall be posted with warning signs calling attention to the danger of bringing naked lights into the vicinity.

Sec. 8. Nitric Acid.—In view of the danger to the worker from inhalation of nitrous fumes in case of fire or of the breakage of carboys, such carboys containing nitric acid shall be stored in detached sheds with sandstone, brick, or other suitable flooring, and in quantities not to exceed one hundred (100) carboys placed in not more than four rows. Nitric acid in carboys may be stored in the open in unlimited quantities.

The following notice will be supplied by the Department of Labor and Industry on application, and shall be posted at all places in plants where there is danger of poisoning by acid fumes.

ACID FUMES.

WARNING.

THE INHALATION OF DENSE ACID FUMES MAY CAUSE DEATH.

Employees are strictly prohibited from entering buildings where dense acid fumes exist, or tanks, or confined spaces which are not entirely clear of acid fumes, unless they wear a helmet.

Employees working in such places shall, in addition to the helmet, wear a life line which is at all times in the hands of an assistant stationed outside of the tank.

Employees who have been exposed to acid fumes and who feel weak, sick, short of breath, or who are attacked with cramps or coughing shall report this condition to their foreman or to the hospital at once so that proper treatment can be given. Don't wait to get home. Delay may be fatal. Take no chances.

Responsibility for complying with these regulations shall rest with the foreman or other person designated for that purpose by the management of the plant.

Failure to comply with these regulations may subject the offender to a penalty of a fine or imprisonment.

DEPARTMENT OF LABOR AND INDUSTRY.

Water shall be always available for use in case of evolution of nitrous fumes caused by breakage or other accident to carboys, and all workers handling such acid shall be warned against sprinkling sand, sawdust, earth or anything other than water or alkalies upon any spilled nitric acid.

ASPHYXIATING OR POISONOUS FUMES, VAPORS OR GASES.

Sec. 9. Places Covered.—In all buildings in which fumes, vapors or gases of an asphyxiating or poisonous nature are manufactured, used, handled or stored and in buildings in which chemicals which give off such fumes, vapors or gases, are produced, used, handled or stored, the following regulations shall be enforced.

Sec. 10. Resuscitation.—For every fifty (50) persons or less employed in such plant and exposed to such risk there shall be present at all times at least two (2) persons who are trained or competent to apply means of resuscitation by the prone pressure or Schaeffer method or by mechanical devices approved by the Industrial Board.

A sufficient number of helmets of a type approved by the Industrial Board shall be kept at each plant, in order that they may be available for use by every employee who has occasion to enter places where there may be asphyxiating or poisonous gases, fumes or vapors.

All employees who are required by the employer to wear helmets in making repairs or in maintenance work shall be thoroughly instructed in the use of such apparatus and be physically examined by a licensed physician at least once in ninety days or after absence from work due to either sickness or accident and the physician shall certify to the proper physical condition of the men so employed and no employee shall be permitted to do such repair work unless so examined and certified.

Sec. 11. Rules of Procedure.—If it is necessary for an employee to enter any vats, tanks or other containers in which there have been used, stored or manufactured, gases, fumes or vapors of an asphyxiating or poisonous nature, or materials which give off gases, fumes or vapors of an asphyxiating or poisonous nature, the following procedure shall be pursued:

(a) Empty containers. Disconnect and blank off all connections.

(b) Clean containers thoroughly by repeated washings with water, soda water, steam, compressed air or other suitable means.

(c) If the person in charge then considers conditions satisfactory, employees may enter such containers. They must use an approved type of helmet and have attached to their bodies a life line or rope if the person in charge considers it necessary.

(d) The life line or rope shall be under the control of one or more fellow workmen, who shall remain outside of the container, in order that they may render assistance if necessary.

(e) After the work is finished the men should take, at once, a bath and change their clothing, including shoes, if the foreman or other person in charge shall deem it necessary. Facilities for taking such baths shall be provided.

The superintendent of the plant shall be held responsible for the enforcement of these regulations.

A copy of the rules for procedure as given above will be furnished by the Department of Labor and Industry and shall be posted at every place in each plant where asphyxiating or poisonous fumes, gases or vapors may be found.

CHEMICALS.

Sec. 12. Scope.—The handling and storage of all acids and other chemicals necessary for the operation of explosives plants, not herein provided for, shall be governed by the regulations as set forth in the code governing the operation of chemical works.

EXPLOSIVES.

Sec. 13. Amount Allowed.—All buildings in which any quantity of explosives is manufactured, handled, used or temporarily stored shall be classed as explosives buildings. Those buildings, wherein finished explosives not being used in the process of manufacture are kept or are stored for periods exceeding forty-eight hours, shall be classed as magazines.

Explosive material, not in process of manufacture but which is being used in loading detonators, timing or priming caps, or in like manufacturing processes, shall not be stored in workrooms wherein people are employed except under the following conditions:

(a) Where the quantity used for the day's run does not exceed one hundred (100) pounds, it is permissible to keep in closely covered receptacles that necessary for the day's run.

(b) Where the quantity necessary for the day's run exceeds one hundred (100) pounds, only one hundred (100) pounds may be stored in the workroom at one time and then only at a place where it shall be suitably protected from

careless or promiscuous handling. Additional supplies shall be brought from the magazine as needed.

(c) Explosive materials being used in the above processes may be stored in any quantity in storage buildings erected for that purpose, provided that such buildings are not used for other purposes and are located at proper distances from other buildings wherein persons are employed, or are protected by suitable natural or artificial barricades.

(d) Fulminates or materials of like sensibility shall be brought into work-rooms in quantities sufficient only for concurrent use.

Explosive material not in process of manufacture and not being used in processes of manufacturing as above provided for shall be stored in magazines.

Sec. 14. Plans of Old Plants.—Each concern, manufacturing, using, handling, or storing explosives shall on and after April 1st, 1917, keep in the office of the superintendent of each plant, a plan of said plant showing the location of all explosives buildings and the distance they are located from other explosives buildings or buildings where persons are employed and from magazines, and these plans shall at all times be open to inspection by a duly authorized inspector of the Department of Labor and Industry. The superintendent of each plant shall, upon the demand of said inspector, furnish the following information:

The number of persons ordinarily engaged at work in or at each building or the proposed number to be allowed there.

The maximum amount and kind of explosive material which is or will be present in each building at one time.

The nature and kind of work carried on in each building and whether or not such buildings are surrounded by natural or artificial barricades and the dimensions of such barricades.

Sec. 15. Plans of New Plants.—Every concern hereafter engaging in the manufacture, use or handling of explosives, shall before or at the time of commencing operations, comply with section 14.

Sec. 16. Admission to Plants.—The entrance to plants manufacturing explosives exclusively, and to all portions of plants where explosives buildings shall be maintained, shall be fenced off in such a manner as to prevent the entrance of persons other than employees unless permission has first been obtained from the superintendent, manager, or proper authorities.

No person other than authorized employees, or State inspectors properly identified, shall be allowed in any plant manufacturing explosives or handling or using the same in the process of manufacture unless they have been given written permission by the superintendent, manager, or proper authorities, and are accompanied by them or their authorized representative. A record of such permission granted shall be kept on file in the office.

No person upon whom the odor of liquor is detected shall be allowed upon the premises of a plant manufacturing or using explosives, or in any explosives building.

No employee, other than those authorized to do work in or around such buildings, shall be allowed to remain near or in explosives buildings.

Sec. 17. Material Allowed in Explosives Buildings.—All explosives buildings shall be kept clean of all unnecessary loose tools, refuse, and debris of any kind, at all times, and shall not be used as temporary storehouses for material not necessary at that time in the process of manufacture.

No explosives building while containing explosives shall be used as a storehouse for implements or other paraphernalia.

Sec. 18. Repairs.—Whenever repairs are necessary in an explosives building, they shall be attended to by either a repairs engineer or other authorized

person. The foreman, or person in charge of the building, shall be responsible for seeing that only those authorized, attend to these repairs, and that in the case of major repairs all explosive material is removed before repairs are undertaken.

Before work may be resumed, after repairs have been made, all articles other than those allowed shall be removed from the building, and the workroom placed in its original working condition.

Sec. 19. Matches.—No employee shall have in his possession at any time in any explosives plant, any match or other flame-producing device unless he is authorized in writing by the superintendent to do so, in which case approved safety matches only may be used.

A search for matches shall be made by some authorized person at least twice a week at irregular intervals. The finding of a match or other flame-producing device on the person of an employee not authorized to have matches in his possession shall be cause for instant dismissal, and the facts shall be reported to the Commissioner of Labor and Industry.

Sec. 20. Clothing of Employees.—All employees handling loose explosives or working in or around explosives manufacturing buildings where there is a possibility of explosion by the attrition of metals shall wear powder shoes or rubber soled shoes (without iron or steel nails). No pockets shall be allowed in the clothing worn in such work except one skeleton pocket in either the coat or trousers. Neither iron nor steel buttons, nor other metal attachments, shall be allowed on such clothes, nor shall metal objects, such as knives, keys, etc., be allowed to be carried in the pockets.

All explosives buildings shall be provided at each entrance with suitable devices whereby the shoes of all those persons entering such buildings can be cleaned and all persons before entering such buildings shall wipe or clean their shoes.

Sec. 21. Change or Locker Houses.—Suitable change or locker houses shall be provided where employees can change their clothes and wash.

No lockers shall be allowed in explosives buildings.

Sec. 22. Transportation, Machinery and Platforms.—All trucks or conveyors used for the transportation of loose explosive material, except smokeless powder not in the dry state or wet nitro compounds, shall be provided with either side or end rails or guards to prevent any explosives from slipping off the truck or other conveyors. Only trucks or other conveyors that are in perfect repair shall be used.

Careful inspection shall be made daily by the foremen to see whether all machinery used in the manufacture or handling of explosives is in perfect order. If not found in such shape, it shall not be used until placed in perfect condition.

All dangerous machinery and moving parts of machinery shall be guarded in approved manner as specified by the Safety Standards of the Industrial Board of the Department of Labor and Industry.

All platforms, stairways, tanks, vats, runways and other dangerous places shall be guarded by standard railings and toe boards as required by the Industrial Board of Standards on Standard Railings and Toe Boards, except where there is danger of dust collecting, when toe boards shall not be used, but in all such instances special permission shall be obtained from the Department of Labor and Industry. Metal shall not be used for railings and toe boards where its presence increases the danger of an explosion and no railings or toe boards shall be installed so as to interfere with safety exits.

Either the tread of all wheels on tracks or conveyors or the rails used inside of explosives buildings shall be composed of nonsparking material.

Sec. 23. Hand Carrying of Explosives.—Where explosives are carried from one building to another, as for instance from magazines to workrooms, employees carrying such explosives shall not be allowed to follow each other closely but must allow an interval of at least one minute in time or one hundred (100) feet in distance. This does not apply to such explosives as trinitrotoluol and smokeless powder.

Sec. 24. Cleanliness.—If any explosive material or ingredients shall be spilled, they shall be immediately cleaned up.

The floors of all explosives buildings shall be so laid as to be as free as possible from cracks, openings or any irregularities and no projecting or visible iron or steel nails shall be permitted in such floors.

Sec. 25. Lighting.—Temporary or loose electric wiring, such as extension lights, etc., is absolutely prohibited in explosives buildings except in case of emergency while making necessary repairs.

All inside electric wiring shall be of a permanent character installed in metal conduit or lead encased cable with vapor proof keyless lamps. Installation of material of same shall conform to the Underwriters' Standards.

Sec. 26. Table of Distances.—(A table of distances is now in process of preparation and will be issued at an early date.)

Sec. 27. Protection Against Lightning.—Lightning protection shall be provided for all electric conduits and circuits entering explosives buildings, by means of suitable lightning arresters installed outside and not on the buildings. All installations must be in accordance with Underwriters' Standards.

