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INDUSTRIAL POISONS USED IN THE RUBBER INDUSTRY.

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INTRODUCTION.

The processes of rubber manufacture in the United States are many and various and there is great difference in the extent to which the men and women employed in the different branches are exposed to the danger of poisonous dusts and of poisonous fumes. It is impossible to make general statements about the dangers in the rubber industry, since what would be true of the manufacture of footwear would not hold at all for the manufacture of rubber toys and balloons, nor of hard-rubber syringes and fountain pens, nor of tires. Not only are there great differences in the processes, due to the different kinds of goods made, but there are differences which depend upon the theories of the manufacturer and the quality of the goods. For instance, the making of rubber clothing may be attended with a great deal of risk to health if the goods are made by spreading and are then vapor cured, but if they are made by frictioning and calendering and then heat cured, there need be no danger to health at all. Nipples for nursing bottles may be dipped and acid cured, both of which are dangerous processes, or they may be made by the safer methods of cementing and heat curing.

The making of rubber is still in an experimental stage. New substances are continually being tried out and adopted or rejected, and there is wide difference of opinion even among rubber chemists as to the value of different methods of compounding and curing. In this report no comment is made upon the advantages or disadvantages of any method, its hygienic significance only being considered. The processes in rubber manufacture which are here described are those in which substances more or less poisonous are handled, and in describing any given procedure its effect upon the workman only is considered, not at all its effect upon the product. Nor has any attempt been made to study the effect of physical conditions in the rubber industry, such as the dampness in the washing rooms, the heat of the vulcanizers, the contamination of the air by starch or soapstone dust, or the fatigue induced by speeding up and by the great physical exertion required, especially in certain parts of tire building, or the mechanical injuries which follow certain processes, such as holding rubber footwear firmly pressed against the stomach for hours during the day. Each of these undoubtedly has its effect upon the health of the rubber workers, but the effect is slow and insidious and difficult to trace with certainty to the source. This study has been confined to the use of poisonous substances and their effects upon the workmen. It has not been easy to secure the information desired, since the nature of the chemicals used in rubber compounding and reclaiming is carefully guarded as a valuable trade secret, while occupational disease among rubber workers often comes to the notice of the company doctor only and he regards it as a duty to his employers to keep such occurrences secret.

NUMBER, LOCATION, AND PRODUCTS OF PLANTS STUDIED.

The report is based upon the investigation of 35 factories in the following cities: Boston, Mass., including three suburbs; Hudson, Mass.; Providence, R. I.; New Haven and Naugatuck, Conn.; Tuckahoe, N. Y.; Trenton and Lambertville, N. J.; Akron, Ashland, Cleveland, and Youngstown, Ohio; Detroit, Mich.; Mishawaka, Ind.; and Chicago, Ill. The goods produced in these factories come under the following general classes: Footwear; rubber clothing; toys, including balls and balloons, and bathing caps; druggists' sundries, including gloves, rubber tubing, catheters, hot-water bags, fountain syringes, rubber dam, sheeting, nipples for bottles; mechanical rubber, including hose, cables, belting, gaskets, buffers, navy sheets, plumber supplies, insulating apparatus; rubber tires; leather pads for horseshoes; hard rubber, including syringe nozzles and other medical supplies, electrical supplies, thermometers, combs, and fountain pens. Reclaiming rubber from scrap is an important branch and may be carried on separately or in connection with rubber manufacture.

PROCESSES WHICH MAY BE DANGEROUS.

VULCANIZATION, INCLUDING COMPOUNDING AND MIXING.

In order to make rubber resistant to changes of temperature and to harden it and make it less adhesive, it must be subjected to a process known as vulcanization, which is essentially the incorporation of sulphur in rubber. By way of preparation for this come the processes of compounding and mixing. Compounding consists of the mixing together of various ingredients, usually metallic oxides and salts. Mixing is the process of incorporating these in the rubber, after which it is ready for vulcanizing. Several methods of vulcanization are in use. The most common is heat vulcanization, in which sulphur is mixed with crude rubber and dry heat or steam is applied with or without mechanical or gas pressure. This process is used very generally in the United States. Cold vulcanization, or "cold cure" or "acid cure," consists in treating rubber with monochloride of sulphur mixed with some solvent of rubber. This process is still employed in many American factories, although it is not used nearly as much as it is in Europe or as it formerly was here. What is called the "vapor cure" is vulcanization by means of sulphur monochloride in the form of vapor, either pure or more often in combination with a volatile solvent of rubber. This is less commonly used than the "cold cure." A fourth method, known as Hancock's, immersing rubber in a bath of molten sulphur, does not seem to be used in this country at all.

In heat vulcanization the heat may be applied in three different ways. In the first, the so-called "open-heat" method, dry hot air, usually heated by steam pipes, is used. Vulcanization by this method is very slow unless something is added to the compound to act as an accelerator; lead or lime salts are usually employed for this purpose. In the second method steam is used, vulcanization takes place rapidly, and it is not necessary to add anything to hasten the process, though lead salts are often used. In the third, the so-called "press-cure" method, heat and pressure are applied simultaneously in a steam-heated hydraulic press, the rubber being at once cured and molded. For this no accelerator is required, though here also lead or some other compounds may be added.

The compound of lead most often used, both in dry heat and in steam vulcanization, is litharge, one of the lower oxides of lead. Next in frequency comes sublimed lead, which is an oxysulphate. The basic carbonate is used much less often than these, and red lead still more rarely.

Another substance which is supposed to act as an accelerator of vulcanization is aniline oil. Its use is apparently increasing and by some rubber chemists it is regarded as a substitute for litharge.

For coloring the finer grades of red rubber, antimony pentasulphide is added, often in great quantities. These substances—litharge, sublimed lead, aniline oil, and antimony pentasulphide—are the poisonous substances used in compounding rubber which is to be vulcanized by heat. There are many other inorganic salts which enter into the composition of rubber, but so far as we know they are of no importance in this connection.

Rubber that is to be cold cured or vapor cured—that is, vulcanized by sulphur monochloride—does not require the addition of lead salts, nor, so far as learned in this investigation, is aniline a constituent of such rubber. The dangers here are not found in the compounding room but in the curing room. The substance essential for these methods of curing, the monochloride of sulphur, is a deep-yellow liquid, the commercial variety of which has a strong, unpleasantly sweetish odor easily recognizable by anyone who has once smelled it. The safest way of using it, namely, exposing the rubber to the pure unmixed vapor in a closed chamber, is also the least common. Much more usual is the treatment of rubber with a mixture of the monochloride and some solvent of rubber which will make it penetrate better. The least harmful of these solvents is benzol. The others, carbon tetrachloride and carbon disulphide, are decidedly poisonous, especially the last.

RUBBER-CEMENT MAKING.

Rubber cement is made by dissolving rubber in one of the petroleum products, naphtha, gasoline, or benzine, or in coal-tar benzol, or in carbon disulphide. The petroleum products are the ones commonly used in this country. Benzol, which is more expensive, is used only for certain special kinds of cement, and carbon disulphide chiefly for the cement sold in tire repair kits. The fumes of all these substances are more or less poisonous, those of the petroleum products being the least harmful. Rubber cement is used not only to hold surfaces together but to make so-called "spread goods"—cloth impregnated and covered with rubber—and dipped goods.

To recapitulate, the rubber industry in its various branches involves the handling of the following poisonous substances: Litharge or lead oxide, sublimed lead or lead oxysulphate, white lead or the basic carbonate of lead, red lead or lead oxide, the golden sulphide of antimony or antimony pentasulphide, aniline oil, carbon disulphide, carbon tetrachloride, coal-tar benzol, naphtha, gasoline, and benzine.

This list is not complete, for it is known that various organic substances more or less toxic are in use in many compounding rooms and in the reclaiming of rubber, but their exact composition is a carefully guarded trade secret. Some undoubtedly are coal-tar derivatives, others are products of petroleum distillation, volatile poisons which affect mainly the central nervous system.

GENERAL CONDITIONS IN THE RUBBER INDUSTRY.

General conditions in the rubber industry in the United States are excellent. Large, new, well-built factories with ample natural ventilation are the rule; low, crowded, old plants, the exception. Indeed, in some of the best of these factories the visitor gains the impression that no expense has been spared in making the workrooms not only sanitary but comfortable and attractive. Many of the rooms have white walls and even white curtains at the windows. Rest rooms are provided for the women; there are excellent toilet and locker rooms for all the employees; bubbling fountains of cold water are very common; the women have seats whenever their work permits of their use; and efforts are made in some factories to reduce the heat in summer weather. Still more elaborate and expensive are the medical first-aid rooms and the examination and treatment rooms attached to most of the large plants. Some even have a small hospital where emergency cases can be given not only first aid but nursing care till they are well. It is quite customary to retain the services of a physician who is expected to visit the plant regularly, and the larger companies have their own visiting nurses.

CARELESSNESS IN HANDLING INDUSTRIAL POISONS.

Yet in these very factories the really dangerous poisonous substances we have mentioned are almost always used with a carelessness that is amazing. The lead salts are scooped from open barrels or shoveled and dumped with as little caution as if they were sulphur or chalk; with much less care, indeed, than lampblack, because the latter flies around and blackens the walls. Aniline is poured into open cans and allowed to stand uncovered, then poured into mixing mills where there are no hoods to carry off the fumes. In the case of the petroleum and coal-tar products, the fire risk, fortunately, is great enough to compel precautions against too much evaporation, but a contamination of the air too small to constitute a fire risk may be large enough to cause headache, lassitude, and loss of appetite, or, on a hot day, fainting, especially in girl workers. It is interesting to note that in all well-equipped plants there is a little first-aid room in close proximity to the room in which the girls are working with rubber cement. Yet only 3 out of 35 factories have introduced so simple a precaution as putting lids on the cement cups and the cups of benzine that stand on the workbenches. In the others one can sometimes see from 50 to 200 men and women in one room, all with open cups or pans before them.

There is a fire risk from the fumes of carbon disulphide also, but the means used to carry off the fumes are not efficient enough to prevent the poisoning of the workmen who use the substance. The risk has led some managers to substitute the noninflammable carbon tetrachloride, but the fumes of this also are poisonous and that fact should be recognized.

If one-tenth of the thought and money that has been expended on the equipment of hospitals and first-aid rooms and on the employment of nurses and doctors had been expended on preventive work, the rubber industry in the United States might have been made one of the safest of occupations. Probably the reason why this has not been done is the fact that the number of employees exposed to poisonous substances is small compared with the whole force in a plant. For instance, in one of the more dangerous branches of the trade, the making of dipped and molded goods, a little over one-fourth of the employees are exposed to lead salts and aniline, to the fumes from naphtha and cement and carbon disulphide. In making rubber footwear, the proportion exposed is much higher, for almost half the force may be using rubber cement, but the risk from that work is slight in comparison with the risk of lead poisoning or of aniline or carbon disulphide poisoning involved in the making of dipped and molded goods. The making of heat-cured rubber clothing is another branch in which the risk is relatively slight. In making tires and mechanical goods only about one-eighth of the force is exposed to the effect of lead compounds, of aniline, carbon disulphide and tetrachloride, and of naphtha or benzol.

FACILITIES FOR WASHING, ETC.

Cleanliness varies, of course, according to the standards of the management and is not always greatest in the best-built factories. Dust is an evil in almost all the factories where steam vulcanization is done, especially in the tubing department. In the matter of washing facilities and a good supply of drinking water conditions are sometimes disappointing, and this is especially true of the provision made for men employed in the compounding room and in mixing. For these men not only basins with hot water, but soap and towels should be furnished. Similar provision should be made for men employed in dipping and in cold curing. For the workers in benzine and naphtha such provision is also desirable, but they are more likely to be given adequate facilities than are the others. In the best factories good drinking water is piped through the plant and delivered in bubbling fountains, but in a few factories there is only scanty provision, and in one tire factory on a hot day nine men were seen lined up waiting their turn at a tin can and a pail of water outside the vulcanizing department. In some factories lunch rooms are provided for the women, rarely is there any factory found where such provision is made for the men. Compounders and mixers who handle lead salts often eat in the workrooms.