Sec. 28. Heating.—The workrooms, when desirable, shall be heated by an approved system of steam, indirect hot air radiation or hot water. The temperature of the steam shall not exceed 120° centigrade. The radiators shall be at least one (1) inch distant from all wooden walls or other inflammable material and shall be attached in such a manner that they can be easily inspected and cleaned.

Sec. 29. Fire Extinguishing Apparatus.—All outside water mains shall be underground below the frost line. The provision of chemical fire extinguishers is recommended under certain conditions but not in high explosives and black powder manufacturing buildings. In workrooms where alcohol or other easily inflammable liquids, in quantities over one barrel, are being used, steam pipes or sprinkler systems for the extinguishing of fires shall be provided.

In addition to the foregoing regulations the following shall be observed with reference to the manufacture and handling of the respective substances enumerated below:

NITROGLYCERIN—ITS COMPOUNDS AND MIXTURES (DYNAMITE, ALL VARIETIES: GELATIN DYNAMITE, ETC.).

NITRATOR HOUSE.

Sec. 30. Floors.—The floor of the nitrator house shall either be covered with sheet lead or the nitrator shall stand in a suitable lead pan, drained to the drowning tank. All seams and joints shall be lead burned in a careful manner, so that there may be no crevices in which nitroglycerin will lodge.

The floor shall be so constructed as to be readily washed and drained.

New lead floor covering shall be extended by means of a round corner at least three inches up each side wall, thus making a sanitary corner.

Sec. 31. Thermometers.—At least two reserve thermometers shall be kept in each nitrator house for use in case of emergency.

Sec. 32. Construction and Operation.—When in the judgment of the Commissioner of Labor and Industry or his authorized representative, fumes are being

given off, adequate vent pipes shall be provided to carry off all fumes from the nitrator to the outside of the building.

There shall be a daily inspection of the nitrator and a test of its coils.

No iron valves shall be allowed on any nitroglycerin pipe lines, except quick opening nitrator plug cocks, which shall be frequently lubricated. All other valves or stop cocks on nitroglycerin pipe lines or containers shall be of stoneware, earthenware, hard rubber or wood and shall be kept clean and greased.

No repairs shall be made during nitration except in emergencies.

Nitrators shall be provided with coils for cooling by cold water, or brine or other suitable means and also with means for both mechanical and compressed air agitation.

No more than two nitrators shall be installed and not more than three employees shall be regularly employed in any one building.

During nitration the attention of one employee shall be given wholly to observing the thermometer and running in the glycerin.

No removal of supplies of acid or glycerin drums shall be allowed in the nitrator house while nitration is going on. The nitrator house shall be located not less than the approved distance from the nearest operating building containing other employees. The glycerin heating house and acid tanks are excepted.

No charge of nitroglycerin shall be sent to the separator house in a hose line while nitrating operations are in process.

Catch boxes shall be provided on all outlets for wash water and inside catch boxes, if used, shall be cleaned weekly, at times when there is no charge of nitroglycerin in the nitrator house.

The floors shall be washed daily at the conclusion of the day's work.

Sec. 33. Drowning Tanks.—Each nitrator house shall be provided with a drowning tank which shall have a water capacity of at least five times the amount of the acid charges and be provided with an air agitator and water inlet. All valves shall be located conveniently for the operators in case of emergency.

SEPARATOR HOUSE.

Sec. 34. Floors.—The floor of the separator house shall be covered with sheet lead with all seams and joints lead burned in a careful manner, so that there may be no crevices in which nitroglycerin will lodge.

The floor shall be so constructed as to be readily washed and drained. The lead floor covering on new buildings shall be extended by means of a round corner at least three inches up each side wall, thus making a sanitary corner.

A lead pan under the receptacle for holding nitroglycerin will be acceptable, in old construction, in lieu of a complete lead floor covering.

Sec. 35. Thermometers.—Plain reading thermometers shall be supplied in each separating tank and a reserve supply of at least two shall be kept in each separator house.

Sec. 36. Construction and Operation.—Not more than two charges shall be allowed in a separator house at one time.

The maximum number of regular employees in each separator house shall be three.

All stopcocks or valves on nitroglycerin pipe lines or containers shall be of stoneware, earthenware, hard rubber, or wood.

Catch boxes shall be provided on all outlets for wash water and inside catch boxes, if used, shall be cleaned weekly, at times when there is no charge of nitroglycerin in the separator house.

No charge shall be sent from the separator house at a time when a charge is being received.

Each separating tank shall be cleaned and the floors washed daily at the conclusion of the day's work.

It is permitted to carry on the three operations of nitration, separation and neutralization in one building, provided that the regulations prescribed for each individual operation are complied with.

Sec. 37. Drowning Tanks.—An air agitator shall be provided for each separating tank and the outlet of each tank shall be suitably arranged so that the entire charge may be drowned in a drowning tank which shall have a water capacity of at least five times that of the acid charge. This drowning tank shall be provided with an air agitator and water supply.

NEUTRALIZING, STORAGE, AND FREEZING HOUSES.

Sec. 38. Floors.—The floors of each of the above houses shall be covered with sheet lead, with all seams and joints lead burned in a careful manner so that there may be no crevices in which nitroglycerin will lodge.

The floors should be so constructed as to be readily washed and drained.

The lead floor covering on new buildings shall be extended by means of a round corner at least three inches up each side wall, thus making a sanitary corner.

A lead pan under receptacles for holding nitroglycerin will be acceptable in old construction in lieu of a complete lead floor covering.

Sec. 39. Construction and Operation.—The maximum number of regular employees in each one of these houses shall be three.

Catch boxes on the outlets for all wash water shall be provided. Inside catch boxes when operating shall be cleaned at least once a week, at a time when no charges are being sent from the house or are being received into it.

No charge of nitroglycerin shall be sent out of a house into a pipe line or gutter during the period in which a charge is being received.

The floors shall be washed daily at the conclusion of the day's work.

Sec. 40. Acid Burns.—A water outlet or shower bath shall be provided inside of all houses where an employee may be in danger of being burned with acid.

TRANSPORTATION.

Sec. 41. Hose Lines.—Before and after a charge of nitroglycerin is sent down a line in cold weather, hot water shall be sent down through the hose line or in a gutter surrounding the hose line.

All nitroglycerin lines shall be carried on substantial scaffolding or runways and shall be protected by suitable covering.

A thorough examination of the complete system shall be made monthly by some responsible person and a written report rendered by the official to the superintendent or manager of the plant.

No nitroglycerin lines shall be located or pass an explosives building in such a way as to be liable to rupture or other injury in case of an explosion occurring in a building with which it is not connected.

Hose lines shall be made of the best grade of rubber.

Sec. 42. Gutters.—If lead gutters are used instead of hose lines, they shall be formed of at least six (6) pound lead, suitably lead burned and located so that they will drain completely toward one end. Rubber gutters are permissible but shall be made of a good quality of rubber.

Sec. 43. Carriages.—All carriages for the transportation of nitroglycerin shall be of an approved design, shall be equipped with rubber tires and be of a capacity not exceeding eight hundred (800) pounds.

Smooth runways for these carriages shall be provided and shall be kept in good repair at all times.

Sec. 44. Hand Mixing House.—The floor of the hand mixing house shall be covered with linoleum, rubberoid or other suitable covering, laid by either lapping joints or cementing their edges.

Sec. 45. Construction and Operation.—The maximum number of employees allowed in the mixing house shall be three, except at a time when supplies are being received or finished material is being taken away, when the number may be increased to five.

Proper precautions shall be taken to prevent the freezing of nitroglycerin.

No nitroglycerin shall be stored in the mixing house in excess of that necessary for the next two charges.

The mixing bowl shall be made of wood, wood, lead lined; or of some other approved substance.

All shovels and rakes shall be made of wood.

No iron or steel tools of any kind shall be allowed in or about a mixing house, at platforms or entrances, except in case of repairs when operations shall cease and explosives shall be removed. No iron drums shall be rolled or dragged over the floor or platform.

The maximum amount of nitroglycerin in a mixing house at one time shall be two thousand (2,000) pounds.

No mixed powder shall be regularly allowed to remain in a mixing house over night.

MACHINE MIXING HOUSE.

Sec. 46. Operation.—The regulations for the hand mixing house shall cover the machine mixing houses with the following exceptions:

The maximum number of regular employees in a mixing house at one time shall be four, except at a time when supplies are being received or finished material is being taken away when the number may be increased to six.

The maximum amount of explosive material allowed at one time in the building shall be four thousand (4,000) pounds.

HAND PACKING OR PUNCHING HOUSE.

Sec. 47. Operation.—The maximum number of regular employees in each hand packing or punching house shall be seven.

The floors of such houses shall be covered with linoleum, rubberoid or other suitable covering laid by either lapping joints or cementing their edges.

No explosive material shall be stored therein during operations except that which is necessary for the day's work.

A thorough cleaning shall be given at the conclusion of the day's work and all refuse material shall be destroyed according to the method adopted at that particular plant.

Proper precautions shall be taken to prevent the freezing of nitroglycerin and no powder shall be packed in a frozen condition.

PARAFFIN DIPPING.

Sec. 48. Operation.—All dipping of cartridges must be done in a jacketed kettle, the heat being supplied by either hot water or steam with a maximum pressure of twenty (20) pounds.

BOX PACKING HOUSE.

Sec. 49. Number of Employees.—The maximum number of regular employees shall be seven. Whenever the output of the plant is such as to require a larger number of employees they shall be placed in a separate unit protected by barricades.

GELATIN MIXING AND PACKING.

Sec. 50. Operation.—All gelatin mixing shall be done in a building provided for that purpose.

The gelatin packer or "sausage" machine shall be located in a separate building, except when the number of employees is four (4) or less when mixing and packing operations may be carried on in the same building.

The maximum number of regular employees in a packing house shall be five.

The maximum number of regular employees in a mixing house shall be four.

When the output is such that it requires an additional number of hand wrappers, they shall be housed in a separate building.

BLACK POWDER MILLS.

Sec. 51. Materials Used.—All materials used in the manufacture of black powder shall, prior to mixing or incorporating, be subjected to a magnetic separator or put through a screen.

Sec. 52. Incorporating Mills.—The mechanism for the starting or stopping of an incorporating mill shall be so arranged that after the material has been placed in the bowl, the mill can be started only by an employee from a reasonably safe station, and then only after all employees have left the building.

No loading or unloading of ingredients or finished mixed material shall be done while the mill is in operation.

It is recommended that all bolts or parts of machinery which might break off and fall into the mill, while it is in course of operation, shall be suitably protected so that in the event of such breakage, these parts will not fall into the mixing bowl.

Sec. 53. Cleaning.—All buildings shall be wet down from time to time as necessity demands and cleaned daily.

On at least one day in each week, at a time designated by the superintendent, there shall be a thorough cleaning of each building with the removal of all accumulated dust on walls and ceiling.

All buildings, in which loose powder is handled shall be provided with suitable hose and water connections so that a wet down can be given as often as necessary.

Sec. 54. Examination of Machinery.—Workmen when going on duty shall first examine each mill or building in their respective charge, oil up, and if anything is out of order, report at once to the superintendent or foreman.

Under no circumstances shall the mill be started unless in proper condition.

When any foreign substance is thought to be in the powder, work and machinery must be stopped at once and report made to the superintendent or foreman.

At the conclusion of the day's run the machinery and belts shall be examined and if not found to be in first-class condition a report shall be made to that effect to the superintendent or foreman.

Sec. 55. Repairs.—In the event of any major repairs being necessary in any of the buildings, work shall cease at once, and those employees so designated shall properly clean up the room and machinery by the removal of all loose powder and dust and afterward thoroughly wet down all parts of the machine and room. Such repairs shall be made only by persons designated by the management.

In order that the number of persons present at such times may be kept to a minimum, the millwright or mechanic shall send away any of his helpers when he can dispense with their services. When repairs are complete, all tools taken to the mill shall be accounted for and removed before starting the mill.

Caked powder can be removed by soaking with water and then loosening by means of a wooden shovel or wooden spud.

Sec. 56. Electric Apparatus and Lighting.—The lighting of all buildings shall be as provided for in Section 5, and no electric devices which may give off sparks shall be permitted in any room where powder dust may accumulate or be present.

Sec. 57. Implements.—No metal implements of any kind except those made of non-sparking metal shall be used in handling powder.

GUNCOTTON, NITROSTARCH, SMOKELESS POWDER AND SIMILAR PRODUCTS.

GENERAL.

Sec. 58. Standard Railings.—All platforms, openings, and stairways shall be guarded with standard railings as provided in Safety Standards of the Industrial Board on Standard Railings and Toe Boards, Vol. 1, No. 2, except where there is danger of explosive or inflammable dust collecting, when toe boards shall not be used. Metal shall not be used for railings and toe boards where its presence increases the danger of an explosion, and no railings or toe boards shall be installed so as to interfere with safety exits.

Sec. 59. Walks or Runways.—Walks or runways should not be built over the tops of tanks or vats but should be located at the sides of such containers at least 3 feet 6 inches below the top. Where such conditions can not be obtained standard railings shall be installed and toe boards where necessary.

Sec. 60. Escape from Buildings.—All explosives buildings two or more stories in height shall have at least one outside means of escape which shall be of the chute type or a sloping lateral runway. In no case shall steps or ladders be considered a sufficient substitute.

Sec. 61. Removal of Acid Fumes.—Provision shall be made for the carrying away of acid fumes at all stages of the nitrating process, i. e., while filling the nitrating vessels with acid, while adding the cotton, and while taking the nitrated cotton from the nitrating apparatus and placing it in wringers or centrifuges.

Sec. 62. Protection of Employees.—Employees shall be urged to wear suitable protective clothing such as rubber gloves, rubber aprons, and rubber shoes or boots. Suitable types of respirators and goggles shall be provided.

Sec. 63. Centrifugal Sheds.—Each centrifugal wringing out waste acid shall be separated from other centrifugals by partitions or shall be located at a safe distance from other centrifugals. The compartments or sections so created shall be so arranged that employees can make a quick get-away in case the cotton should ignite.

Adequate water facilities shall be provided for fire fighting apparatus and also for outlets for washing purposes and for shower baths. The latter are necessary especially in the event of workmen receiving acid burns.

ROOMS CONTAINING ETHER VAPOR.

Sec. 64. Operation.—All rooms which may contain ether vapor shall be governed by section 3 to section 6 inclusive.

Sec. 65. Electric Apparatus.—No electric apparatus capable of giving off a spark shall be allowed in such room.

Sec. 66. Floors.—Floors shall be of such construction that they can be kept clean.

Sec. 67. Doors.—An approved number of exit doors for a quick get away shall be provided in such buildings.

DRY HOUSES, DRY DUMP HOUSES AND BLENDING HOUSES.

Sec. 68. Grounding of Bins.—All powder bins shall be suitably grounded to insure safety from static electricity.

A monthly inspection and report shall be made of the condition of such apparatus by a competent person designated by the superintendent.

Sec. 69. Number of Employees Allowed. (A) *Dry Houses and Dry Dump Houses.*—Not more than six employees shall be allowed inside of a dry house or dry dump house or around such houses while a filling or emptying process is being carried on.

(B) *Blending Houses.*—(a) Not more than twelve employees shall be allowed inside of a cordite blending house.

(b) Not more than ten employees shall be allowed inside of a gravity type of blending house. By gravity type is meant that type of blending house in which the entire charge of powder is deposited in a bin or funnel situated one or more floors above the packing floor.

(c) Not more than eight employees shall be allowed inside of a bin type of blending house, i. e., a house in which all operations are carried on on one floor.

If more than eight men are necessary to carry on operations in a gravity or bin type of blending house, a maximum number not exceeding twelve men will be permitted, providing a fire resisting wall of a type approved by the Commissioner of Labor and Industry, or his authorized representative, shall be erected. This wall shall separate the employees who are engaged in weighing, packing and inspecting from the bins containing the powder. A covered fire resisting means of escape, extending at least seventy-five (75) feet from the building, shall be erected. The plan and type of this means of escape shall be approved by the Commissioner of Labor and Industry, or his authorized representative.

The restrictions as to the number of men mentioned above is intended to include laborers and foremen but not to include inspectors, superintendents or other members of the plant manager's staff, whose duties may require their presence occasionally to see that the work is being carried on properly.

APPENDIX B.

RULES AND REGULATIONS SUGGESTED BY THE MASSACHUSETTS STATE BOARD OF LABOR AND INDUSTRIES FOR SAFETY IN THE MANUFACTURE OF BENZENE DERIVATIVES AND EXPLOSIVES.¹

PREPARED BY THOMAS F. HARRINGTON, M. D., DEPUTY COMMISSIONER OF LABOR.

Evidence of the danger to the life and to the health of persons employed in the manufacture and use of various benzene derivatives has accumulated in this State during the past year. The experience of countries, where manufacturing processes have been carried on in an extensive way for many years, shows that the industry can be regulated without hindrance to its development and with comparative safety to the workers engaged in the manufacturing processes.

The State Board of Labor and Industries presents the following regulations to insure safety to the workers in this State, and will welcome any observations manufacturers or employees may desire to make on these proposals.

CLASSIFICATION.

The following substances shall come within these regulations:—

Nitrobenzol.	Trinitrotoluol.
Dinitrobenzol.	Anilin hydrochloride.
Dinitrotoluol.	Anilin oil.
Trinitrophenol (picric acid).	

Also all compounds in which any of the foregoing is a part of the manufacturing process.

DANGERS.

In the various processes of manufacture in which any of the foregoing substances are used, a danger to health arises in three ways, viz.:—

1. From the inhalation of fumes before the process of crystallization is completed.
2. From the inhalation of dust given off in the breaking up or crushing of the crystallized mass.
3. From the absorption through the skin by contact with the material in either the liquid or solid state.

PREVENTION.

The danger to health can be reduced to a minimum by—

1. The removal of fumes and dust.
2. The prevention of absorption of the poisonous material through the skin.

¹ Industrial Bulletin No. 11, Massachusetts State Board of Labor and Industries, Boston, 1916.

To make prevention effective the fumes and dust must be removed at or very near to the point where they are produced, and the following means employed:—

A. VENTILATION.

1. Every vessel containing any substance included in these regulations shall, if steam is passed into or around it, or if the temperature of the contents be at or near the temperature of boiling water, be covered in such a way that no steam or vapor may be discharged into the open air at a less height than 25 feet above the heads of the workers.

2. In every room in which fumes from any of the substances included in these regulations are evolved in the process of manufacture and are not removed as provided in section 1 there shall be provided and maintained thorough ventilation by means of a fan or other exhaust system.

3. No substances mentioned in these regulations shall be crushed, ground, mixed or packed in a crystalline condition except with an efficient exhaust system, so arranged as to carry away the dust as near as possible at its point of origin.

4. No substances mentioned in these regulations shall be broken by hand in a crystallizing pan, nor shall any liquid containing it be agitated by hand, except by means of an implement at least 6 feet long that shall prevent the workers' hands and faces from coming into close proximity with the substances used.

5. In the filling of cartridges with any of the substances mentioned in these regulations, the process shall not be done by hand except by means of suitable scoops.

6. Drying stoves shall be efficiently ventilated to the outside air in such a manner that hot air from the stoves shall not be drawn into the work-room. No person shall be allowed to enter a stove to remove the contents until a free current of air has been passed through it. All openings in stoves, retorts, vats, etc., for the admission of workmen into the interior of such stoves, vats, etc., shall be sufficiently large to permit the easy passage of the body of such workmen.

B. WASHING FACILITIES.

There shall be provided and maintained in a cleanly state, in good repair, and properly lighted for the use of all persons employed on the substances mentioned in these regulations—

1. At least one washbowl, sink, or other appliance for every five persons and provided with running hot and cold water.

The number of bowls, sinks, or other appliances required shall be based upon the maximum number of persons entitled to use the same at any one time. Twenty inches of sink will be considered as an equivalent to one washbowl.

2. A lavatory within reasonable access and under cover, with a sufficient supply of clean towels and of soap and nailbrushes.

3. Sufficient and suitable bath accommodations (shower or other), with hot and cold water, and a sufficient supply of soap and towels.

C. TOILET FACILITIES.

Rules and regulations for toilet facilities, adopted by the State Board of Labor and Industries, shall prevail in all establishments where the manufacturing processes concerned in these special regulations are carried on.

D. SPECIAL CLOTHING.

There shall be provided and maintained for the use of all persons employed in the manufacturing processes included in these regulations—

1. Suitable overalls or suits of working clothes. Overalls included in these regulations shall be washed or renewed at least once every week.
2. India rubber gloves, which shall be collected, examined and cleansed at the close of the day's work and shall be repaired or renewed when defective. Equivalent protection for the hands, when they come in contact with the substances mentioned in these regulations, may be substituted for gloves.
3. Clogs or other suitable protection for footwear that shall guarantee against contact with the substances mentioned in these regulations.
4. A suitable clothes room for changing and for keeping clothing put off during working hours.
5. A suitable locker, separate from the clothes room and meal room, for the storage of overalls and other work clothes.

E. DINING ROOM.

1. In establishments included in these regulations a suitable meal room shall be provided unless the establishment is closed during the meal hours. This dining room shall be separated from any room in which a process using materials mentioned in these regulations is carried on.
2. Suitable provision shall be made for the keeping of food brought by persons employed.
3. Adequate washing facilities, equipped with running hot and cold water, shall be provided in or adjacent to the meal room.
4. No person shall introduce, keep, prepare or partake of any food, drink, or tobacco in any room in which a process using substances mentioned in these regulations is carried on.

MEDICAL REQUIREMENTS.

Each establishment in which manufacturing processes using materials mentioned in these regulations are carried on shall employ and keep in employment one or more duly qualified physicians to act as medical officer or officers, who shall be in attendance at all necessary times while such work is in progress, so as to guarantee constant medical supervision and care of workers engaged in these processes of manufacture.

Such medical officer shall also be charged with the duty of enforcing the following regulations:—

1. Examine every person employed in these processes of manufacture either before said person begins employment, or within seven days after beginning said employment.
2. Reexamine every person employed in these processes at least once in each calendar month, or at such other intervals as may be necessary to insure protection to the workman against poisoning from the substances used in the process of manufacture; also before permitting a workman to return to work after absence or suspension on account of illness.
3. The medical officer shall have the power of suspension because of physical unfitness of any person employed on any of these processes of manufacture, and no person, after such suspension, shall be reemployed without written sanction of the medical officer.

4. The medical officer shall give such instruction to employers and to employees concerning the danger to health from the particular process of manufacture being carried on in the establishment as will best qualify such persons to—

(a) Recognize the signs of poisoning.

(b) Apply suitable first-aid treatment to workmen taken ill upon the premises.

5. The medical officer shall keep a full and complete record of all examinations made by him, which record shall contain the date on which examinations are made, name, address, age, height, weight, physical condition of heart and lungs of all persons examined by him; also a full and complete record of all illnesses, accidents and deaths occurring among the employees under his charge. These records shall be open to the inspection of the State Board of Labor and Industries or its representatives, and a copy thereof shall be forwarded to said Board within forty-eight hours following the occurrence of the accident, illness or death, stating as fully as possible the cause of said illness, accident or death of employees.