EMPLOYMENT OF WOMEN AND GIRLS.

The rubber industry in the United States employs many women and girls, especially in the manufacture of small articles, such as druggists' sundries, overshoes, rubber bands, parts of rubber mackintoshes, bathing caps, toys, and balls. In rubber-footwear factories the women form about 50 or 60 per cent of the force, and in the making of druggists' sundries the proportion is about the same. In mechanical rubber works and in tire factories a large proportion of the employees consists of men, with young boys as helpers, though women may be employed in the inner-tube department and in making accessories. One tire factory, for instance, employing between 2,500 and 2,600 workpeople, has only 25 women; another, with 640 workpeople, has no women at all.

All of the really dangerous work is done by men, not women or boys. Only men are exposed to the lead compounds and to aniline fumes. Men make the rubber cement and run the spreading machines and apply the varnish. Men also make almost all of the dipped goods. Women are exposed to benzine fumes in applying cement, and they work sometimes in the rooms where dipped goods are drying, but that is all. Curing by vapor or by dipping or by painting is men's work, and women are exposed to the fumes of carbon disulphide only when this work is carried on carelessly and the fumes are allowed to escape into the finishing room.

The men and women employed in the rubber industry are for the most part unskilled or semiskilled and entirely unorganized. Superintendents say that most of the different processes can be learned in a month's time, though naturally much more skill is acquired later. The industry employs many men and women of foreign birth, especially in the larger cities of Ohio and New Jersey, and in some of the Massachusetts factories. On the other hand, in the smaller cities of New England, New Jersey, Ohio, and Indiana the proportion of native Americans is very high, and in a large factory in Detroit also the majority of workmen were Americans.

HOURS OF LABOR.

With the exception of a few jobs the work is almost all piecework, and, in the making of footwear, the pace set impresses one as extremely rapid, though this is only a superficial impression. The workmen say that the speeding up is quite as bad in other processes, but as they are more complicated and require greater range of movement the speed is not as evident to the casual observer as it is in boot and shoe making, where relatively simple movements are made over and over again. The working day is usually 10 hours, sometimes 12 hours. When two shifts are employed, the day shift works 10 hours, the night shift 12 or 12½ hours. In rare instances there are three shifts of 8 hours each. There is said to be a great deal of slack time, during which the working day is often 8 hours or even less.

SUMMARY.

The investigation on which this study is based covered 35 rubber factories, located in 15 cities or towns in 9 States. Practically every branch of the rubber industry was included among the activities of these different factories. As there are many trade secrets in the manufacture of rubber articles, it was impossible to make the investigation as complete as was desired, but the following points were clearly established.

In the main, conditions as to light, ventilation, and physical surroundings in the rubber factories visited are excellent. In the newer plants especially there was an evident intention to make the workplaces not only sanitary, but comfortable.

The processes of rubber manufacturing involve the use of several poisonous substances, of which lead salts, antimony pentasulphide, aniline oil, carbon disulphide, and carbon tetrachloride are the most dangerous. The operations involving exposure to these poisons employ but a small proportion of the workers. No women and very few boys are engaged in such operations. A lesser danger is found in the use of coal-tar benzol and of various petroleum products such as naphtha, benzine, etc. A considerable number of the workers, including women and boys, are exposed to the fumes of these compounds.

It is possible so to equip and manage a rubber factory that exposure to these various industrial poisons may be reduced to an insignificant minimum or wholly eliminated. Relatively little, however, seems to have been done in this direction. Often the danger is not realized, so that even when the equipment of a factory permits a given process to be carried on safely, through ignorance or carelessness it may be performed in a fashion which makes it dangerous.

The dangerous nature of some of the compounds used in the rubber industry is not as yet commonly known, so that cases of industrial poisoning may occur without being recognized as such and ascribed to their true cause. Also, in the case of some of the compounds, the symptoms of poisoning due to their use may be obscure or may not develop until some time after the exposure has taken place, so that again the resultant harm may not be ascribed to its true cause. It was therefore impossible to get accurate data as to the frequency of industrial poisoning in the rubber industry. Records were secured of 66 cases of lead poisoning which occurred in 1914 among rubber workers in the United States. Cases were also found of naphtha poisoning and of poisoning from carbon disulphide, carbon tetrachloride, and aniline oil. Nothing approaching a complete record of such cases, however, was available.

POISONS USED IN THE RUBBER INDUSTRY.

The substances used in rubber manufacture which have more or less poisonous properties and which form the subject of this report are, with the exception of the lead salts and the golden sulphide of antimony, volatile substances, which are absorbed chiefly through the respiratory tract, though somewhat through the skin, and which affect the central nervous system.

LEAD.

The lead salts are well known as producers of industrial disease. Indeed, plumbism is said by the Germans to be the most important of all industrial diseases. Of the lead compounds used in rubber, the most dangerous is probably white lead, the basic carbonate, although litharge comes close to it. White lead is more soluble than litharge, and quantity for quantity it is more poisonous, but it is not so light and fluffy, and, therefore, practically it may be less harmful. Some German factory inspectors consider litharge the worse of the two. Litharge is much more important than white lead in the American rubber industry, for it is used in great quantities while white lead is used less and less each year. Sublimed white lead, also called lead oxysulphate,[1] is not nearly so soluble in the human stomach as litharge and white lead, but it is poisonous enough to cause serious injury if it is handled carelessly and if the workmen are forced to inhale much dust. Sublimed lead is very light and fluffy and therefore needs to be handled with unusual care.[2] Red lead is seldom used. In poisonousness it would rank lower than litharge, higher than sublimed lead.

Dust is the great danger in processes where lead salts are used, for poisoning is most often caused by breathing lead-contaminated air and swallowing the lead which has become mixed with the saliva. Another way of contracting lead poisoning is by eating food or by chewing tobacco that has been handled with lead-smeared hands. If the workman goes home with his clothes and his hair filled with lead dust, he increases very much the danger of lead poisoning. It is easy to see, then, what means of prevention should be used against lead poisoning: First, the prevention of dust, and, second, ample provisions for bodily cleanliness.

LEAD POISONING AMONG RUBBER WORKERS.

Lead poisoning is essentially a chronic disease marked by acute attacks. The development of the symptoms is slow and insidious, and by the time they become acute the man has absorbed a good deal of the poison, and recovery from the acute symptoms does not mean that he is free from chronic plumbism. The first symptoms usually noted are loss of appetite, a disagreeable taste in the mouth, indigestion, loss of strength, constipation, more or less insomnia and headache. An acute attack is usually ushered in by obstinate constipation and is characterized by agonizing colic. In other cases it is the nervous system chiefly that is affected. Insomnia, headache, weakness of the muscles most often used, chiefly of the extensors

[1] Sublimed "blue lead" is used in some factories in the place of sublimed white. It is the product of the first sublimation; the white is the product of the second.

[2] Bulletin of the United States Bureau of Labor Statistics, No. 120, May 13, 1913, p. 19.

of the wrist, attacks of mental confusion, even loss of consciousness and convulsions, are the symptoms in this type of cases, and they may or may not be accompanied by typical lead colic. Aside from these acute attacks a slow chronic change takes place in the lead-poisoned workman, leading to profound anemia, hardening of the blood vessels, and alterations in such organs as the kidneys, liver, and heart, and to more or less permanent paralysis of forearms or ankles. There are many other changes which may be brought about by lead poisoning, but the above is a description of the more typical forms.

Lead poisoning is mentioned by German and British authorities as one of the dangers of the rubber industry, but not much stress is laid upon it and few actual cases are reported by factory inspectors. In Prussia,[1] for instance, only two cases of lead poisoning are mentioned as occurring in the rubber industry in 1912. The British reports, which, unlike the German, summarize the findings for the whole country, give six cases of lead poisoning in this industry in 1905,[2] and in 1909[3] give seven as having occurred within the last three years, but there is no mention of rubber workers later than that year. Rubber is, however, always included in the list of miscellaneous trades in which lead poisoning occurs to some extent.

The occurrence of lead poisoning in connection with rubber work in this country is certainly not notorious. A few of the many physicians interviewed had seen an occasional case among compounders or men at the mixing mills, but by far the greater number had never seen any such cases. It is very possible that an occasional case may have escaped detection, as the physicians are not on the lookout for it in rubber workers. Still, lead poisoning must certainly be rare in the industry or men practicing in towns given up to this one industry would be familiar with it. Among five physicians in a small town with three rubber works, one had seen no lead poisoning at all in 10 years; a second, who had practiced 20 years, had seen a case now and then, but rarely; a third had had a case 2 years before; a fourth, none for more than 10 years; and the fifth, a careful and scientific man, had seen 12 or 14 cases in the course of a practice extending over 24 years. Probably these men did not all follow the same methods of examination, but even the one who had detected the largest number of cases had seen very few in proportion to the number of people employed in the rubber factories. The truth is that so small a number of men handle lead in the rubber industry that the rate of poisoning among them may be fairly high

[1] Jahresberichte der Gewerbe-aufsichtsbeamten und Bergbehörden, 1912, Vol. I, p. 71.

[2] Annual Report of the Chief Inspector of Factories and Workshops for the year 1905. Reports and statistics. p. 167.

[3] Idem, 1909, p. 196.

without attracting any general attention. In connection with some factories a very high proportion of cases has been found. For instance, in a plant making mechanical rubber chiefly and employing about 1,200 persons not more than 25 men handle the lead salts, but in 1914 there were four cases of lead poisoning in the compounding room and seven at the mixing mills. This factory has one of the dustiest compounding rooms in the country, the bolting room is the dustiest of all that were visited, and the mixing mills have no hoods at all. A large tire factory, employing some 44 men in bolting and compounding, had 15 cases of lead poisoning last year. Here, also, there are no hoods over the mills, and the bolting and weighing of litharge and red lead is very carelessly done.

There is a very excellently equipped and managed factory for the making of footwear in Massachusetts, in which the dangerous character of the work of compounding and mixing seems to have escaped the attention of the management, for the weighing and mixing of the compounds is done at one end of the mill room, and the large quantities of litharge which go into the rubber are weighed on open scales and handled with no care at all. The hoods over the mills are practically useless because the exhaust is so feeble, and dust lies over every surface. Only about 22 men are engaged in this work, but lead poisoning is very common among them. One physician saw 4 acute cases and 10 chronic cases during 1913 and 1914.

Records were secured of 66 cases of lead poisoning in rubber works during 1914, distributed among the various branches of the trade as follows: Tires 27, footwear 9, clothing 6, druggists' supplies 3, mechanical rubber 1, factories making all kinds of goods 20. These men were working in the compounding and mill rooms. The greater number had been employed more than a year, but one compounder had worked only 3 months, another 9 months, and a third 11 months before they were taken ill. The men who had worked for longer periods showed evidence of chronic plumbism.

Typical cases among rubber workers in the United States.

Case 1 was that of an American, 34 years old, who worked in a fairly typical rubber-clothing factory where both litharge and sublimed lead were used. He had been employed for six years at one of the mixing mills in the same room with 12 or 13 others. There was a great deal of dust in this room. Six years prior to the investigation he had had an attack of acute lead poisoning. He was suffering from pain in the abdomen and back, nausea, pain in the joints, loss of muscular strength in the hands, crawling sensation on forearms and legs. He had a lead line and the red blood corpuscles showed the characteristic stippling of lead poisoning.