No statement contained in any such report shall be admissible as evidence in any action arising out of said accident, illness or death herein reported.

6. There shall be provided a suitable medical or hospital room for the care and treatment of workmen taken ill upon the premises. This room shall be conveniently located, properly lighted, heated and ventilated, and shall contain the following minimum equipment:—

(a) A couch or bed.

(b) Pair of blankets.

(c) Two hot-water bottles.

(d) Tank of oxygen, with apparatus for using the same.

(e) A lungmotor.

(f) An oxygen helmet for rescue work.

(g) Suitable ropes for rescue work.

(h) Medical and surgical chest as prescribed by the rules of the State Board of Labor and Industries.

PRINTED NOTICE POSTED.

A printed notice in language intelligible to all the workers, and in type sufficiently large to be legible to all workers, labeled "caution," shall be conspicuously posted and maintained in all departments where any of the substances mentioned in these regulations are used in any processes carried on therein. Said notice shall contain the following:—

1. In large conspicuous type the common name of the poisonous substance in use in that particular room.

2. That the substance named is capable of causing poisonous symptoms if precautions are not observed.

3. Signs and symptoms of poisoning, viz.: Throbbing of blood vessels, giddiness, dizziness, headache, weakness of legs, palpitation of heart, nausea, blue-ness, cyanosis, unconsciousness.

4. First-aid treatment, viz.:—

(a) Remove poisoned person to the fresh air. Keep him quiet and warm.

(b) Do not let person walk home until advised by physician.

(c) Use hot coffee as stimulant.

(d) If person is unconscious, apply artificial respiration; lungmotor; oxygen inhalation; keep patient warm.

5. Prevention:—

- (a) Avoid dust, fumes and chemical compounds on hands, feet and clothes.
- (b) Wash hands before eating and after day's work is finished.
- (c) Do not eat food nor chew tobacco in workroom.
- (d) Do not wear same clothes in workroom and at home.
- (e) Use extra protection on hands, feet and clothes while at work on any of the substances mentioned in these regulations.
- (f) Bathe regularly.
- (g) Consult a physician if losing color or weight.
- (h) Do not enter stoves, vats or retorts for repair work unless in the presence of another workman.
- (i) Have emergency appliances ready for use in all dangerous repair work.
- (j) Watch for leaky joints in pipes, ducts, valves, etc., carrying the gas or chemical compounds.

APPENDIX C.

TNT MANUFACTURE IN GREAT BRITAIN. PRECAUTIONARY MEASURES. 1916.¹

PRECAUTIONS AGAINST POISONING.

NITRATING SHED AND ACID PLANT.

Illness is due principally to escape of (1) nitrous fumes evolved mainly in the manufacture of nitric acid and during the dilution of the TNT waste acids, and (2) chlorine and compounds of chlorine given off at the commencement of working each charge when not thoroughly absorbed in the towers.

The full effect of inhaling nitrous fumes is not felt immediately, and unless workers are warned of the danger they may continue to work and unwittingly inhale a fatal dose. The usual course, in other than slight cases, is for cough and difficulty of breathing to set in three or four hours after exposure to the fumes, the reason being that it takes this time for the damage done to the lungs to show itself.

The best precaution is to insure very thorough ventilation at all points where fumes are likely to be evolved. In the acid plant, where the evolution of fumes in excess is unavoidable, only the wearing of an air helmet will insure safety. In the shed itself, acid-resisting fans, fixed at suitable points, as, for example, in connection with hoods over the pelleting tanks, will assist in keeping the atmosphere clear. All nitrating vessels should be kept under a slight negative pressure by a duct (preferably of earthenware pipes) connected with a fan or other effective exhaust.

TNT PLANT AND PACKING SHED.

Illness may result from—

(1) General effects of DNT and TNT on the constituents of the blood. The first symptoms are headache, nausea, and high-colored urine. Outward signs become distinctive in lividity of the lips, shortness of breath, and sometimes jaundice—a grave symptom.

Absorption of the poison takes place—

- (a) by inhalation of the vapor or dust;
- (b) by contact with the skin;
- (c) by the alimentary canal.

The first of these can be dealt with by effective ventilation; in particular, by arranging a strong exhaust draught over the cooling trays or granulating rollers. The casting should be commenced at the trays nearest to the fan and should proceed backwards from that point. The motor for driving the fan should be totally inclosed.² Similar arrangements may be necessary to prevent inhalation of dust or fume at the packing bench.

¹ Published by the Factory Department, Home Office, Great Britain, March, 1916.

² A totally-inclosed machine is one in which the inclosing case and bearings are dust proof, and which does not allow a circulation of air between the inside and outside of the case.

The second is best met by proper provision and maintenance of the overall suits, gloves, washing accommodation, and meal room required by the Regulations of the Home Office (*see* Appendix), and the personal cleanliness of the workers.

The third effect is most marked if the stomach is empty. It is recommended that milk or cocoa should be provided for those who want it before commencing work; suitable canteen arrangements are very necessary. Alcohol dissolves TNT, and symptoms are markedly brought out after alcoholic indulgence.

Workers are advised to eat potatoes, green vegetables, and uncooked fruit—especially apples. As drinks, orange or lemon juice or lime juice are all good.

Symptoms may develop quickly, especially where there has been exposure in a confined space. The best treatment in such circumstances is inhalation of oxygen (*see* p. 7), a cylinder of which (with suitable connections) should be kept in readiness.

(2) Local effects—dermatitis or eczema. TNT sets up in some workers an irritating rash on the arms. Such cases should be referred for treatment to the doctor who will examine those coming into contact with the material once at least every month. Sleeves should not be rolled up. Gloves if worn require careful supervision, as men are very careless about them. Naturally, if TNT gets inside the gloves they are worse than useless. The cuff of the glove should be inside, that is, under the sleeve of the overall which must be fastened securely at the wrist. All openings in overalls should fasten securely and overlap, if possible. Evidence accumulates to show that if the washing facilities are suitable, and are regularly used by the workers, the hands being thoroughly dried afterwards, occurrence of eczema is rare.

Toxic jaundice is one of the diseases which, if contracted in a factory, must be notified to the factory department. The occupier is required to report every such case to the district inspector and to the certifying surgeon, and the medical practitioner in attendance has also to report it to the chief inspector (S. 73, Factory Act, 1901, and Order of 27th November, 1915).

INSTRUCTIONS AS TO ACCIDENTS, MINOR INJURIES, USE OF AIR HELMETS, USE OF OXYGEN CYLINDER, AND ARTIFICIAL BREATHING.

Any workman meeting with an injury, however trivial it may seem, in the execution of his duty, should report it to his foreman. Similarly he should report—

- (1) A persistent cough due to no known cause;
- (2) Unaccustomed shortness of breath;
- (3) Fatigue not explained by exertion;
- (4) Pains coming on suddenly in the feet and legs.

Such symptoms should not be disregarded because they are trivial. In fact, they are only trivial if attended to in time. They may indicate the slight beginnings of poisoning, the effects of which rapidly become serious if the poisonous influences are not counteracted.

In the case of minor injuries causing abrasion to the skin, however slight, the worker is not to touch, wash, or attempt to dress the wound; he or she is to go to the nearest place where first-aid dressings are kept and have the wound attended to by the person in charge of the first-aid dressing box.

Remedies for acid burns must be applied very promptly. The utmost care is to be used in dealing with acid burns to the eyes. When any acid gets into the eyes, they are to be attended to at once by the person in charge of the first-aid dressing box.

GASSING.

Workers are to remember that the effects of breathing irritating gases, such as nitrous fumes, may not manifest themselves for several hours. A worker is, therefore, to report immediately to his immediate superior if, either under exceptional conditions, or during ordinary work, he is subjected to the action of such gases, or should he, in the performance of his ordinary duty, feel the effects of such gases.

Prevention.—Notices, warning those employed of the danger of remaining in an atmosphere containing nitrous fumes, should be posted in places where there is any possibility of these fumes escaping. (See pp. 11–13.)

Emergency helmets of such a pattern that they can be easily and quickly put on, and provided with a fresh air supply from without, should be kept in accessible places at hand, and the efficiency of such helmets should be tested at least once a month.

Respirators, such as are effectual in intercepting dust, are useless against gases and must not be used. A wet handkerchief absorbs the fumes to some extent but should not be relied on except when the fumes are slight.¹

The Use of Air Helmets.—In the department producing or employing acids or dealing with irritating or injurious gases or fumes, emergency operations including urgent repairs, the result of accident or otherwise, are, when there is evolution of fumes, to be controlled by some responsible person.

Air helmets are to be used in all such cases unless the person in charge considers the chances of saving life, or minimizing injury to workers, are increased by not using them. In such cases he is to take every other precaution possible to reduce risk to the worker carrying on the necessary operations.

Ordinary repairs or alterations where fumes are liable to be present are to be dealt with as above. Such operations are to be carried out under the supervision of some responsible person.

Air helmets may either be supplied with air from taps provided on the compressed air mains, through a suitable pressure-reducing arrangement or, when compressed air is not available or convenient, from the bellows provided.

Treatment.—In a case of gassing by nitrous fumes a doctor should be sent for at once. The following routine may usefully be pursued pending his arrival:

Make the patient lie down.

Keep him warm.

See that he has plenty of fresh air.

If he is blue in the face—

Administer oxygen; and

If he has not been sick, give a drink of 1 ounce of salt in 10 ounces of lukewarm water, and repeat the dose until he is sick.

Persons even apparently slightly affected must not be allowed to walk home until permitted to do so by the doctor.

¹ A better protection would be a respirator made up of 20 folds of butter muslin which has been previously soaked in the strip in a solution containing washing soda 80 parts, glycerin 15 parts, and water 100 parts, and fitted with elastic to keep it close to the face. After use the respirator should be discarded.

USE OF OXYGEN CYLINDER.¹

The cylinder should be provided with a lever key, nipple and union, together with a rubber tube at the end of which is a glass or metal mouthpiece. Open the valve gradually by tapping the lever key (which must first be extended to its full length) with the wrist until the oxygen flows in a gentle stream from the mouthpiece into the patient's mouth. The lips should not be closed round the mouthpiece. The nostrils should be closed during breathing in and opened during breathing out.

If the teeth are set, close the lips and one nostril. Let the conical end of the mouthpiece slightly enter the other nostril during breathing in and remove it for breathing out.

ARTIFICIAL BREATHING (SCHAEFER METHOD).

Place the patient face downwards.

Kneel at the side of the patient and place your hands flat in the small of his back, with thumbs nearly touching, and the fingers spread out on each side of the body over the lowest ribs.

Then promote artificial breathing by leaning forward over the patient, and, without violence, produce a firm, steady downward pressure. Next release all pressure by swinging your body backwards without lifting your hands from the patient.

Repeat this pressure and relaxation of pressure, without any marked pause between the movements, *about fifteen times a minute*, until breathing is established.

INSTRUCTIONS FOR FIRST-AID ATTENDANT.**A SCRATCH OR SLIGHT WOUND.**

Do not touch it.

Do not bandage or wipe it with a handkerchief or rag of any kind.

Do not wash it.

Allow the blood to dry and so close the wound naturally; then apply a sterilized dressing and bandage.

If the bleeding does not stop, apply sterilized dressing and sterilized wool, then bandage firmly.

If the wound is soiled with road dirt or other foul matter, swab freely with wool soaked in the iodine solution² (which may be provided in the form of ampoules) and allow the wound to dry before applying sterilized dressing.

AN ACID BURN.

Do not touch it.

Do not apply oil or grease of any kind.

Sprinkle the burn with powdered bicarbonate of soda. Omit this if the burn is not caused by acid.

Apply a sterilized burn dressing of suitable size.

However slight the burn, if the area affected is extensive the doctor must be consulted.