Case 2 serves as an illustration of the theory now very generally held that the location of lead palsy is determined by the overuse of certain muscles. This case was that of an Italian, 44 years old, employed for 12 years as a compounder in a mechanical rubber shop. He said that he always wore gloves when at work. A great deal of litharge was used in this factory. In addition to weighing out the compounds he had to make certain muscular motions over and over, grasping his knife tightly to cut pieces of old rubber to add to the mixture. As a result he had a lead palsy of the ulnar nerve of the right hand. There was no gastric discomfort, but his breath was foul and he had a lead line on the gums.

Case 3 shows that a workman who is not engaged in handling the lead compounds may be poisoned by the dust raised in the course of other men's work. This case was that of an American, 38 years old, a "breaker up" in a large boot and shoe factory. Breaking up means working the rubber into a paste in a mill. The man did not handle any lead salts but he worked beside a mixing mill. After 25 years' employment at this factory he was suffering from chronic plumbism, anemia, arthralgia, and loss of strength, and he showed both the lead line and stippling of the red blood corpuscles.

Case 4 was that of a Pole, 45 years old. For six years he worked in the compounding room of a rubber-shoe factory weighing out litharge and other chemicals and handling them with his bare hands. He suffered from chronic lead poisoning with abdominal pain, constipation, nausea, poor appetite, and loss of weight. He had a lead line and the red blood cells were stippled.

ANTIMONY.

There are several different grades of antimony sulphide used in the rubber industry, the pentasulphide (Sb_2S_5), the trisulphide (Sb_2S_3), the oxysulphide, and several mixtures of these with some neutral salt, such as calcium or barium sulphate. "Sulphurated antimony" is the term often used in the industry.

The golden sulphide of antimony seems to be almost unknown as an industrial poison. Toxicologists, such as Gadamer,[1] Von Jaksch,[2] and Peterson and Haines,[3] say that it is of no importance as a poison. Kobert,[4] however, believes that in spite of its not being readily soluble it might cause symptoms in workmen exposed to large quantities of the dust. He gives the symptoms of chronic antimonial poisoning as follows:[5] Abdominal pain, nausea, loss of appetite, dysenteric

[1] Gadamer, Lehrbuch d. chemischen Toxikologie. Göttingen, 1909, p. 195.
[2] Von Jaksch, Die Vergiftungen, 2d edition. Vienna, 1910, p. 161.
[3] Peterson and Haines, Legal Medicine and Toxicology, vol. 2, p. 433.
[4] Kobert, Lehrbuch d. Intoxikationen. Stuttgart, 1906, vol. 2, p. 1245.
[5] Idem, p. 279.

attacks, sores in the mouth, salivation, wasting, weak heart, attacks of dizziness, and albuminuria or glycosuria. In the rubber industry the golden sulphide is handled in large quantities and usually with the utmost recklessness. One can see men powdered with it from head to foot. The fact that no physician who was interviewed had ever seen what he recognized as a case of antimony poisoning in a rubber worker is not very significant because the symptoms of antimony poisoning could easily be masked by or mistaken for the symptoms of lead poisoning, since both chemicals are used in the compounding rooms and on the mixing mills.

In the effort to discover how far this salt must be regarded as a poison, Dr. A. J. Carlson, of the physiological department of the University of Chicago was asked to test its solubility in human gastric juice. The results of Dr. Carlson's tests are given in Appendix B. They show that pentasulphide of antimony may cause poisoning in workmen who are exposed to large quantities of it.

ANILINE OIL.[1]

Industrial poisoning from aniline oil is well known, for many cases have occurred in the great German factories in which aniline derivatives are made. The oil is a volatile poison affecting the nervous system and acting destructively upon the red blood corpuscles. The first symptom of aniline poisoning is pallor, which soon changes to a striking bluish color, especially in the lips. There is usually severe headache and general weakness and, if the exposure to the fumes continue, loss of consciousness which may be prolonged alarmingly. The breath and the urine smell of aniline and the blood shows changes due to the withdrawal of oxygen and the destruction of the red blood cells.

It is not necessary that the exposure to aniline fumes be long continued or intense for serious symptoms to ensue. There are two cases reported from the Zeiss Optical Works in Jena [2] which came on after an exposure of only two hours in one case and between three and four hours in the other. The men were testing the clearness of quartz crystals, dipping them first in aniline oil which was contained in a small receptacle beside them. The researches of K. B. Lehmann show that very small quantities of aniline vapor in the air are sufficient to cause symptoms of poisoning (see table on p. 35). Unfortunately the workman is not warned of danger by the irritating effect on eyes or mucous membranes, as is the case with most volatile poisons. The odor of aniline is pleasantly aromatic and not at all

[1] Aniline oil as used in industry is a mixture of aniline (amido-benzol) and varying quantities of meta-, para- and ortho- toluidin and xylidin. (Von Jaksch, Die Vergiftungen, 2d edition. Vienna, 1910, p. 328.)
[2] Krause, Med. Klinik, 1908, vol. 4, p. 10.

irritating. Chronic aniline poisoning is called by the Germans "anilismus." Von Jaksch describes it as characterized by skin affections, anemia, headache and nausea, dizziness, staggering gait, twitching of the muscles, and bladder troubles.

Lately several cases of poisoning have been reported by German factory inspectors as having occurred in works where rubber is reclaimed from scrap or extracted from the crude gum. Rubber-reclaiming works, according to the report of 1909,[1] gave rise to several cases of aniline poisoning. In one of these factories there were four acute cases, and 15 men showed signs of chronic poisoning. In a second factory 14 out of 25 workmen were overcome by aniline fumes and all but four were ill for as much as 10 days. Another wholesale case of poisoning from aniline in the extraction of crude gum was reported in 1908.[2] Seventeen men were working for 12 hours a day and 11 of them were poisoned, some of them severely. Two were carried unconscious to the hospital.

ANILINE POISONING IN THE RUBBER INDUSTRY IN THE UNITED STATES.

Very few cases of aniline poisoning have been reported in this country, but it is probable that more will be heard of in the future, for since the war has cut off the supply of aniline oil from Germany it has become necessary to manufacture it in this country. A large rubber factory in Akron has recently added a department for the manufacture of nitrobenzol from benzol and aniline from nitrobenzol, with a daily output of some 2,500 pounds and the employment of 12 to 14 men in two shifts. In spite of good ventilation by means of exhaust pipes, the men suffer from the fumes and during the last four months not fewer than 15 have left because they could not endure it, though employment was hard to find in Akron at the time. The use of alcohol, even in moderation, increases very much the susceptibility to these fumes. In this plant the aniline oil is only one of the factors, for nitrobenzol is also present; but one case was described to us for which aniline alone was responsible. A foreign workman who was a habitual drinker was told to fill a drum with aniline oil, and while doing so he lost consciousness and had to be sent home. The next day he returned to work, but as he walked through the room in which aniline oil was being poured he again fainted away and after that he gave up the work.

Aniline oil vaporizes at room temperature and is absorbed chiefly through the respiratory tract, but may be absorbed also through the skin as is shown in the case described by Dr. Luce in Appendix A. In the rubber industry the men are exposed to the fumes of aniline in the compounding room, where it is kept and measured out, and in the

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[1] Jahresberichte der Gewerbe-aufsichtsbeamten und Bergbehörden, 1909, Vol. I, p. 282.

[2] Idem., 1908, Vol. I, p. 283.

mill room, where it is poured over the rubber in the mixing mills or in the "warm-up" mills. The cylinders of these mills are heated to soften the rubber, and the heat aids in volatilizing the aniline. Even the rubber on the calenders may give off fumes of aniline.

It is probable, however, that much of the aniline poisoning in our rubber works comes from the same department as in the German works, the reclaiming of rubber scrap. This can not be stated positively, because no part of a rubber factory is so jealously guarded against outsiders as is the reclaiming plant, and everything that goes on there is a trade secret. Still it is known that much larger quantities of aniline are used in reclaiming than in compounding, and it is certainly safe to conclude that this is the department at fault when, as happened in the case of a large plant in Ohio, no aniline was detected in the compounding or mixing rooms; access to the reclaiming department was refused, and a number of cases of aniline poisoning were traced to the plant.

Acute aniline poisoning, both mild and severe, is not at all uncommon in Akron, and not only workmen, but physicians, speak of the victims as "blue men" or "blue boys," because the most distinctive symptom is the intense cyanosis. It is said that severe cases used to occur quite often a few years ago when aniline was first introduced into the Akron plants, and the doctors did not at once recognize which was the chemical responsible for the trouble. Since that time serious efforts have been made in some plants to protect the users from fumes. The first record of aniline poisoning in the rubber industry in this country seems to be that contained in the recent report of Dr. E. R. Hayhurst, of the Ohio State Board of Health.[1] Dr. Hayhurst found three cases of aniline poisoning in the compounding and milling departments of rubber factories in Ohio. (See Appendix C.)

It is not at all easy to learn the truth about aniline poisoning in rubber works because of the secrecy which shrouds the processes, nor do superintendents and foremen like to admit that there is any danger from a substance which is in use in the factory. However, after they have given up using some chemical, they are generally quite frank in talking about its disadvantages. In a tire factory, where the use of aniline had been abandoned a little while before, the foreman said that he was thankful not to have to handle it any more, for he had had so much trouble with the fumes from the mixing mills.

Most of the information gathered concerning cases of aniline poisoning in Akron dated back several years, to the time when the danger was not appreciated and safeguards not yet introduced. One physician attached to a large plant said that he had seen in all over a hundred cases of aniline poisoning, but in this plant hoods have been

[1] Industrial Health Hazards and Occupational Diseases in Ohio, by E. R. Hayhurst, A. M., M. D., director division of occupational diseases, Ohio State board of health. Columbus, February, 1915, pp. 208, 210.

installed to carry off the fumes, and the men have been instructed to watch for the warning symptoms and then to go out into the open air at once. He never has any but very slight cases now.

Another Akron physician described three fairly severe cases, two of them recent and acute, the other a chronic case of three or four years back. The first two men were handling aniline, in some way not ascertainable, in a factory where dipped goods chiefly are made. They had the usual history of extreme flushing of the face and severe headache, then the red color changed to a deep blue and unconsciousness came on, lasting several hours. The next day both declared that they were quite well, but one was still cyanotic and remained so for three or four days. In the chronic case the man consulted the physician for a persistent cyanosis which had led other doctors to treat him for heart disease. It was found that he had been working with aniline for some time, that he was profoundly anemic and subject to headache and breathlessness, symptoms which had not been improved by treating him for heart trouble. This physician advised him to quit work of that kind, and when seen some months later he had completely recovered.

An interesting case indirectly connected with the rubber industry was described by an Akron physician. An old boiler was sold by one of the rubber factories and the boiler repairer who undertook to clean it and put it in order had a typical attack of aniline poisoning.

A study of aniline poisoning in the rubber industry of Akron, Ohio, and an analysis of a typical case is to be found in Appendix A.

COAL-TAR BENZOL.

Benzol is not used nearly so much in the United States as in Germany. It is twice as expensive as petroleum in this country, while in Germany and Austria it is somewhat cheaper than petroleum. A very complete study, both historical and experimental, on the effects of the vapors of coal-tar benzol and petroleum naphtha and benzine as used in industrial processes was made by K. B. Lehmann and his assistants in the University of Wurzburg.[1] Benzol is a product of the distillation of coal tar or coke, passing over at about 90° to 95° C. The commercial variety is about 85 per cent pure. Lehmann's experiments on animals showed that the fumes of benzol cause irritation of the mucous membranes of throat and larynx, and of the eyes, muscular twitchings, and, later, convulsions, unconsciousness, fall of body temperature, and death from respiratory paralysis. The same symptoms have been noticed in cases of violent acute poisoning in human beings who have entered vats containing benzol or spilled large quantities of it and inhaled the fumes, but the poisoning that

[1] K. B. Lehmann, Archiv für Hygiene, 1911, vol. 74, p. 1.

occurs in rubber factories is neither so rapid nor so intense and the symptoms are not so typical.