¹ This apparatus should be in charge of not less than two persons instructed in its use. It should be their duty to gauge the cylinders (by means of a pressure gauge) whenever they have been used, and to see that they are adequately charged for future use. The apparatus should be examined once a month by them, when the condition of the mouthpiece and of the rubber tubing should be observed. If the rubber becomes hard and dry warm water will restore the pliability.

² An alcoholic solution containing 2 per cent of iodine.

Destroy all dressings which have been opened but not used; they soon become infected with microbes from the air and then are not safe to use.

Read the instructions on the dressings and adhere to them strictly.

Do not remove any dressing until the wound is healed, but, if the injured part becomes painful and begins to throb, arrange for the doctor to see the patient at once.

EYE INJURIES.

An Acid Burn.—Brush the affected eyeball thoroughly with solution No. 1.¹ Then apply solution No. 2² in the same way.

Instructions to chemist for making eye drops.—Weigh 95 grams of castor oil into a flask capable of holding twice the quantity. Add 0.5 grams of powdered cocaine. Warm on a water bath till dissolved. While the solution is still warm (but not hot) add 1 cubic centimeter of a solution containing 3.3 grams of mercuric chloride in 100 cubic centimeters of absolute alcohol. Mix the solutions by rotating the flask. About half an ounce, or 15 c.c., of this solution should be supplied in a bottle, from the cork of which a camel's-hair brush is pendent in the fluid.

Apply an eye-pad and tie up with clean handkerchief or bandage.

Send patient to the doctor *at once*.

A Foreign Body.—Apply the eye drops to the affected eyeball by means of the camel's-hair brush in the bottle.

Do not try to remove any particle which can not be brushed away.

Tie up with a clean handkerchief or bandage.

Send patient to the doctor *at once*.

Note.—Danger from minor injuries arises from blood poisoning which is caused when microbes infect a wound. The majority of wounds are at first "clean," that is, they are not infected with microbes; such infection usually occurs later and comes from handkerchiefs or other materials applied to stop bleeding or to wipe away blood, and, in the case of eye injuries, from efforts to remove fixed particles, with unclean instruments. *It is better to leave a wound alone than to introduce microbes by improper treatment.* The congealing of blood is nature's way of closing wounds against infection, and should not be interfered with.

Burns and scalds, when the skin is not broken, will heal if left alone; all that is necessary is rest and a protective covering. When blisters form they must not be pricked, except under medical advice.

Rest is an important aid to healing. A short rest at first allows healing to commence and often saves a long rest later. An injured hand or finger can be rested in a sling, and an injured eye by a bandage, but an injured foot or toe can only be rested in bed.

NITROUS FUMES.³

1. Workmen are warned against breathing brown acid fumes.
2. Always put on the air helmet before repairing leaks or entering, or remaining in, a part of the room heavily charged with the fumes.
3. The fumes if breathed may cause shortness of breath some hours later and lead to serious illness.
4. If these symptoms develop at home send at once for a doctor, and meanwhile keep in the open air as much as possible.

¹ Solution No. 1:—Sodium bicarbonate, 15 grains; water, 1 ounce.

² Solution No. 2:—Eye Drops—Cocaine, 0.5 per cent; Hyd. Perchlor, 1 in 3,000 in castor oil.

³ This part is issued separately as a placard (Form 358).

5. If they develop at the works send at once for the doctor. Pending his arrival, the right treatment is to—

Make the patient lie down.

Keep him warm.

See that he has plenty of fresh air.

If he is blue in the face—

Administer oxygen; and

If he has not been sick, give a drink of 1 ounce of salt in 10 ounces of luke-warm water, and repeat the dose until he is sick.

6. Keep the air helmet handy and in good repair, as you never know when you may want it.

TNT POISONING.¹

If TNT enters into the system as fume or dust or through the bare skin it causes changes in the blood, of which the first obvious sign is blueness of the lips. Recovery from the symptoms, if taken in time and on temporary removal from contact with TNT, is quick and complete.

To avoid effects of TNT:—

1. Don't keep your head over pans or vats containing molten TNT; if there are hoods don't work under them.
2. Keep as much as you can to the windward side of the fumes.
3. Don't be afraid of plenty of ventilation in the shed.
4. Wear gloves without holes in them, and don't let TNT get inside them.
5. Wash the hands before meals and before going home; and dry them well.
6. Wear the special clothing provided, and don't work with the sleeves rolled up.
7. Change your working clothes before going home. On no account let TNT hang about you at home.
8. Don't commence work on an empty stomach. Milk is the best antidote.
9. A careful man who keeps off beer and spirits has little to fear from TNT.
10. Chewing tobacco carries TNT from the fingers into the mouth.
11. If there is dust a respirator would lessen the quantity breathed. Give it a trial.

APPENDIX.

The regulations which apply in factories where TNT is manufactured are printed on pp. 15 to 19. They were drawn up in 1908, and recent development in certain processes has led to modified application of Regulations 2-5 and 14 (c). Although TNT is not in the heading, it is included in Schedule A.

While the definition of "Employed" is limited to persons employed in any process mentioned in the schedules, it would be well to consider as included under this designation all mechanics, because they may be exposed at times to the poison in greater degrees than those merely working the process.

The following suggestions are offered as to Regulations 6-11:—

Regulations 6-9.—Periodic Medical Examination.

After each visit the appointed surgeon should state in writing in the health register the names of those (if any) whom he considers should be either:—

- (a) *suspended* as definitely suffering from TNT symptoms, necessitating absence from work until complete recovery, or
- (b) *transferred* temporarily to other work as a precautionary measure on account of equivocal signs.

¹ This part is issued separately as a placard (Form 359).

Regulation 10 (a).—Overall Suits.

If women are employed in superintending TNT plant, overalls, consisting of a short skirt reaching to the knees, and puttees would be appropriate.

Regulation 10 (c).—Cloak Room.

The best arrangement is to have cupboards (with wire front)—one for clothing put off during working hours and the other for the overall suits.

Regulation 10 (e).—Gloves.

Gloves of rubber, leather, chamois leather, or with linen back and leather facing have all been found serviceable. For the way in which they should be worn in relation to the overall, *see* p. 4.

Regulation 11.—Washing Accommodation.

Supply of warmed water from a jet or spray so that washing of hands is done under running water is, if it can be arranged, very satisfactory. Roller towels should be at least 15 square feet in area for every three persons employed, and renewed daily.

The soap supplied should be the ordinary yellow or other neutral kind.

Regulation 10 (b).—Meal Room or Canteen.

This subject has been fully dealt with in the memorandum on Industrial Canteens [Cd. 8133, 1915, price 1*d.*] issued by the Health of Munition Workers Committee.

The proper use of the above-mentioned appliances can only be secured by discipline and supervision. In particular, some one person should be made responsible for seeing to (1) cleanliness of lavatories and adequate supplies of water, soap, and towels, (2) proper provision and maintenance of overalls and gloves, and (3) cleanliness of meal room.

REGULATIONS, DATED DECEMBER 30, 1908, MADE BY THE SECRETARY OF STATE, FOR THE MANUFACTURE OF NITRO AND AMIDO DERIVATIVES OF BENZENE, AND THE MANUFACTURE OF EXPLOSIVES WITH USE OF DINITROBENZOL OR DINITROTOLUOL.

Whereas the manufacture of nitro and amido derivatives of benzene, and the manufacture of explosives with use of dinitrobenzol or dinitrotoluol. have been certified in pursuance of Section 79 of the Factory and Workshop Act, 1901, to be dangerous;

I hereby, in pursuance of the powers conferred on me by that Act, make the following regulations, and direct that they shall apply to all factories and workshops in which the said manufactures are carried on.

Provided that Regulations 1 (*a*), 2, 3, 4, and 14 (*c*) shall not apply to any process in the manufacture of explosives in which dinitrobenzol is not used.

Definitions.

“Employed” means employed in any process mentioned in the schedules.

“Surgeon” means the certifying factory surgeon of the district or a duly qualified medical practitioner appointed by written certificate of the Chief Inspector of Factories, which appointment shall be subject to such conditions as may be specified in that certificate.

"Suspension" means suspension by written certificate in the health register, signed by the surgeon, from employment in any process mentioned in the schedules.

Duties.

It shall be the duty of the occupier to observe Part I of these regulations.

It shall be the duty of all persons employed to observe Part II of these regulations.

Part I.—Duties of Occupiers.

1.—(a) Every vessel containing any substance named in Schedules A or B shall, if steam is passed into or around it, or if the temperature of the contents be at or above the temperature of boiling water, be covered in such a way that no steam or vapor shall be discharged into the open air at a less height than twenty feet above the heads of the workers.

(b) In every room in which fumes from any substance named in Schedules A or B are evolved in the process of manufacture and are not removed as above, adequate thorough ventilation shall be maintained by a fan or other efficient means.

2. No substance named in Schedule A shall be broken by hand in a crystallizing pan, nor shall any liquor containing it be agitated by hand, except by means of an implement at least 6 feet long.

3. No substance named in Schedule A shall be crushed, ground, or mixed in the crystalline condition, and no cartridge filling shall be done, except with an efficient exhaust draft so arranged as to carry away the dust as near as possible to the point of origin.

4. Cartridges shall not be filled by hand except by means of a suitable scoop.

5. Every drying stove shall be efficiently ventilated to the outside air in such manner that hot air from the stove shall not be drawn into any workroom.

No person shall be allowed to enter a stove to remove the contents until a free current of air has been passed through it.

6. A health register, containing the names of all persons employed, shall be kept in a form approved by the Chief Inspector of Factories.

7. No person shall be newly employed for more than a fortnight without a certificate of fitness granted after examination by the surgeon by signed entry in the health register.

8. Every person employed shall be examined by the surgeon once in each calendar month (or at such other intervals as may be prescribed in writing by the Chief Inspector of Factories) on a date of which due notice shall be given to all concerned.

9. The surgeon shall have power of suspension as regards all persons employed, and no person after suspension shall be employed without written sanction from the surgeon entered in the health register.

10. There shall be provided and maintained for the use of all persons employed—

(a) suitable overalls or suits of working clothes which shall be collected at the end of every day's work, and (in the case of overalls) washed or renewed at least once every week; and

(b) a suitable meal room, separate from any room in which a process mentioned in the schedules is carried on, unless the works are closed during meal hours; and

(c) a suitable cloakroom for clothing put off during working hours; and

(d) a suitable place, separate from the cloakroom and meal room, for the storage of the overalls;

For the use of all persons handling substances named in the schedules—

- (e) india-rubber gloves, which shall be collected, examined, and cleansed, at the close of the day's work and shall be repaired or renewed when defective, or other equivalent protection for the hands against contact;

For the use of all persons employed in processes mentioned in Schedule A—
(f) clogs or other suitable protective footwear.

11. There shall be provided and maintained in a cleanly state and in good repair for the use of all persons employed:—

A lavatory under cover, with a sufficient supply of clean towels, renewed daily, and of soap and nail brushes, and with either:—

(a) a trough with a smooth impervious surface, fitted with a waste pipe without plug, and of such length as to allow at least two feet for every five such persons, and having a constant supply of warm water from taps or jets above the trough at intervals of not more than two feet; or

(b) at least one lavatory basin for every five such persons, fitted with a waste pipe and plug or placed in a trough having a waste pipe and having either a constant supply of hot and cold water or warm water laid on, or (if a constant supply of heated water be not reasonably practicable) a constant supply of cold water laid on and a supply of hot water always at hand when required for use by persons employed;

For the use of all persons employed in processes mentioned in Schedules A and B—

(c) sufficient and suitable bath accommodation (douche or other) with hot and cold water laid on and a sufficient supply of soap and towels. Provided that the chief inspector may in any particular case approve of the use of public baths, if conveniently near, under the conditions (if any) named in such approval.

12. No person shall be allowed to introduce, keep, prepare, or partake of any food, drink, or tobacco in any room in which a process mentioned in the schedules is carried on.

Part II.—Duties of Persons Employed.

13. Every person employed shall:—

- (a) present himself at the appointed time for examination by the surgeon as provided in Regulation 8;
- (b) wear the overalls or suit of working clothes provided under Regulation 10 (a), and deposit them, and clothing put off during working hours, in the places provided under Regulation 10 (c) and (d);
- (c) use the protective appliances supplied in respect of any process in which he is engaged;
- (d) carefully clean the hands before partaking of any food or leaving the premises;
- (e) take a bath at least once a week, and when the materials mentioned in the schedules have been spilt on the clothing so as to wet the skin. Provided that (e) shall not apply to persons employed in processes mentioned in Schedule C, nor to persons exempted by signed entry of the surgeon in the health register.

14. No person employed shall—

- (a) after suspension, work in any process mentioned in the schedules without written sanction from the surgeon entered in the health register;
- (b) introduce, keep, prepare, or partake of any food, drink, or tobacco, in any room in which a process mentioned in the schedules is carried on;
- (c) break by hand in a crystallizing pan any substance named in Schedule A, or agitate any liquor containing it by hand, except by means of an implement at least 6 feet long;
- (d) interfere in any way, without the concurrence of the occupier or manager, with the means and appliances provided for the removal of the fumes and dust, and for the carrying out of these regulations.

H. J. GLADSTONE,

One of His Majesty's Principal Secretaries of State.

Home Office, Whitehall,

30th December, 1908.

Schedules.

A.—Processes in the manufacture of—

Dinitrobenzol.

Dinitrotoluol.

Trinitrotoluol.

Paranitrochlorbenzol.

B.—Processes in the manufacture of—

Anilin oil.

Anilin hydrochloride.

C.—Any process in the manufacture of explosives with use of dinitrobenzol or dinitrotoluol.

APPENDIX D.

TENTATIVE SAFETY STANDARDS OF THE STATE OF PENNSYLVANIA FOR THE MANUFACTURE OF NITRO AND AMIDO COMPOUNDS.

SECTION 1. *Buildings.*—The buildings in which nitro and amido compounds are manufactured or are regularly recovered in considerable quantities shall be properly ventilated.

Buildings in which twice or more nitrated compounds of benzol or of toluene or of phenol are manufactured shall be of fire-resisting material, or shall be separated from other buildings.

SEC. 2. *Platforms.*—It is recommended that platforms be so erected that there shall remain a free space at least equal in surface to a quarter of the floor space of the building. (It is recommended to leave between platforms and the outer walls either a free space or a space covered by slats $\frac{1}{2}$ to 1 meter wide, and the area of this space is to be added to the free space in calculating the latter.)

The distance of the larger platforms from the floor and from each other shall be 10 feet, as far as possible and practical. For smaller platforms a smaller distance is permitted, provided that it does not interfere with the ventilation of the building.

On top of melting kettles and distilling apparatus, such platforms only shall be built as are absolutely necessary for the proper handling of the apparatus, and care should be taken that all apparatus be so constructed that vapors and gases can not escape and thereby injure those obliged by reason of their duties to be upon said platforms.

Platforms on which work is regularly carried on with nitro and amido compounds shall be light and easy to clean—covered with sheet lead where advisable.

Platforms shall be equipped with railings and toe boards in accordance with the safety standards on these subjects of the industrial board of this Commonwealth.

SEC. 3. *Floors.*—The floor of the workroom and the storage room shall be nonabsorbent, smooth and easy to clean. Where necessary wooden or cement floors are permissible.

SEC. 4. *Walls.*—The walls of the workroom shall be kept clean. If painted with calcimine they shall be repainted at least once a year. Windows which can be opened shall be provided on at least two sides.

SEC. 5. *Roof.*—If necessary the roof shall have a sufficient number of ventilators or other appliances which allow sufficient ventilation of the workroom and which can be kept open, even if it rains. Windows or skylights shall be so constructed that they can be operated from the floor or platform. Skylights in the roof shall be constructed of wire glass.

SEC. 6. *Manufacture.*—The work in the above factories shall be regulated in such manner that the men do not come in direct physical contact with nitro and amido compounds. It is therefore recommended, when practicable, that liquid nitro and amido compounds be transported through closed pipe lines either by pumping, blowing, suction or by gravity.

As a general rule gravity or suction is to be preferred because in the use of compressed air fine parts of the compounds go off with the air. It is also necessary that spent compressed air be vented outside. If, in the latter case, this is obnoxious to the neighborhood, it is suggested that the spent air shall be purified before being expelled. The same refers to the air which is expelled from vacuum pumps of distilling apparatus, as it frequently contains small quantities of anilin, etc.

Liquid nitro and amido compounds shall be kept and stored only in covered vessels. Wherever the above nitro and amido compounds are handled in such a manner that dust, gases, or vapors are generated, especially in powdering, sifting, and packing operations, the work shall be carried on as far as practicable in covered or closed apparatus. The vapors from receivers of distillates shall be excluded from work buildings.

Chiseling out of solid nitro and amido compounds, which are explosive, is strictly forbidden; and, when poisonous, is permitted only if proper precautions are taken.

Drying should be done in separate buildings used for drying only, or in properly constructed apparatus.

Frequently drying can be avoided by melting the nitro and amido compounds and breaking them up when cold.

Where boilers are fed with water containing anilin, the boiler shall be fitted with suitable safety valves and water glasses which absolutely prevent the entering of steam or water containing anilin into the workroom.

When in the judgment of the commissioner of labor and industry, or his authorized representative, it is deemed necessary, all apparatus and machinery in which nitro and amido compounds are manufactured, transported, treated, distilled, centrifuged, filtered, dried, ground, mixed, etc., packed, or filled shall be fitted with a reliable attachment, which removes such dust, gases, or vapors which may be generated.

Special care should be taken so that all vapors which are generated in the opening, discharging, and filling of dry rooms, melting kettles, autoclaves, and other pressure vessels will be harmlessly disposed of, when in the judgment of the commissioner of labor and industry or his authorized representative it is deemed necessary to do so.

SEC. 7. *Cleanliness.*—The workroom shall be kept as free from nitro and amido compounds as possible. If any of the above compounds are spilled, they shall be removed as soon as possible. The floor shall be cleaned at least once every 24 hours.

SEC. 8. *Health precautions.*—The employer shall inform the workmen employed in the manufacture, etc., of the above nitro and amido compounds as to the poisonous quality of these products and the necessity of strictly observing the following precautions:

Shirts, overalls, caps, stockings, shoes, gloves, and other wearing apparel which have become saturated with poisonous nitro or amido compounds in such manner that the skin comes in immediate contact with them shall be immediately taken off, the skin washed first with vinegar and then with water, and the employee must then put on clothing which has not been in contact with these substances.

Employees shall be warned that the use of alcoholic liquors and chewing tobacco is harmful to their health. Smoking in the workroom is strictly forbidden.

Food shall be neither kept nor eaten in the workroom. A suitable dining room, absolutely separate from the workroom, where necessary, shall be provided. Employees shall not be allowed to enter this room until they have washed both face and hands. For this purpose wash and dressing rooms and bathrooms, absolutely separate from the workroom, shall be provided. These rooms shall be suitably fitted up, kept clean, and properly heated. Nobody shall be allowed to keep any wearing apparel in the workroom. All process men shall dress in the dressing or wash room provided. Each process man shall be provided with two lockers, one for his working and one for his street clothing, or a properly divided double locker, or such other method for storing clothing as shall be approved by the commissioner of labor and industry or his authorized representative. An approved number of washing appliances shall be provided. Soap and towels shall be furnished in suitable number and free of charge.

It is recommended that every working man who comes in contact with the above nitro and amido compounds shall take a bath daily before he leaves the factory.

Men who suffer from inflammation of the bladder should not be employed in the above factories.

Men who are addicted to the use of alcoholic liquors must not be employed, and no employee upon whom the odor of alcoholic liquor is detected shall be allowed to enter the factory.

It is recommended that process men be between the ages of 22 and 50 years. It is also recommended that applicants for employment presenting evidences of anemia or of emaciation should not be employed as process men by reason of their increased susceptibility.

The employment of females except in the office, or works hospital, or welfare room or building is prohibited.

Toilets shall be provided in accordance with the sanitary code of the industrial board of this Commonwealth.

The employer shall provide and maintain a sufficient number of sanitary drinking fountains, readily accessible, for the use of all employees.

All process men should be cautioned of the danger of commencing work on an empty stomach.

It is recommended that those who suffer from excessive perspiration should not be employed as process men.

Bodily cleanliness is essential to good health. It is recommended that those employees who do not take frequent baths be not employed as process men.

Process men are those employees whose work brings them in immediate contact with nitro and amido compounds, either in the manufacture of those compounds or in the repair of apparatus used in their manufacture. The term does not include employees whose duty is in the power plants, nor other employees whose work does not bring them in such contact.

SEC. 9. *Repairs.*—All repairs and changes on the machinery, apparatus, and pipes for nitro and amido compounds shall be made only after they have been thoroughly cleaned.

All work in the inside of apparatus, vessels, boilers, etc., shall be done in accordance with the following rules of procedure:

If it is necessary for an employee to enter any vats, tanks, or other containers in which there have been used, stored, or manufactured gases, fumes,

or vapors of an asphyxiating or poisonous nature, or materials which give off gases, fumes, or vapors of an asphyxiating or poisonous nature, the following procedure shall be pursued:

(a) *Empty containers.*—Disconnect and blank off all connections.

(b) Clean containers thoroughly by repeated washings with water, soda water, steam, compressed air, or other suitable means.

(c) If the person in charge then considers conditions satisfactory, employees may enter such containers. They must use an approved type of helmet and have attached to their bodies a life line or rope if the person in charge considers it necessary.

(d) The life line or rope shall be under the control of one or more fellow workmen who shall remain outside of the container in order that they may render assistance if necessary.

(e) After the work is finished the men should take, at once, a bath and change their clothing, including shoes, if the foreman or other person in charge shall deem it necessary. Facilities for taking such baths shall be provided.

The superintendent of the plant shall be held responsible for the enforcement of these regulations.

A copy of the rules for procedure as given above will be furnished by the department of labor and industry, and shall be conspicuously posted at every place in each plant where asphyxiating or poisonous fumes, gases, or vapors may be found.

SEC. 10. *Resuscitation.*—For every fifty (50) process men or less employed in such plant and exposed to such risk there shall be present at all times at least two persons who are trained or competent to apply means of resuscitation by the prone pressure or Schaeffer method or by mechanical devices approved by the industrial board of this Commonwealth.

A sufficient number of helmets of a type approved by the industrial board of this Commonwealth shall be kept at each plant, in order that they may be available for use by every employee who has occasion to enter places where there may be asphyxiating or poisonous gases, fumes, or vapors.

All employees who are required by the employer to wear helmets in making repairs or in maintenance work shall be thoroughly instructed in the use of such apparatus and be physically examined by a licensed physician at least once in ninety days or after absence from work due to either sickness or accident and the physician shall certify to the proper physical condition of the men so employed and no employee shall be permitted to do such repair work unless so examined and certified. The examining physician shall report the results of these examinations, within 48 hours after each examination, to the commissioner of labor and industry of this Commonwealth, upon blanks which will be furnished upon request.

Oxygen inhalation apparatus shall be kept on hand and the foremen and authorized employees shall be instructed in its use. In all cases in which the apparatus has been used a physician shall at once be called or the sick employee removed to a hospital. A supply of oxygen or the means for its production must be kept on hand.