The most famous cases of benzol intoxication in rubber workers were reported by Santesson,[1] a Swedish physician, from a factory in Upsala where velocipede tires were made. Here young girls were employed in painting the tires with a solution of rubber in crude benzol, and before the breaking out of symptoms of sickness among them there had been a rush season and they had worked sometimes from 5 in the morning to 11 at night. Santesson gives the histories of four fatal cases, four severe but not fatal cases, and three or four light ones. In addition to the nervous symptoms, these cases were characterized by hemorrhages and by profound anemia.

Santesson's report was published in 1897. In 1911 Selling[2] reported three similar cases from a canning factory in Maryland, where instead of solder a thin solution of rubber in crude benzol had recently been introduced to seal the cans. Here, also, the victims were young girls, only 14 years old, although two men suffered from light symptoms of the same character. There were two rapidly fatal cases, one severe case with recovery, and, including the two men, four light cases. Hemorrhages and profound blood changes were the most striking features of these cases.[3]

In the Austrian factory inspector's report for 1911,[4] there is a note as to a curious disease among rubber workers, characterized by little hemorrhages into the skin. Several light cases were found and two severe cases which ended fatally, both in men employed at spreading machines. The inspectors attributed them to benzol fumes.

One would expect to find more trouble from benzol in European factories than in our own, not only because it is the solvent commonly used there, but also because their methods call for much larger quantities of rubber solution or cement than ours do. The Germans use spreading machines where we use frictioning and calendering, and it is in spreading that the fumes from the solvent are especially heavy. In 1908 German factory inspectors stated that benzol poisoning was growing more frequent in rubber works because the use of benzol in place of naphtha was increasing.[5] In the United States benzol is used in certain special cements, such as cement for the inner tubes of tires and for the better class of druggists' supplies,

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[1] Santesson, Archiv für Hygiene, 1897, vol. 31, pp. 336-376.

[2] Selling, Bulletin of the Johns Hopkins Hospital, 1910, vol. 21, pp. 33-37.

[3] Charles Glaser published an analysis of the benzol used in this factory and concluded that the substance responsible for the poisoning was not benzol but aniline, which was present as an impurity and which was isolated from the urine of two of the cases. They have, however, been generally accepted as instances of benzol poisoning and have, indeed, been made the basis of Koranyi's now well-known treatment for leukæmia. The disappearance of leucocytes in Selling's cases has been brought about in cases of leukæmia by the administration of benzol medicinally.

[4] K. K. Gewerbe-Inspektoren, 1911, p. 490.

[5] Jahresbericht der Gewerbe-aufsichtsbeamten und Bergbehörden, 1908, vol. 3, 25, 18-19.

and it is also used occasionally as a diluent for sulphur monochloride in cold curing.

PETROLEUM PRODUCTS: NAPHTHA, BENZINE, GASOLINE, ETC.

The usual solvent for rubber in the United States is one of the low boiling distillates of petroleum—gasoline, naphtha, benzine, etc.—or a mixture of these with a boiling point under 150° C. (302° F.). According to Lewin,[1] naphtha which boils at 100° C. (212° F.) loses 100 per cent by evaporation, that which boils at 120° C. (248° F.) loses 44.5 per cent, and that which boils at 120° to 150° C. (248° to 302° F.) loses 31.3 per cent.

A series of experiments as to the effect of benzine and naphtha vapor on human beings was made by Felix on a number of prisoners in a penitentiary in Bucharest.[2] He administered it in the same way as chloroform is administered for anæsthesia, measuring the quantity accurately, and found that from 5 to 15 grams (1.3 to 3.9 drams) given during 7 to 12 minutes caused in most of the subjects dizziness, nausea, vomiting, injection of the conjunctiva, burning sensation in the chest, sometimes a cough, always drowsiness. Twenty to 40 grams (5.1 to 10.3 drams) for 8 to 12 minutes brought about a condition of sleep and anæsthesia, followed after 2 to 8 minutes by the symptoms described above. There were, however, some of the prisoners who could stand as much as 50 to 55 grams (12.9 to 14.1 drams) without any disturbance. This resistance on the part of some individuals and oversusceptibility on the part of others is noted by all who have experimented with these substances, in animals as well as in human beings. Thus Lehmann finds some cats very sensitive to vapors, others not at all.

Benzine and naphtha are far less toxic than benzol, but the difference is probably one of degree, not of kind. According to the careful tests made by Lehmann, commercial benzol in small doses is 25 times as poisonous to animals as is light benzine, in large doses 3.2 times as poisonous. Testing the two substances on themselves, Lehmann and Gunderson found that 15 milligrams (0.243 grains) of commercial benzol in a quarter of an hour caused a feeling of confusion, slow and difficult mental action, and weakening of the will, while as much as 45 milligrams (0.730 grains) of light benzine was required to produce the same result.

ACUTE PETROLEUM POISONING.

The symptoms of poisoning by benzine vapors are usually given as headache, nausea, stupid feeling, heaviness or sleepiness, roaring in the ears, inclination to cough, feeling of irritation and constriction in

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[1] Lewin, Virchow's Archiv, 1888, vol. 112, pp. 35, 59.

[2] Felix, quoted in Lehmann, Archiv für Hygiene, 1911, vol. 74.

the throat, trembling of the hands and arms, sensation of crawling over the skin, excitement or irritability. Girls are said to grow very talkative and foolish and laugh a great deal; men are said to be easily provoked to anger and unreasonable. These symptoms may be felt most intensely during the first hours of the day, but in other cases they come on when the person leaves work and goes out into the open air. The workpeople call an acute attack of such poisoning a "naphtha jag."

Rarely is the severe acute form of benzine poisoning seen in this country except in places such as oil wells and refineries, where the exposure to fumes is great. Occasionally, however, a severe case may occur among the men employed in the naphtha churning rooms of a rubber factory, for when many different kinds of cement are used, the churns have to be cleaned out and the fumes of naphtha may be heavy enough to overcome the workmen who do this. Another place where severe naphtha poisoning may occur is in the dipping room. The men here work over large tanks filled with thin rubber cement and the temperature of the room is kept at 90° to 98° F., to hasten the evaporation of the naphtha. A case of this sort from a dipping room was reported to us by a physician in an Ohio town. The patient, a strong man, was found by the physician lying in bed comatose, with cold skin, pale, and almost pulseless. He had been dipping wooden forms of gloves into the tank of cement and had felt so dizzy and ill that he was obliged to leave work and go home, but on the way he began to stagger and would have fallen had not two men half carried him home. He was put to bed and not till then did he lose consciousness. His illness lasted several days but he recovered completely, never, however, venturing to go back to the same sort of work.

CHRONIC PETROLEUM POISONING.

Whether or not there is a chronic form of benzine poisoning has been questioned by the Germans.[1] The English committee on dangerous trades, of which Sir Thomas Oliver was the medical member, describes disturbances of health in rubber workers who are continually breathing naphtha fumes and says that such work tends to undermine the constitution.[2] The workpeople claim that they taste naphtha all the time and that this destroys their appetite for food. An attack of "naphtha jag" is succeeded by a stage of depression and dullness with clouded memory, and on the following day headache, loathing for food, and a feeling of exhaustion. A report on the rub-

[1] Dorendorff described four cases of very severe chronic benzine poisoning among rubber workers in Berlin in which the symptoms included lancinating pains in the limbs, coldness and numbness of the right hand, and loss of strength. There was also depression, loss of memory, and, in one case, difficult speech. Münchener medicinische Wochenschrift, 1901, vol. 48, p. 236.

[2] Home Office: Interim Report of the Departmental Committee upon Certain Miscellaneous Dangerous Trades, 1896 [C. 8149], p. 16.

ber industry in Great Britain made in 1896 describes a far greater degree of air contamination from naphtha than was found in any factories in the United States during this investigation.[1] According to a personal communication from Oliver there has been a decided improvement in British rubber factories since that time, but the fact that spreading is much more generally used in Great Britain than in the United States means that naphtha fumes are a greater evil there than here.

Chronic naphtha poisoning is mentioned in the report of the chief factory inspector for Great Britain in 1910,[2] where the statement is made that vulcanizing by means of carbon disulphide has been almost entirely given up, and yet the health of rubber workers continues to be unsatisfactory. Women who work in processes requiring the use of rubber cement complain of headache, drowsiness, and loss of appetite, the latter being increased by the necessity of eating lunch in the naphtha-laden air of workrooms. In 1912 an inspector states that "downward suction has been found to be the best means of drawing away the fumes in the drying room, as exhaust fans placed in the roof failed to remove the heavy fumes either quickly or completely."[3]

It is difficult to diagnose with certainty mild cases of chronic benzine or naphtha poisoning. When one interviews the young men and women who work with rubber cement in footwear or raincoat manufacture or in tire building, or in making inner tubes, or in cementing the seams of hot-water bags and syringes, one is very often told of symptoms of ill health which the workers attribute to the disagreeable fumes of benzine or benzol. They say that they are never quite well, that they are losing strength, losing color and weight, they have headaches, feel stupid and listless, do not care for their food, do not sleep well, have constipation and pain in the stomach and that no doctor seems to be able to cure them. The symptoms are worse on hot, muggy days in summer, and in damp, cold weather when the windows are closed. All of these symptoms might be caused by the benzine or benzol fumes, but it is difficult to establish the connection with certainty.

The Massachusetts General Hospital has had during the last few years an excellently organized clinic for industrial diseases, and patients who come to the hospital or dispensary are questioned as to their occupation and as to the conditions under which they work. In the fall of 1913 and the spring of 1914 a number of rubber workers applied for treatment on account of disorders of various kinds and among them were some whose illness could be clearly traced to their

[1] Home Office: Interim Report of the Departmental Committee upon Certain Miscellaneous Dangerous Trades, 1896 [C. 8149], pp. 14–19.

[2] Annual Report of the Chief Inspector of Factories and Workshops for the year 1910, p. 127.

[3] Idem., 1912, p. 102.

occupation, others in whom the connection between occupation and illness was less certain. It is not so easy to decide that a condition of general nervous derangement, impaired digestion, anemia, etc., is caused by exposure to benzine fumes, as it is to say that the more definite symptoms of lead poisoning are to be traced to contact with lead dust. The fact that the symptoms began with the exposure to these vapors and improved when work was interrupted is a help to diagnosis, but even that does not render it certain, for the patient may never have done any other sort of work and the disturbance of health may be caused simply by factory life, by the confinement, the lack of fresh air, the long hours, monotony of movement, and the nervous strain of piecework. The cases of chronic benzine poisoning in the records of the Massachusetts General Hospital are not regarded as being beyond doubt. All that the physicians would say of them is that they occurred in the course of exposure to the fumes of petroleum products which have been experimentally shown to be capable of producing such symptoms.

Typical cases among rubber workers in the United States.

The following are a few typical case histories from these records:

Case 1: A Pole, 28 years old, had worked for six years cementing shoes in a room where 40 men were employed at the same work. The cans of cement were all uncovered and he smeared a good deal of it on his hands as well. He complained of colic, pain in the back, digestive disturbances, loss of appetite, headache, sleeplessness, loss of weight.

Case 2: A German Jew, 25 years old, had been cementing facings and pockets of raincoats for four and a half years. As he was very nearsighted, he was forced to stoop over his work. He complained of being sleepy all the time, was pale, suffered from constipation and continual headache.

Case 3: An Armenian, 26 years old, worked in the naphtha room of a rubber-shoe factory making cement. He described the fumes as being very strong, and complained of feeling sleepy all day and then being unable to sleep at night. He had severe abdominal pain, coming on about three hours after meals, constipation, and headache.

Case 4: A Pole, 18 years old, was employed for six months making and using rubber cement on the seams and facings of raincoats. Every two days he made the cement, using his hands to break up and knead the rubber in the naphtha. He was tired and weak, sleepy all the time, suffered from headache and constant cough, and could not work properly, especially in the morning, because his muscles would shake and twitch. Case 5, a case of slow, chronic poisoning, is a contrast to this fairly quickly developing case.

Case 5: An American, 60 years old, had worked with rubber cement for 20 years in the belting department of a mechanical rubber factory. He suffered from nervous disturbances, loss of prick and touch sense in the toes of the right foot, numbness in the toes and pain along the right sciatic nerve. His gait was stiff. There was also a slight atrophy of the optic nerve.

Case 6 shows probably the combined effect of mechanical injury and chronic intoxication. He was an American, 58 years old. For 13 years he had cemented shoes, pressing the shoe forcibly against his stomach to hold it steady. He complained of digestive disturbances, vomiting about twice a week, constipation, headache, pain in the eyes, ringing in the ears, and chills.

A fairly serious case of chronic poisoning was found in an Ohio town in the course of this investigation. A man engaged in dipping for three years was suffering from attacks of dizziness, was very nervous and anemic, and was losing power in his right arm.

Other men who were interviewed complained more especially of gastric symptoms—pain, indigestion, and eructations of gas. It is noteworthy that though physicians who practice in rubber towns usually make general statements as to the occurrence among girl cement workers of vague digestive disturbances, nervous disorders, and anemia, the specific instances they relate are almost always in men. The men are more apt to remain for many years in the industry and they are also exposed to much heavier fumes than the women are.

Industrial benzine poisoning is usually said to take place only through inhalation of fumes, but some authorities believe it can also enter through the skin. There is certainly in some people a local irritation from the benzine which shows itself in pustular acne, or in some form of dermatitis, though this is not nearly so common as it is in workmen who handle the heavier petroleum distillates, paraffin and vaseline. An Italian physician described recently two cases from a rubber factory in Turin.[1] These were both young men who had worked with their hands in rubber cement, and in both cases there were quite symmetrical patches of a painful inflammation with small vesicles, which developed in the spaces between the fingers. The condition cleared up under appropriate treatment, after the work with cement had been discontinued.

CARBON DISULPHIDE.

DANGEROUS CHARACTER OF THE COMPOUND.

The two most dangerous poisons which are encountered in the rubber industry are used in the so-called acid cure or cold cure and in the vapor cure, processes by which sulphur in the form of the monochloride is introduced into the rubber. It is not the monochloride

[1] Vignolo-Lutati, Il Lavoro, 1913, vol. 6, pp. 229–233.

itself that is dangerous, for, according to Lehmann,[1] who tested it experimentally, sulphur monochloride causes nothing more than an irritation of the conjunctiva and of the mucous membranes of nose and throat. The danger is in the addition of carbon disulphide or carbon tetrachloride or benzol, and these are poisonous in the order mentioned.

In European countries where carbon disulphide seems to be used very extensively, the possibility of poisoning from this source has caused the rubber industry to be ranked as a dangerous trade. The Germans recognize carbon disulphide as a specific poison for the central nervous system, and many cases are described in German literature of nervous and mental derangements caused by exposure to this substance. It is said to have been first discovered by Lampadius of Freiburg in 1796[2] and was recommended as a remedy for a great variety of diseases. Carbon disulphide was, in fact, used in medicine more or less for the next half century, but its real importance was its value in industry because of its property of dissolving fats and such substances as gutta-percha, rubber, and sulphur. It had been used some time in industry before a Frenchman, Payen, in 1851, first called attention to the danger. Five years later, another Frenchman, Delpech,[3] gave a description of carbon disulphide poisoning which is still classical. The first case in a German rubber factory was reported in 1871 by Bernhardt,[4] but it was not until 1886 that much was written on the subject in Germany. Since then there have been many German reports of nervous diseases resulting from carbon disulphide[5] fumes, and Laudenheimer calls such poisoning the typical rubber workers' disease.

Only two fatal cases are reported in the literature of the subject, but the picture drawn of the severer nonfatal cases is often deplorable. Thus Delpech, writing in 1863, says that rubber workers, after showing all manifestations of excessive exaltation of the nervous system, fall into an increasing state of general breakdown and at the end of several years' work are degenerated, both morally and physically, quite incapable of making a living any longer. Although such extreme cases are rarely described in the more recent literature, there are reports from time to time of fairly serious nervous impairment among women vulcanizers, especially young women. Laudenheimer, of Leipzig, wrote a monograph in 1899[6] on carbon disulphide poisoning, as seen in the Leipzig factories, where cold vulcanizing seems to have been the only method used. He says that in Leipzig in 1897

[1] K. B. Lehmann, Archiv für Hygiene, 1894, vol. 20, pp. 26-77.
[2] Harmson, Vierteljahresschrift für gericht. Med. 1905, 3d series, vol. 30, pp. 149-185.
[3] Quoted by Harmson in above report.
[4] Bernhardt, Berliner klinische Wochenschrift, 1871, p. 13.
[5] Koester, Archiv für Psychiatrie und Nervenkrankheiten, 1899, vol. 32, pp. 568-626; 1900, vol. 33, pp. 872-891.
[6] Laudenheimer, Die Schwefelkohlenstoffvergiftung in Gummiarbeiter. Leipzig, 1899.

among 758 rubber workers, 265 were exposed to the effects of this poison through inhalation and through the skin, and that these figures did not give the whole truth, for the workers were very shifting, 460 being employed in one year to keep up a force of 120, so that an even larger number than 265 were exposed in the course of a year. Laudenheimer collected the histories of no less than 50 cases of carbon disulphide insanity from the Leipzig asylum. The early symptoms of these cases consisted usually of transient excitement and slight delirium, very like alcoholic intoxication. Later deep depression came on, then, if the exposure continued, an increasing indifference, apathy, or melancholy, and always a weakened memory. Drowsiness and stupidity would then sometimes pass suddenly into acute mania, or into melancholia with delusions of persecution. These might terminate in recovery or end in incurable dementia. Such cases usually developed during the first weeks or months of work.

Laudenheimer also describes nervous symptoms which do not develop as rapidly and do not end in insanity: Headache, dizziness, and an increasing weariness in the legs so that the person experiences great difficulty in walking, and especially in climbing stairs. More serious cases may have disturbances of sensibility and even paralysis of certain nerves and incoordination of muscles.

The cases studied by Laudenheimer and other observers were chiefly women, often young women, because the dipping of rubber objects into the vulcanizing solution is done mostly by young girls in European factories. The French, under the influence of Marie,[1] believe that carbon disulphide is not really a primary cause of nervous derangement but only the exciting cause of hysteria in people already predisposed to it. This is still a subject of controversy between scientists in the two countries, but there is no question as to the functional nervous disturbances occurring in and as a result of work with carbon disulphide. Bacquias,[2] in France, writes of headache, dizziness, excitability, causeless laughing or crying, or fits of anger followed by depression, fatigue, and insomnia, all resulting from the work of vulcanizing rubber with carbon disulphide. Briau,[3] of Lyons, was puzzled to discover that in a certain foundry there was a most unusual amount of mental breakdown among the workmen. Within a short time 8 out of a group of 30 men had symptoms varying in severity from mere overexcitement to pronounced mental disease. Investigation showed that these men were employed in repairing machine belting and had to paste rubber strips on the leather belting

[1] Marie, Pierre, Bulletin et Mémoires de la Société Médicale des Hôpitaux de Paris, 3d series, 1888, vol. 5, pp. 445–454.

[2] Bacquias, Annales d'Hygiène publique et de Médecine légale, 4th series, 1904, pp. 79–82.

[3] Briau, Lyon Medical, 1912, vol. 119, pp. 897–901.

with carbon disulphide. There had been no cases of mental disturbance before the year that this repair work was introduced. This is practically the same sort of work as the making of rubber and leather horseshoe pads in our country.

Though many reforms have been made in German factories of late years, there is still danger from the use of this substance, as can be seen from the factory inspection reports. The report for 1909[1] tells of three cases of severe poisoning in the Erfurt district. One of them became extremely nervous and irritable and then maniacal, and finally died of heart failure. In the two nonfatal cases the symptoms were sudden loss of consciousness, pallor, dilated pupils, no response to stimuli, lowered temperature, and quickened pulse and respiration. After recovering consciousness, they suffered for several days from dizziness and headache, burning in the throat, inflammation of the eyes, and salivation. In 1910,[2] ten cases were reported from two factories in Bavaria, but they were slighter in character, and in 1912[3] there were two slight cases in Munich.

Evidently cold vulcanizing is still far more common in Germany than in the United States. The factory inspection report for Prussia in 1910[4] speaks of a factory where a machine had just been installed that would require only 4 men and would displace 150 women vulcanizers. There are not more than 130 men who do this kind of vulcanizing in all the 35 American factories visited, and not one woman.

In England the report of the departmental committee on dangerous trades states[5] that functional nervous derangements, paralysis, and insanity were not at all uncommon among girl vulcanizers some years ago, and also among men vulcanizers. All the workers of this class who appeared as witnesses before the committee had been ill, and among the severe cases were two men who had lost the use of their legs completely for about a fortnight and had recovered very slowly. A girl vulcanizer had attacks of uncontrollable excitement, in the intervals between which she would sit in a dull stupor crouching over the fire, and had to be carried to bed. Another girl lost the use of her fingers and partly of her legs, walking slowly and laboriously. Oliver even describes a factory in which the windows of the vulcanizing room had been barred to keep acutely poisoned men from leaping out during attacks of mania. Frost[6] also writes in 1886 of an earlier British inquiry into the effects of carbon disulphide, in which 33 cases of nervous and mental derangement were recorded, 24 of them involving some affection of the optic nerve.

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[1] Jahresberichte der Gewerbe-aufsichtsbeamten und Bergbehörden, 1909, vol. 1. pp, 225, 226.

[2] Idem, 1910, vol. 2, p. 26.

[3] Idem, 1912, vol. 2, p. 23.

[4] Idem, 1910, vol. 1, p. 251.

[5] Home Office: Interim Report of the Departmental Committee upon Certain Miscellaneous Dangerous Trades, 1896 [C. 8149], pp. 16, 17.

[6] Lancet (London), 1885, vol. 1, p. 113.

In 1908 T. M. Legge[1] examined 19 workpeople who were exposed to the fumes of carbon disulphide from goods which had been treated with it and hung up to dry outside the range of the exhaust ventilation provided for these fumes. He found muscular tremors in 4, that 7 were cachectic in appearance, and that 2 had slight weakening of the grasp.

Light cases of carbon disulphide intoxication show much the same symptoms as light cases of benzol intoxication. Indeed, Lehmann claims that in intoxication from carbon disulphide, from benzol, and from benzine, there is no difference except in degree. The fact that the benzol used in the rubber industry often contains large amounts of carbon disulphide, sometimes as much as 50 per cent, also increases the difficulty in deciding which is the cause of the intoxication. The odor of carbon disulphide when pure is very like the odor of chloroform, though at a distance it has an added odor, hard to describe, which the Germans think resembles horse-radish. In Lehmann's[2] experiments on human beings it was found that no appreciable trouble was experienced when the amount of fumes in the air was less than 1 milligram per liter (0.016 grain per 2.11 pints). After that there was increasing discomfort, clouding of mentality, headache, and dizziness till the quantity reached 3.5 milligrams per liter (0.057 grain per 2.11 pints), when serious symptoms developed rapidly.[3]

Most of the physicians in our rubber-manufacture towns do not seem to have even heard of the use of carbon disulphide in the rubber industry, nor are they familiar with its toxic properties, consequently it is very hard to determine whether or not our way of using it results in serious trouble. It is certainly possible that the insane asylums have received cases of unrecognized carbon disulphide psychosis, since insane rubber workers are committed from these towns without any inquiry being made as to the exact occupation of the patient and the possible industrial source of his disease. Most of the cases of poisoning discovered in the course of this inquiry were described by foremen of factories, only a few by physicians. These are some of the case histories which were secured:

Typical cases among rubber workers in the United States.