If oxygen tanks are used at least two must be kept on hand at all times, one of which shall be full.

SEC. 11. *Physical examination.*—All applicants for employment as process men shall be physically examined by a licensed physician either before commencing work or before the expiration of 24 hours after their employment.

All process men shall be physically reexamined by a licensed physician at least once in every 30 days and before resuming work after an absence due to sickness or to accident or to any other cause.

These examinations shall each consist in the determination and recording of the following facts, either in a book or upon a card:

Name _____; Age _____
 Address _____; Process _____
 Height _____; Weight _____
 Pulse _____; Blood pressure _____; Haemoglobin _____
 Examination of urine—Reaction _____; Specific gravity _____
 Albumen _____; Sugar _____; Casts _____

The records of these examinations shall at all times be open for inspection by the commissioner of labor and industry of this Commonwealth or his authorized representative.

The examining physician shall report the results of these examinations to the commissioner of labor and industry of this Commonwealth within 48 hours after such examinations, upon blanks which will be furnished upon request.

It shall be the duty of the examining physician to request the factory manager or superintendent to suspend from work any process man whom he believes to be suffering from poisoning, and it shall be his further duty to report such case to the department of labor and industry of this Commonwealth upon the following blank:

<p>COMMONWEALTH OF PENNSYLVANIA.</p> <p>DEPARTMENT OF LABOR AND INDUSTRY</p> <p>DIVISION OF INDUSTRIAL HYGIENE AND ENGINEERING.</p> <p><i>Report of Case of Occupational Disease</i></p>	<p>Please mail this report in all cases of either suspected or diagnosed industrial disease to Dr. Francis D. Patterson, Chief of Division of Industrial Hygiene and Engineering, Department of Labor and Industry, 511 Kunkel Building, Harrisburg, Pa., who will furnish additional copies of this blank upon request.</p>												
<p>Name of Patient Address, Street and Number City or village County</p>													
<p>Sex..... Age.... Color..... Nativity..... S. M. W. D. Number of dependents.....</p> <p style="text-align: center;">OCCUPATION.</p> <p>A. Present trade, profession or work..... B. Exact occupation in this trade..... C. Date of entering this trade..... D. Date of commencing this work..... E. Previous occupations.....</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="width: 60%;">Name of occupation.</th> <th style="width: 20%;">Entered.</th> <th style="width: 20%;">Left.</th> </tr> </thead> <tbody> <tr> <td>1.</td> <td>.....</td> <td>.....</td> </tr> <tr> <td>2.</td> <td>.....</td> <td>.....</td> </tr> <tr> <td>3.</td> <td>.....</td> <td>.....</td> </tr> </tbody> </table> <p>F. Previous illness, if any, due to occupation.... 1. 2. 3.</p> <p>G. Employer's name..... H. Employer's address, street and number..... City or village..... I. Employer's business.....</p>	Name of occupation.	Entered.	Left.	1.	2.	3.	<p>A. Diagnosis of present illness..... B. Chief symptoms..... C. Date first symptoms appeared..... D. Complicating diseases..... E. Additional facts..... F. Date of diagnosis..... G. Date of this report.....</p> <p style="text-align: right; margin-top: 20px;">Signed M. D. Address, Street and number..... City or village.....</p>
Name of occupation.	Entered.	Left.											
1.											
2.											
3.											

It shall be the duty of the employer to provide, without expense to the employee, a hospital room or dispensary, separate and apart from the workroom or rooms, which room shall be equipped with a couch, bed, or surgical table,

two pairs of woolen blankets, two hot-water bottles, two tanks (one completely full) of oxygen and the necessary apparatus for administering the same, an oxygen helmet for rescue work, such device or devices for artificial respiration as are approved by the approvals committee of the industrial board of this Commonwealth, and a shower bath with hot and cold water, and a toilet, which toilet shall comply with the sanitary code of the industrial board of this Commonwealth.

At least one stretcher shall be provided.

It shall be the further duty of all employers to keep in a book or on a card a record of all employees, showing their exact employment and all changes to other work, which record shall at all times be open for inspection by the commissioner of labor and industry of this Commonwealth or his authorized representative.

TRINITROTOLUOL.

SEC. 12. *Scope.*—Beyond the regular regulations for the erection and conducting of factories in which poisonous nitro and amido compounds are manufactured or regularly recovered in considerable quantities, the following additional regulations shall govern the manufacture of trinitrotoluol and ammunition from it.

SEC. 13. *Buildings.*—Trinitrotoluol shall be manufactured in a special plant which is an approved distance from other factories or portions of factories.

Buildings in which twice or more nitrated compounds of benzol or twice or more nitrated compounds of toluol are manufactured shall be of fire-resisting material or shall be separated from other buildings.

Trinitrotoluol factories which are not on the land of an explosives factory shall be surrounded by a fence which prevents the entering of outsiders. At the gates proper signs shall be provided which prohibit the entrance of unauthorized outsiders. Smoking upon the premises shall be prohibited.

SEC. 14. *Nitration.*—Nitration shall be performed in high, airy rooms, allowing easy escape of vapors, and in which no nitrated product is stored or handled in a dry condition. There shall be an approved number of easily accessible exits.

SEC. 15. *Storage of acids.*—The storage of spent acids is best done in tanks standing in the open air and only roofed over.

SEC. 16. *Washing and centrifuging.*—All washing and centrifuging operations shall be performed in a building in which no nitrated product is stored. Ample ventilation shall be provided.

SEC. 17. *Recrystallization.*—The recrystallizing of the crude trinitrotoluol with easily inflammable solvents, such as alcohol, benzol, or toluol, shall take place in a building standing alone. All solution tubs, crystallizing vessels, centrifuges, and conveying apparatus shall be closed in such manner that vapors in dangerous quantities can not escape into the workroom. Proper ventilation of the workroom shall be provided. All platforms in this building shall have an exit into the open air.

SEC. 18. *Drying.*—The drying of the trinitrotoluol shall be carried on in a building standing alone. The separation of the pure trinitrotoluol from the solvent may be done in the building for the recrystallizing if the apparatus provided avoids accumulation.

SEC. 19. *Packing.*—All packing shall be done in separate packing houses.

SEC. 20. *Storage.*—Trinitrotoluol shall be stored in separate stock rooms, protected by an approved type of barricade. The location of the stock rooms from the nearest manufacturing building shall be at an approved distance.

SEC. 21. *Storage of inflammable solvents.*—The storage tanks of inflammable solvents or of toluol shall be constructed in such a manner that the contents of

the tanks, in case of leakage, can not run over the surroundings. Wherever practicable, storage vessels should be below ground. If the above solvents are stored above ground, they shall be stored in an approved manner. Storage in open air in iron drums in a suitable place is permissible.

Earth embankments of sufficient height to hold the contents of tanks in case of leakage shall be placed around all tanks of inflammable materials when such tanks are located above ground.

SEC. 22. *Manufacture of ammunition.*—The manufacture of ammunition from trinitrotoluol shall be conducted in a separate building or plant. For the storage of the ammunition the same regulations govern as for the storage of the trinitrotoluol.

SEC. 23. *Doors.*—All doors which lead into the open air shall open outward.

SEC. 24. *Nitrating apparatus.*—All nitrating vessels shall have reliable appliances for stirring and for the regulation of the temperature as well as ventilating apparatus for the removal of the vapor.

SEC. 25. *Drying apparatus.*—If the drying is done on small drying hand trays the heating elements shall be arranged in such a manner that the material to be dried or the dust can not come in direct contact with them. The temperature in the drying chambers shall not exceed 60° C. All drying apparatus shall be constructed in such manner that the gases can escape easily without dangerous pressure, if the trinitrotoluol should ignite.

If the drying is done in large drying pans, hot water or low-pressure steam at not over 20 pounds pressure per square inch shall be employed for heating. The contents shall be kept in constant motion and the apparatus shall be constructed so as to prevent the escape of vapors into the workroom.

SEC. 26. *Dust.*—The drying and shifting apparatus shall be so constructed as to prevent as far as practical the escape of dust. All walls, floors, radiators, electric bulbs, etc., shall be kept free from the accumulation of trinitrotoluol dust. All employees shall be provided with respirators, cloths, or sponges for their protection against dust, without cost.

SEC. 27. *Fire prevention.*—In rooms in which there are easily inflammable solvents or dried TNT (trinitrotoluol), electric motors, electric bells, or other sparking apparatus shall not be employed. Centrifugals shall not have a brake nor shall it be allowed to brake them in any manner. Oily waste shall be kept outside the workroom in safety cans which shall be cleaned frequently. In all drying, breaking, and sifting operations the friction of iron against iron shall not be permitted.

SEC. 28. *Refuse.*—Impure trinitrotoluol shall be refined and purified before being used. All refuse from the nitration or recrystallizing rooms which is still useful shall be removed from the above rooms and shall be kept in a special room until it is refined. It shall not be permissible to bury any refuse which contains trinitrotoluol. Such refuse shall be placed in containers and shall be destroyed from time to time under the supervision of an experienced foreman.

SEC. 29. *Repairs.*—Repairs on apparatus and other tools which have been in contact with trinitrotoluol are permissible only after they have been thoroughly cleaned. The remelting of old vessels, lead pipe, etc., is permissible only after they have been burned off on an open fire. All other vessels, etc., which have become useless shall be treated in the same manner or shall be destroyed by explosion.

SEC. 30. *Nitric acid.*—In view of the danger to the worker from inhalation of nitrous fumes in case of fire or of the breakage of carboys, carboys containing nitric acid shall be stored in detached sheds with sandstone, brick, or other suitable flooring, and in quantities not to exceed 100 carboys placed in

not more than four rows. Nitric acid in carboys may be stored in the open in unlimited quantities.

The following notice will be supplied by the department of labor and industry on application and shall be posted at all places in plants where there is danger of poisoning by acid fumes:

ACID FUMES.

WARNING.

The Inhalation of Dense Acid Fumes May Cause Death.

Employees are strictly prohibited from entering buildings where dense acid fumes exist, or tanks or confined spaces which are not entirely clear of acid fumes, unless they wear a helmet.

Employees working in such places shall, in addition to the helmet, wear a life line which is at all times in the hands of an assistant stationed outside of the tank.

Employees who have been exposed to acid fumes and who feel weak, sick, short of breath, or who are attacked with cramps or coughing shall report this condition to their foreman, or to the works dispensary, or hospital at once so that proper treatment can be given. Don't wait to get home. Delay may be fatal. Take no chances.

Responsibility for complying with these regulations shall rest with the foreman or other person designated for that purpose by the management of the plant.

Failure to comply with these regulations may subject the offender to a penalty of a fine or imprisonment.

JOHN PRICE JACKSON,
*Commissioner, Department of Labor and Industry,
Commonwealth of Pennsylvania.*

Water shall be always available for use in case of evolution of nitrous fumes caused by breakage or other accident to carboys, and all workers handling such acid shall be warned against sprinkling sand, sawdust, earth, or anything other than water or alkalies upon any spilled nitric acid.

At all places where there is danger of an employee becoming burned by contact with acid there shall be a shower bath.

Sec. 31. *Avoidance of accumulations.*—No more trinitrotoluol shall be kept in the workroom than is necessary for concurrent use.

CHEMICALS.

Sec. 32. *Scope.*—The handling and storage of all acids and other chemicals necessary for the operation of plants not herein provided for shall be governed by the regulations as set forth in the code governing the operation of chemical works.

Sec. 33. *Heating.*—The workrooms, when desirable, shall be heated by an approved system of steam, indirect hot air radiation, or hot water. The temperature of the steam shall not exceed 120° C. The radiators shall be at least 1 inch distant from all wooden walls or other inflammable material and shall be attached in such a manner that they can be easily inspected and cleaned.

INDEX.