Case 1 was that of a tire splicer who worked at his trade some years ago, before the foreman or anyone else in the factory realized that there was any danger in this sort of work. Suddenly he became maniacal and had to be sent to the insane asylum, but he recovered

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[1] Annual Report of the Chief Inspector of Factories and Workshops for 1908, p. 203.

[2] K. R. Lehmann, Archiv für Hygiene, 1894, vol. 20, p. 71.

[3] C. O. Weber, The Chemistry of India Rubber, London, 1903, p. 195, says that as little as one-tenth of 1 per cent is perceptible in the air and that for hygienic reasons no solvent naphtha should be used which contains carbon disulphide.

completely after a few weeks and came back to the factory to work in another department.

Case 2 was that of an American, 22 years old, who had worked a year dipping rubber goods in a bath of carbon disulphide and who suffered from nervousness, loss of appetite, increasing muscular weakness, and attacks of dizziness. He was still working at the time he was interviewed.

Case 3 was that of a man who, when seen, was splicing inner tubes for tires and had been doing this work for three years. He complained of indigestion, vomiting, feeling of weakness, loss of appetite, and burning of the eyes. He was obliged to quit work every now and then on account of illness.

The foreman of the cold-curing department of a dipped-goods factory was very eloquent on the subject of carbon disulphide poisoning. He said his men used to go crazy from the fumes until he made them work for short spells only, alternating with other work. During the preceding year he had had 12 men under him and all had felt the effects in some way, complaining of headache and dizziness, or indigestion, or loss of mental power, or loss of memory, or muscular weakness, especially in the legs. He himself suffered a good deal from dizziness and severe occipital headache, and had lost strength. He said he always felt the effects of the fumes most at the beginning of the week or after a vacation. Sleeplessness was one of his chief complaints, while one of his workmen said that the fumes made him drowsy all the time—he could drop off to sleep whenever he sat down.

The fumes in this particular dipping room are very imperfectly carried off by feeble exhausts. Three of the men who worked here during the year preceding had had pronounced nervous symptoms. One became partly paralyzed after 18 months' work. His legs were weak, though he managed to get about the house, but his arms were so helpless that his wife had to dress him and feed him. This condition lasted for months. A second man had been at work only one month when he began to get excited without cause and to talk foolishly, wanting to argue about irrelevant subjects. The foreman, familiar with these symptoms, was alarmed and advised him to quit, which he did, and recovered. The third man also had worked only a month when he showed signs of mental disturbance. He was a Hungarian who spoke no English, and the foreman did not recognize his condition until he became very much excited and unmanageable. He was sent home, and his wife reported that he acted so strangely and was so uncontrollable that she took him to a doctor. When the latter asked him about his work he told a long rambling tale of lumbering down the river, and could not be convinced that he had ever worked in a rubber factory. The foreman thought he had recovered, but he never came back to the factory. These last three cases bear out the statement of Laudenheimer that a carbon disulphide psychosis develops after a very short exposure to the poison, while cases of paralysis require a longer exposure.

CARBON TETRACHLORIDE.

In the effort to avoid the fire risk from carbon disulphide fumes several American rubber factories are now using the noninflammable carbon tetrachloride, which is, however, not as powerful a rubber solvent as carbon disulphide and is more expensive. Superintendents and chemists in the factories where the former is used are apparently ignorant of its harmfulness, and this is hardly to be wondered at since the ordinary textbooks of toxicology do not even mention it, and the few that do have very little to say about it. Von Jaksch [1] speaks of severe nervous disturbances having occurred among workmen who used a mixture containing carbon tetrachloride on the inside of boilers to prevent incrustations. Gadamer simply states that this substance is used in industry and may cause poisoning with symptoms like those of chloroform.

The two substances, chloroform and carbon tetrachloride, are of course closely related, both being methane derivatives and differing only in the substitution of an atom of chlorine for an atom of hydrogen. It is to be expected that the physiological effect of the two would be very similar, and it was even suggested some years ago that carbon tetrachloride be used as an anæsthetic, but the action was found to be slower than that of chloroform and attended with more risk. A fatal case of poisoning occurred in London in 1909. At that time the carbon tetrachloride was being used in a certain establishment for a dry shampoo, where it seems several women had experienced discomfort from the fumes, even faintness and transient loss of consciousness. The fatal case was that of a healthy young woman who collapsed in two minutes after the liquid was poured on her head and died almost immediately.[2] At the inquest it was shown that the shampoo had been given in a small cubicle, and the vapors, which are heavy, had probably been present in concentrated form, and as the woman had her head bent down she would breathe more of them. In connection with an earlier nonfatal case of the same kind, Prof. C. R. Marshall,[3] of the University of St. Andrews, stated that this little-known substance was investigated in the sixties by Richardson, Simpson, Sansom, and Nunnely, and at that time was recommended to be given by inhalation for headache, neuralgia, and chorea, but such serious effects resulted from its use that it was given up. Marshall studied its action in 1898 and found that it resembled chloroform, but was more toxic, more irritant to the mucous membranes,

[1] Von Jaksch, Die Vergiftungen, 2d edition. Vienna, 1910, p. 349.

[2] Waller and Veley, Lancet (London), 1909, vol. 2, pp. 369, 1162, 1307.

[3] Colman and Marshall, Lancet (London), 1907, vol. 1, p. 1709.

and much more depressant to the circulatory and respiratory systems. Anæsthesia comes on more slowly than with chloroform, but also passes away more slowly.

Further investigations were carried on after the occurrence of the fatality described above by Waller [1] of the University of London and his assistant Veley. They tested both chloroform and carbon tetrachloride on isolated muscle and found the action of the latter slower but much more deadly. The muscle recovered gradually after chloroform poisoning, but was killed by the carbon tetrachloride. They stated that chloroform is 100 times as toxic as ethyl alcohol; carbon tetrachloride twice as toxic as chloroform. On the other hand, K. B. Lehmann's[2] animal experiments show it to be, in large doses, less than one-half as poisonous as chloroform; in small doses, about equally so. Rambousek finds it only half as narcotic but more irritant.[3]

Of late years physicians have learned much about what is called delayed chloroform poisoning with symptoms coming on many hours after the direct effect of the anæsthetic has passed away. The cause is supposed to be found in a disturbance of the function of the liver cells under the action of the chloroform.[4] It is not known whether such a late form of poisoning can result from the inhalation of carbon tetrachloride also.

The carbon tetrachloride was found actually in use in only three factories. In one of them a man who had dipped rubber goods in a solution for seven months complained of nausea and loss of appetite, which he attributed to his occupation. In another, a tire factory where the liquid is painted on the ends of inner tubes, a workman stated that since he had been doing this sort of work he had lost weight and that he felt a constant irritation of the eyes, nose, and throat. In the third factory two tire splicers believed that their health had suffered from the effects of the carbon tetrachloride vapors. One, especially, said that he had lost many pounds in weight, that he had nausea and loss of appetite, vomited frequently, and felt weak all over. The men who do the work without wearing gloves are liable to a dermatitis of hands and arms.

PHENOL AND OTHER ORGANIC COMPOUNDS.

This finishes the list of poisonous substances which have been found in use in rubber factories in the United States, but it is not a complete list. As has been said, the chemistry of rubber is still in

[1] Waller and Veley, Lancet (London), 1909, vol. 2, pp. 369, 1162, 1307.
[2] K. B. Lehmann, Archiv für Hygiene, 1911, vol. 74, pp. 1-60.
[3] Gewerbliche Vergiftungen. Leipzig, 1911, p. 262.
[4] Wells, Journal of the American Medical Association, 1906, vol. 46, p. 341.

the experimental stage and all the time new substances are being tried out in the various plants and accepted in some and rejected in others. Organic substances which can do the same work as aniline oil are continually sought for, especially in connection with rubber reclaiming. Though it was not possible to visit any reclaiming plant in such a way as to discover what was really being used there, it was easy to learn that large quantities of the phenols of various degrees of crudeness are used. The phenol group have as a common characteristic their excretion by the kidneys, and consequently if the amount taken in is greater than can be decomposed by the kidneys a toxic effect is produced and nephritis results. Poisoning from this group may take place through the inhalation of fumes or through long-continued exposure of the skin to weak solutions or a short exposure to strong solutions. The symptoms of chronic phenol poisoning, the form most common in industrial processes, are indigestion, total loss of appetite, nausea, diarrhea, wasting, headache, irritative cough, and a chronic nephritis which eventually causes death. In Germany the substitution of phenol for aniline in rubber reclaiming is regarded as a great improvement by the factory inspectors, who, however, say that men with weak heart or lungs must not be employed where there are phenol vapors.

Other substances which are used, especially in rubber reclaiming, are pine oil and turpentine and what is called "aniline salt." This last is said to be thiocarbanilide ($CS\ (NHC_6H_5)^2$) and is the product of the action of carbon disulphide (CS_2) on aniline ($C_6H_5NH_2$). On heating with rubber, it is said to decompose, giving off guanidin compounds. Guanidin is classed by Kobert[1] among the nerve poisons producing in animals an irritation which is shown by epileptoid attacks. It affects also the motor ends of the nerves, the centers of respiration and of vomiting and of pupillary dilatation. Still other substances mentioned in connection with rubber compounding and reclaiming are aliphatic volatile poisons belonging to the same group as the naphthas, and also aromatic compounds with properties similar to coal-tar benzol.

LEHMANN'S TABLE OF POISONOUS INDUSTRIAL GASES.

The table following, compiled by K. B. Lehmann from the results of tests made with measured quantities of gases, shows the relative poisonousness of the principal volatile substances used in rubber manufacture.[2] It shows that smaller quantities of aniline can be tolerated than of any other substance, even including the notoriously dangerous carbon disulphide.

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[1] Kobert, Lehrbuch d. Intoxikationen. Stuttgart, 1906, vol. 2, p. 1109.

[2] After K. B. Lehmann, in Kobert's Praktische Toxikologie. Stuttgart, 1912, p. 45.

SMALLEST QUANTITY OF HARMFUL INDUSTRIAL GASES WHICH CAUSE SERIOUS SYMPTOMS AND QUANTITY WHICH CAN BE BORNE WITHOUT INCONVENIENCE.

	Dangerous in one-half hour.	Can be inhaled for one-half to one hour without severe disturbances.	Only slight symptoms after several hours.
Benzine		15 to 25 mg. (0.243 to 0.406 gr.).	5 to 10 mg. (0.081 to 0.162 gr.).
Benzol		10 to 15 mg. (0.162 to (0.243 gr.).	About 5 mg. (0.081 grs).
Carbon disulphide	10 to 12 mg. (0.154 to 0.184 gr.).	2 to 3 mg. (0.032 to 0.049 gr.).	1 to 1.2 mg. (0.016 to 0.019 gr.).
Carbon tetrachloride	150 to 200 mg. in 1 liter (2.304 to 3.072 gr. in 1 qt.).	25 to 40 mg. in 1 liter (0.384 to 0.614 gr. in 1 qt.).	About 10 mg. (0.162 gr.).
Chloroform	70 mg. (1.136 gr.)	25 to 30 mg. (0.406 to 0.487 gr.).	About 10 mg. (0.162 gr.).
Aniline and toluidine		0.4 to 0.6 mg. (0.006 to 0.010 gr.).	0.1 to 0.25 mg. (0.002 to 0.004 gr.).

SUMMARY OF POISONOUS COMPOUNDS USED.

It may be well to summarize briefly the statements as to the use of these substances in the manufacture of different kinds of rubber goods. Molded goods and mechanical rubber may be made with lead compounds if the color does not render this impossible, but they are never cold cured or vapor cured, nor do they require much cement. For rubber tires, lead, aniline, and antimony pentasulphide are used. Much cement also is required, and this cement may contain aniline, carbon disulphide, or benzol. On the other hand, it is only on the inner tubes of tires that the cold cure is used, and it is done in such a way as to require small quantities only of carbon disulphide or carbon tetrachloride. Footwear requires large quantities of lead compounds, of cement, and of varnish, but it is always heat cured, and so far as we know aniline is not added to the compounds. Druggists' supplies may contain lead, but not the white nor the bright red brown articles. These last are colored with large quantities of antimony sulphide. It seems that aniline may also be added to this class of rubber goods. Rubber clothing may be compounded with lead and made on calenders and heat cured, or it may be lead free, made on a spreading machine and vapor cured. In the latter case, naphtha and carbon disulphide fumes will probably be abundant and in either case large quantities of rubber cement are needed. Dipped goods and goods made of thin sheeting are lead free, but involve the use of large amounts of naphtha and carbon disulphide, or carbon tetrachloride or benzol. Finally, hard rubber contains little lead or none at all, needs no cement, and is always heat cured.

PROCESSES USED IN THE MAKING OF RUBBER.

COMPOUNDING.

The first process in a rubber factory which is of interest from the point of view of this investigation is the preparation and measuring and weighing of the chemicals which are to be added to the crude rubber. In some factories the lead compounds are used just as they come from the manufacturer, but in others they are first put through sifting or bolting machines, since it is important to have the compounds as finely separated as possible. Such machines are usually very badly constructed and managed as far as the control of dust is concerned. They frequently leak, and even when they are dust tight, the method of filling them from the kegs and barrels of lead salts leaves much to be desired. In one large admirably constructed plant, with an elaborate "safety and welfare department," the bolting room is described by an investigator as follows:

The room is large with ample natural ventilation, but dust lies thick on the floor, on the covers of the bolters, and on all other surfaces. To fill the machines the men shovel the litharge or sublimed lead from an open barrel and drop it into a big unprotected hopper with an opening 3 feet long by 18 inches wide. A great deal of dust was rising while the hopper was being filled with litharge. When full it was raised about 6 feet and emptied into a bolter through an opening which also had no hood to catch the dust. There is so much dust that it is hard to tell whether or not part of it comes from leaking bolters. The discharge of the bolting machine is better, for the fine powder falls through a canvas chute in the floor to a bin in the room below. Both litharge and sublimed lead are handled in this way. Red lead is not bolted.

In another factory the lead salts are not sifted, but are used just as they come, so that this source of dust is eliminated. It is, however, a plant in which large quantities of litharge are used, and in opening the kegs and dumping them into the storage bins much dust is raised. The foreman said that he found it best to open 26 kegs at once. "At the end of that job everyone feels pretty sick, but it is better to have it over with instead of stringing it along." This man thinks that only about 1 man in 15 can stand the work without getting lead colic or some other kind of lead poisoning. He has been at it for three years, but only a few of his men have stayed as long as one year.

In the compounding room crude rubber is weighed in batches, put in a lidless tin box, and the various chemicals, sulphur, lead salts, etc., are added to it. There is rarely any evidence of care in handling the poisonous powders in a compounding room. Probably the men do not know that one powder is more dangerous than another or that it makes any difference whether or not they stir up dust. The foreman of the room usually answers intelligently when asked about the use of litharge, sublimed lead, etc., but not always. More than once the question as to the use of lead was answered negatively by foremen, and when it was explained that lead meant litharge they expressed surprise and said that they had never thought of litharge as having anything to do with lead. Almost invariably the keg of litharge and the barrel of white lead stand open anywhere in the room, the open scales stand near, the powder is scooped up and dropped onto the scales, sometimes carefully, much more often carelessly, and the weigher commonly uses his hand to take out the excess and drop it back into the barrel. Compounding rooms are often thick with dust, even when the floor is of cement and could easily be kept clean. The men's overalls are covered with powder, which is especially conspicuous when the golden sulphide of antimony is used, for then they often look a reddish brown from head to foot. The fact that a plant is well built and that the management shows unusual interest in the welfare of the men does not at all mean that the compounding room will be found clean and well cared for; often the contrary is true. In one instance this room in a new and beautifully built factory not yet a year old was already inches deep with dust and it was easy to understand why this should be so when one watched the careless, slovenly methods of the old head compounder. At 10 o'clock in the morning he was already covered with dust, and his eyelashes and nostrils were quite white.

In another factory three men weigh out into batches 2,000 pounds of litharge a day, using open scales. The floor is of wood and dusty and is cleaned by dry sweeping. In still another, five foreigners were found working. They did not know anything about the different compounds they were weighing and used their hands to scoop up the litharge and sublimed lead.

In the best plants washing facilities are provided for men in the compounding room, but in many plants they seem to have been overlooked. Even when sinks with hot and cold water are to be found in other parts of the factory, the men engaged in the very sort of work that makes personal cleanliness the most important may be given no proper provision for it. There is a tire factory in which white lead is used instead of litharge, but the men who handle it have nothing in which to wash their hands but a pail of water.

The danger from a dusty compounding room is not always confined to those working in it, since this room may be only partially separated from the mill room, its walls not running up to the ceiling. In one dusty plant the compounding room is in the center of the mill room and the walls are made of wire net only.

A greater degree of cleanliness and care is seen in some compounding rooms, for there are always some foremen who insist upon strict cleanliness for its own sake, even if they do not recognize the danger from dust. In a large tire works in Detroit this department employs 20 men. The room is scrupulously clean, the compounds are kept in covered bins, and that they are handled with great care is evident from the dustless condition of the floor and all other surfaces. Very little litharge is used here, but a fair quantity of sublimed lead. The one improvement which could be suggested for this place is that the weighing of litharge and sublimed lead be done under a hood with an exhaust. This perfectly obvious and simple precaution has not been introduced in any of the factories visited. If one suggests it, the answer is that the scales must be moved from bin to bin and a movable exhaust would be impossible, but obviously a second pair of scales could be procured and used for the lead salts only.

The danger from aniline fumes begins in the compounding room. Five tire factories certainly use aniline, several others may possibly use it, and one uses an "aniline substitute" or "aniline salt," which is probably thio- or sulpho-carbanilide. The aniline is usually kept in the compounding room in large cans and poured from them into measures and sent down to the mills. In one factory many of these cans stood open on the floor of the compounding room. In another, not only were the cans covered, but a heavy piece of canvas was laid over them to prevent the escape of fumes. In still another, the aniline is piped to the compounding room and when needed it is run into small cans, which are then covered. This shows that there is on the part of some superintendents a recognition of the danger from aniline fumes.

MIXING.

The crude rubber, together with the chemicals which are to be mixed with it, is carried in an open pan or box to the mill room and given to the men at the mixing mills. Each man takes his pan, lifts it about as high as his head, and empties it into the open mill, striking the pan repeatedly against the mill to get rid of the last of the powder. The rubber and the dry chemicals are caught and carried between two revolving heated cylinders, which grind the compounds into the rubber. As the mixture is carried around, much of the dry powder falls off and is caught in a mill pan under the cylinders. The workman stoops down and with a long-handled brush sweeps this dust into a pile, scoops it up with a shovel, and drops it onto the rubber in the mill.[1] Every few minutes he cuts off the rubber coming out between the cylinders and throws it back into the mill.[2] This he does over and over again until the powder is thoroughly incorporated with the rubber and no more falls off. At the beginning, when the mixture is first thrown into the mill, and later on, whenever the powder is swept up from the pan and thrown back into the mill and the sheet of rubber cut off and dropped back, a great deal of dust rises and envelops the workman and spreads out into the room. One man may mix as much as 50 batches of rubber a day. The men work rapidly, for they are usually on piecework.

Aniline may be added first, being poured from a can over the crude rubber and mixed in what is called a "warm-up" or "break-up" mill.[3] Then this mixture is taken to the mixing mill and the solid

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[1] See Plate 2. [2] See Plate 3. [3] See Plate 1.

PLATE 1.—WORKING UP THE RUBBER.

The mill nearest is a "break-up" or "warm-up" mill, for working up the rubber; the second is a mixing mill, where compounds and rubber are ground together. There is an apron on this mill, but no hood.

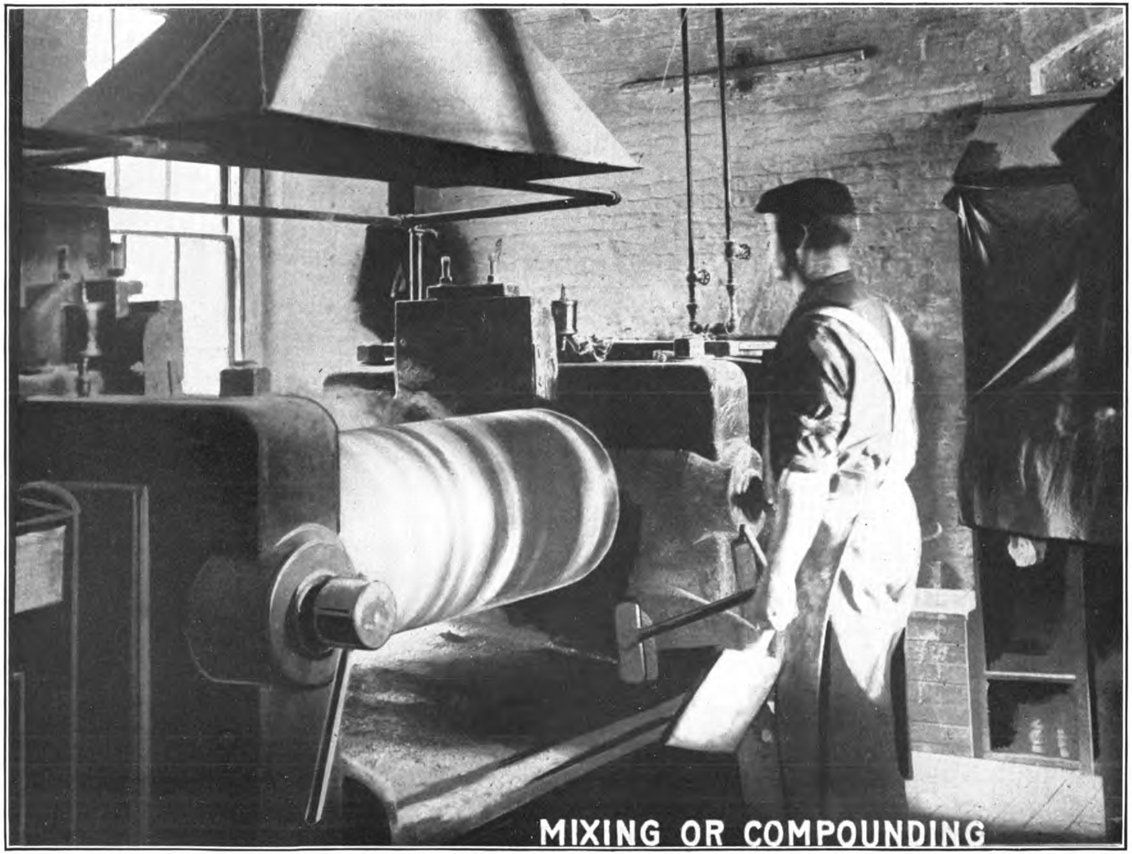

PLATE 2.—MIXING OR COMPOUNDING.