	Page.
Acetone, physiological action of.....	53
Acid burns, treatment of, in TNT manufacture.....	124, 125
Acid recovery (sulphuric and nitric acids).....	62
Acids, mixed, physiological action of.....	24
Alcohol and ether, physiological action of.....	54-57
Alcohol, influence of, on poisoning from volatile compounds.....	57-59
Amatol, use of, in filling shells.....	88
Amido derivatives of the benzene series. (See Nitro and amido derivatives of the benzene series.)	
Ammonal, use of, in filling shells.....	88
Ammonia gas, physiological action of.....	52
Ammonium nitrate, manufacture of.....	92
Ammonium nitrate, physiological action of.....	52, 53
Amyl acetate, physiological action of.....	53
Anilin, manufacture of.....	88, 89
Anilin, physiological action of.....	46, 47
Benzene derivatives, manufacture of, rules and regulations suggested by Massachusetts State Board of Labor and Industries.....	116-120
Benzene series. (See Nitro and amido derivatives of benzene series.)	
Benzol, physiological action of.....	25-27
Benzol, typical cases of poisoning by.....	26, 27, 78
Carbolic acid. (See Phenol, or carbolic acid, physiological action of.)	
Chlorine gas, physiological action of.....	53, 54
Dermatitis, treatment of cases of.....	101, 102
Dimethylanilin, physiological action of.....	47
Dinitrochlorbenzol. (See Nitrochlorbenzol, physiological action of.)	
Diphenylamin, manufacture of.....	90
Diphenylamin, physiological action of.....	47
Displacement process of nitration, in manufacture of nitrocellulose. (See Nitrocellulose, manufacture of.)	
Distribution of explosive manufacturing industry.....	9
Dust, prevention of, in manufacture of explosives.....	94-97
Employees, character of, in manufacture of explosives.....	10
Ether, physiological action of. (See Alcohol and ether, physiological action of.)	
Ether, typical cases of poisoning by.....	55, 56
Ethyl nitrite, physiological action of.....	5, 52
Explosives, list of, in which poisonous substances are used.....	8, 9
Explosives, manufacture of:	
Amount of industrial poison discovered in the inquiry.....	11-13
Character of employees engaged in.....	10
Description of the industry.....	8, 9
Distribution of the industry.....	9
Hours of work.....	11
Influence of alcohol on poisoning from volatile compounds.....	57-59
Poisons, manufacture of, used in.....	59-92
Poisons, physiological action of.....	14-57
Prevention of industrial poisoning in.....	92-97
Rules and regulations suggested by Massachusetts State Board of Labor and Industries.....	116-120
Safety standards of industrial board of Pennsylvania Department of Labor and Industry.....	103-115
Treatment of cases of industrial poisoning in.....	99-102
Wages and housing.....	10, 11
Eye injuries, treatment of, in TNT manufacture.....	125
First aid, instructions, TNT manufacture.....	124, 125
Fulminate of mercury:	
Manufacture of.....	90-92
Physiological action of.....	50, 51
Treatment of cases of poisoning by.....	102
Fume poisoning, number of cases in certain plants.....	73
"Fume sickness"—nitrogen-oxide poisoning, physiological action of.....	14-23
Fumes, prevention of, in manufacture of explosives.....	92-94
Fumes, treatment of cases of poisoning by.....	99-101
Gassing, treatment of, in TNT manufacture.....	123
Great Britain, home office, factory department, precautionary measures in TNT manufacture.....	121-130
Guncotton, manufacture of (nitrocellulose).....	62-70
Guncotton, military, manufacture of.....	70-72
Hours of work in manufacture of explosives.....	10, 11
Housing and wages in manufacture of explosives.....	10, 11
Industrial poisoning:	
Amount of, discovered in manufacture of explosives.....	11-13
Prevention of, in manufacture of explosives.....	92-97

	Page.
Industrial poisoning—Continued.	
Treatment of cases of	99-102
Dermatitis	101, 102
Fulminate of mercury	102
Nitro and amido compounds	100, 101
Nitrous fumes	99
Picric acid	102
Tetryl dermatitis	102
Trinitrotoluol	101
Massachusetts State Board of Labor and Industries, rules and regulations suggested by, for safety, etc.	116-120
Medical care, necessity for, in prevention of industrial poisoning	96
Mercury, fulminate of, manufacture of	90-92
Mercury, fulminate of, treatment of cases of poisoning by	102
Mercury, physiological action of	50
Methyl benzol. (See Benzol and toluol, or methyl, benzol, physiological action of.)	
Mixed acids, physiological action of	24
Naphthalene, manufacture of. (See Nitronaphthalenes, manufacture of.)	
Naphthalene, physiological action of. (See Nitronaphthalenes, physiological action of.)	
Nationality of employees engaged in manufacture of explosives	10
Nitration, in manufacture of nitrocellulose. (See Nitrocellulose, manufacture of.)	
Nitration, physiological action of	14
Nitric acid:	
Manufacture of	59, 60
Physiological action of	23, 24
Recovery of	62
Nitro and amido compounds, tentative safety standards for manufacture of, State of Pennsylvania	131-138
Nitro and amido compounds, treatment of cases of poisoning by	100, 101
Nitro and amido derivatives of the benzene series, physiological action of	29-48
Anilin	46, 47
Dimethylanilin	47
Diphenylamin	47
Nitrobenzol	45, 46
Nitrochlorbenzol and dinitrochlorbenzol	46
Nitronaphthalenes	45
Picric acid	33-35
Tetranitranilin	47, 48
Tetranitromethylanilin, or tetryl	35-48
Trinitrotoluol, or toluol, or triton, or trotyl, or TNT	35-45
Nitrobenzol and anilin, manufacture of	88, 89
Nitrobenzol, physiological action of	45, 46
Nitrocellulose, manufacture of (guncotton)	62-70
Centrifugal or mechanical nitration	63-66
Displacement process	69, 70
Pot nitration or direct dipping	66-69
Nitrochlorbenzol and dinitrochlorbenzol, physiological action of	46
Nitrogen oxide poisoning—"Fume sickness," physiological action of	14-23
Nitrogen oxide, typical cases of poisoning by	18-23
Nitroglycerin, manufacture of	79, 80
Nitroglycerin, physiological action of	48-50
Nitronaphthalenes, manufacture of	88
Nitronaphthalenes, physiological action of	45
Nitrous fumes poisoning, treatment of cases of	99, 100
Nitrous fumes, treatment of poisoning by, TNT manufacture	125, 126
Nobel's process in manufacture of nitroglycerin	79, 80
Oil of murbane. (See Nitrobenzol, physiological action of.)	
Oxygen cylinder, use of, in TNT manufacture	124
Pennsylvania, department of labor and industry, industrial board, safety standards	103-115
Percussion caps, use of fulminate of mercury in manufacture of	91, 92
Phenol, manufacture of	76-79
Phenol or carbolic acid, physiological action of	27-29
Phenol or carbolic acid, typical cases of poisoning by	28, 29
Physiological action of poisons. (See Poisons, physiological action of.)	
Picric acid:	
Manufacture of	72-76
Physiological action of	33-35
Treatment of cases of poisoning by	102
Typical cases of poisoning by	34
Poisoning, industrial:	
Amount of, discovered in manufacture of explosives	11-13
Prevention of, in manufacture of explosives	92-97
Prevention of, records of three model plants	97, 98
Treatment of cases of, in manufacture of explosives	99-102
Typical cases of—	
Benzol	26, 27, 78
Ether	55, 56
Nitrogen oxide—"Fume sickness"	18-23
Phenol or carbolic acid	28, 29
Picric acid	34
Trinitrotoluol	36-41
Poisons, manufacture of	59-92
Acid recovery (sulphuric and nitric acids)	62
Ammonium nitrate	92
Anilin	88, 89
Diphenylamin	90
Fulminate of mercury	90-92

	Page.
Poisons, manufacture of—Continued.	
Guncotton (nitrocellulose)	62-70
Nitric acid	59, 60
Nitrobenzol and anilin	88, 89
Nitrocellulose (guncotton)	62-70
Nitroglycerin	79, 80
Nitronaphthalenes	76-79
Phenol	72-76
Picric acid	70-72
Smokeless powder and military guncotton	61, 62
Sulphuric acid	89, 90
Tetryl	80-84
Trinitrotoluol	14-57
Poisons, physiological action of	
Acetone	53
Alcohol and ether	54-57
Ammonia gas	52
Ammonium nitrate	52, 53
Amyl acetate	53
Anilin	46, 47
Benzene series. (<i>See Nitro and amido derivatives of the Benzene series.</i>)	
Benzol and toluol or methyl benzol	25-27
Chlorine gas	53, 54
Dimethylanilin	47
Diphenylamin	47
Ether	54-57
Ethyl nitrite	52
Fulminate of mercury	50, 51
Mercury	50
Mixed acids	24
Nitration	14
Nitric acid	23, 24
Nitro and amido derivatives of the Benzene series	25-28
Nitrobenzol	43, 46
Nitrochlorbenzol and dinitrochlorbenzol	44, 46
Nitrogen oxide—"Fume sickness"	14-23
Nitroglycerin	48-50
Nitronaphthalenes	45
Phenol, or carbolic acid	27-29
Picric acid	33-35
Sulphuric acid fumes (sulphur dioxide)	24
Tetranitranilin	47, 48
Tetranitromethylanilin, or tetryl	47, 48
Trinitrotoluol, or toluol, or triton, or trotyl, or TNT	35-45
Pot nitration or direct dipping in manufacture of nitrocellulose. (<i>See Nitrocellulose, manufacture of.</i>)	
Powder, smokeless, manufacture of	70-72
Precautionary measures in TNT manufacture, Great Britain	121-130
Prevention of industrial poisoning in manufacture of explosives	92-97
Pyroxylin, manufacture of. (<i>See Smokeless powder, etc.</i>)	
Respirators, use of, in prevention of industrial poisoning	94
Safety in manufacture of benzene derivatives and explosives. (<i>See Massachusetts, State Board of Labor and Industries, etc.</i>)	
Safety standards of industrial board of Pennsylvania Department of Labor and Industry	103-115
Safety standards, tentative, for manufacture of ami nitro and amido copounds, State of Pennsylvania	131-138
Shells, filling with trinitrotoluol	84-88
Smokeless powder and military guncotton, manufacture of	70-72
States in which explosives are manufactured	9
Sulphuric acid fumes (sulphur dioxide), physiological action of	24
Sulphuric acid, manufacture of	61, 62
Sulphuric acid, recovery of	62
Tetranitranilin, physiological action of	47, 48
Tetranitromethylanilin or tetryl, physiological action of	48
Tetryl dermatitis, treatment of cases of	102
Tetryl, manufacture of	89, 90
Tetryl poisoning. (<i>See Tetranitromethylanilin, physiological action of.</i>)	
TNA poisoning. (<i>See tetranitranilin, physiological action of.</i>)	
TNT. (<i>See Trinitrotoluol.</i>)	
Toluol. (<i>See Benzol; also trinitrotoluol, physiological action of.</i>)	
Treatment of cases of industrial poisoning	99-102
Trinitrotoluol:	
Filling shells with	84-88
Manufacture of	80-84
Physiological action of	35-45
Precautionary measures in manufacture of	121-130
Safety standards for manufacture of, Pennsylvania	136-138
Treatment of cases of poisoning by	101
Typical cases of poisoning by	36-41
Triton. (<i>See Trinitrotoluol.</i>)	
Trotyl. (<i>See Trinitrotoluol.</i>)	
Volatile compounds, poisoning from, influence of alcohol on	57-59
Wages and housing in manufacture of explosives	10, 11
Washing facilities, use of, in prevention of industrial poisoning	95
Women and girls, employment of, in filling shells with trinitrotoluol	85