A very common kind of hood over a mixing mill, too open and high to be efficient unless the suction is much stronger than is ever found. The safety clutch bar is seen just under the edge. There is no apron, and the mill pan below is covered with powder, which the workman is about to brush up.

chemicals added, or the aniline and chemicals may go together into the mixing mill. The pleasant nutty odor is easily perceptible near these mills and even near the calenders where the compounded rubber is being spread on cloth.

The mixing mills are often in the same room as other mills and, therefore, others beside the mixers themselves are exposed to the dust and vapors. This dust is or is not harmful, according to the amount of its lead content, although the sulphide of antimony can not be ignored. The danger has been recognized to a certain extent in American factories, and in about half of them hoods have been placed over the mills to catch the dust; but as a rule these hoods are placed too high (as in the mill shown in Plate 2), and the exhaust is far too slight to act with efficiency in carrying off the dust. The usual objection made to the suggestion that the hood be placed lower is that it would interfere with the safety clutch, a device commonly used for protection against accident to the fingers of the millman. This safety clutch consists very often of a horizontal bar running across the mill at about the level of the man's head.[1] He is supposed to grasp this in case the fingers of his hand get caught between the cylinders, and by pulling down on it stop the revolutions of the mill. This bar could not be used if the hood were installed low enough to be of real use. Of course it is not necessary to have this kind of a safety device, and in the better-built factories the bar is placed at one side. In those which use electric power, the mills can be stopped instantly by pressure on a button.

In some factories the hoods are well placed and have inclosed sides coming all the way down to the floor, which adds greatly to their efficiency; but in no case was an entirely satisfactory hood seen. The best ones were in a large Ohio factory for dipped and molded goods, in a large rubber-footwear factory in Indiana, and in the rubber-reclaiming department of an Ohio tire factory. Here the exhausts were strong and the superiority of the hood consisted not so much in its construction as in the strength of the suction. Obviously the best-shaped hood is of no use unless it is provided with a draft strong enough to carry off the dust; indeed, with a very weak draft all it seems to do is to catch the dust and bring it down again, instead of letting it float away as it would if there were no hood at all.

Heil and Esch describe a German device for delivering finely ground compounds to the mills without causing dangerous dust.[2] The mill is fitted with a revolving sieve driven by a toothed-wheel gearing from the axle of the mill. In this the compounds are sifted and fall into a funnel-shaped hopper from which they are dropped onto the rubber on the cylinders. A celluloid cover, transparent, is fitted over the sieve and rests lightly against the rubber rolls, keeping the dust from escaping.

[1] See Plates 2 and 3. [2] Manufacture of Rubber Goods. Translated by E. W. Lewis. London, 1909, pp. 45, 46.

In addition to the zinc lined or iron box, called a mill pan, which is placed under the compounding mill to catch the powder, one often finds the mill provided with a so-called apron,[1] a heavy sheet of leather stretched under the cylinders to catch the compounds and hold them so that the cylinders in their lower revolution will come in contact with them. When they are well adjusted, these aprons seem to save a good deal of the dusty work of sweeping and shoveling, but they never do away with it entirely, and in some cases there is little if any improvement over the ordinary mill pan.

The following description of a mill room in a large, new, unusually well-conducted factory is quite typical, showing as it does a good equipment which simply fails to work. There are 24 mixing mills, all provided with hoods which come down to within 4 inches of a man's head. Each is furnished with two exhaust pipes 12 inches in diameter. The safety stop in front of the hood is easily accessible. The sides of the hood are built down to the floor and the back is filled in with a heavy canvas curtain. The apron is well adjusted and hugs the cylinder closely. The aniline, which is to be added to the compounds in the mixing mills, is brought in 1-gallon open cans. A man fed in the compounds carefully enough with a small shovel, but at the end beat the inverted box several times over the mill to get it empty. As the apron turned, quantities of the powder dropped into the pan and the man stooped down and brushed it into a dustpan and threw it into the mill again. As one stood at the side, it was easy to see clouds of dust come down and escape around the edges of the hood; in fact, it was impossible to see that any of it was carried off by the exhaust. The day was windy and through the open windows the wind blew the dust about. This particular compound seemed to contain a great deal of litharge, and the odor of aniline was very distinct. Another new and well-built factory, making mechanical goods, has not even hoods over the mills, though no less than 130 men are employed in the compounding and mill rooms.

Even worse conditions are, of course, to be found in some of the older and less well equipped plants. For instance, a factory where rubber clothing is made uses, according to the superintendent, tons of litharge every month and chromate of lead is also used in making tan goods, for the combination of litharge and chrome yellow produces a good shade of tan. In this factory the mill room is low and dark and dirty, with windows along one side only. The mills are not provided with hoods and there is no attempt to prevent dust.

Still worse is another rubber-clothing factory, old, neglected, and dirty, with wooden floors worn rough. The long, dark mill room has 15 mills in a double row, all in use. There was an unusual amount of dust in the air of this room and one could see it on the men's faces and in their nostrils. Some of the mills are covered with square-topped hoods

[1]Shown in Plate 1.

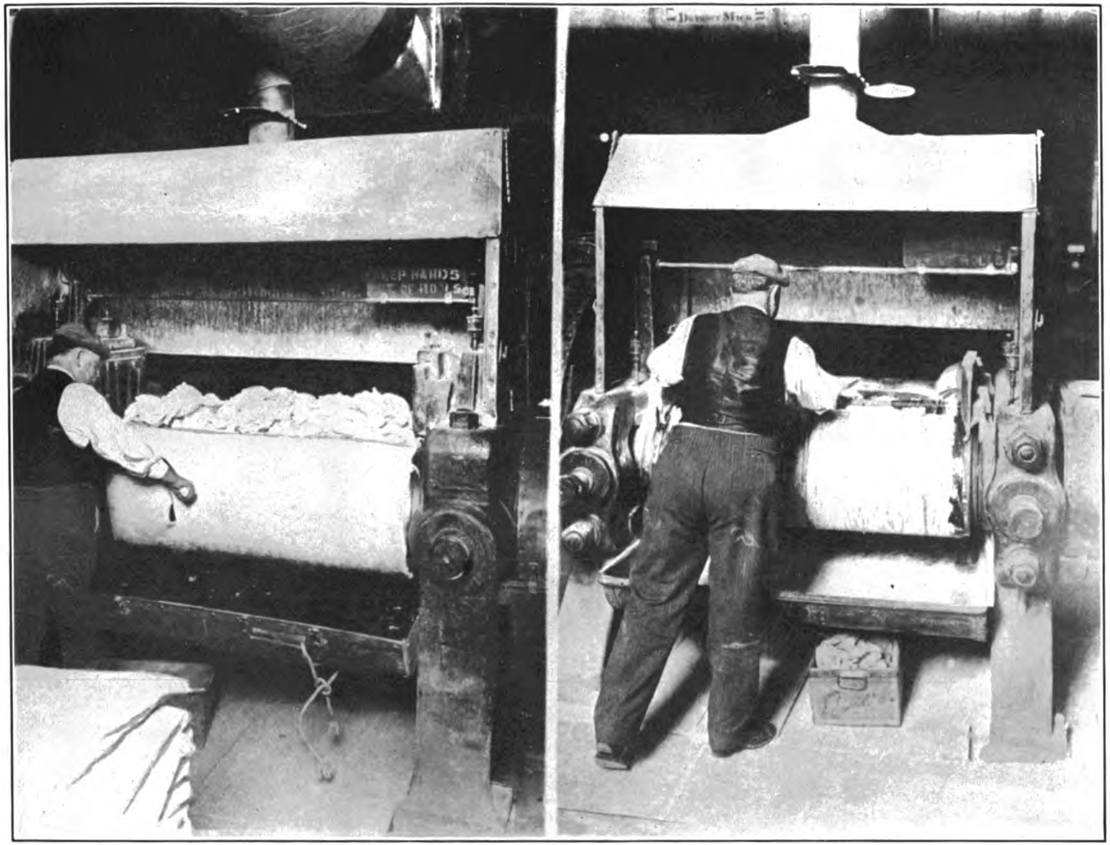

PLATE 3.—MIXING OR COMPOUNDING.

The hood here shown is better than the one shown in Plate 2, for the sides and part of the back are inclosed. The narrow duct, however, would need a very stong draft to carry off the dust.

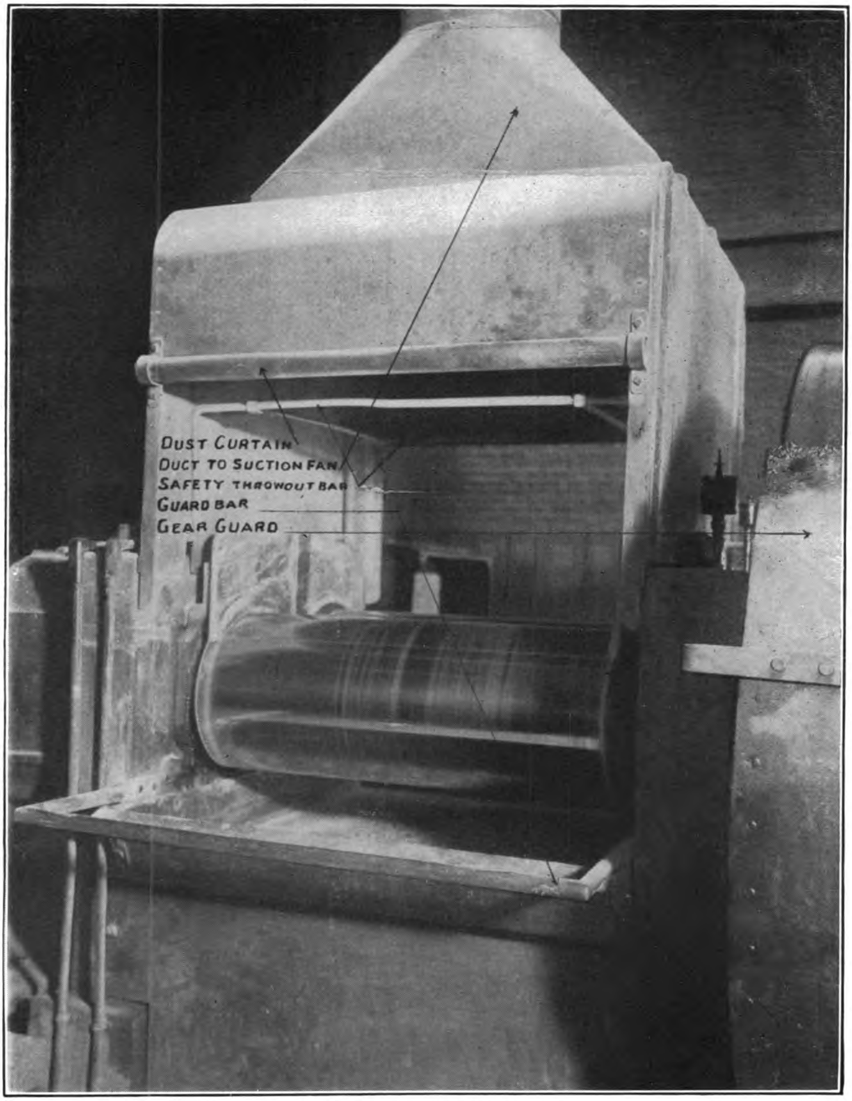

PLATE 4.—A MIXING MILL.

A very good type of mixing mill, with hood, suction pipe, and a curtain which may be let down to prevent dust from escaping.

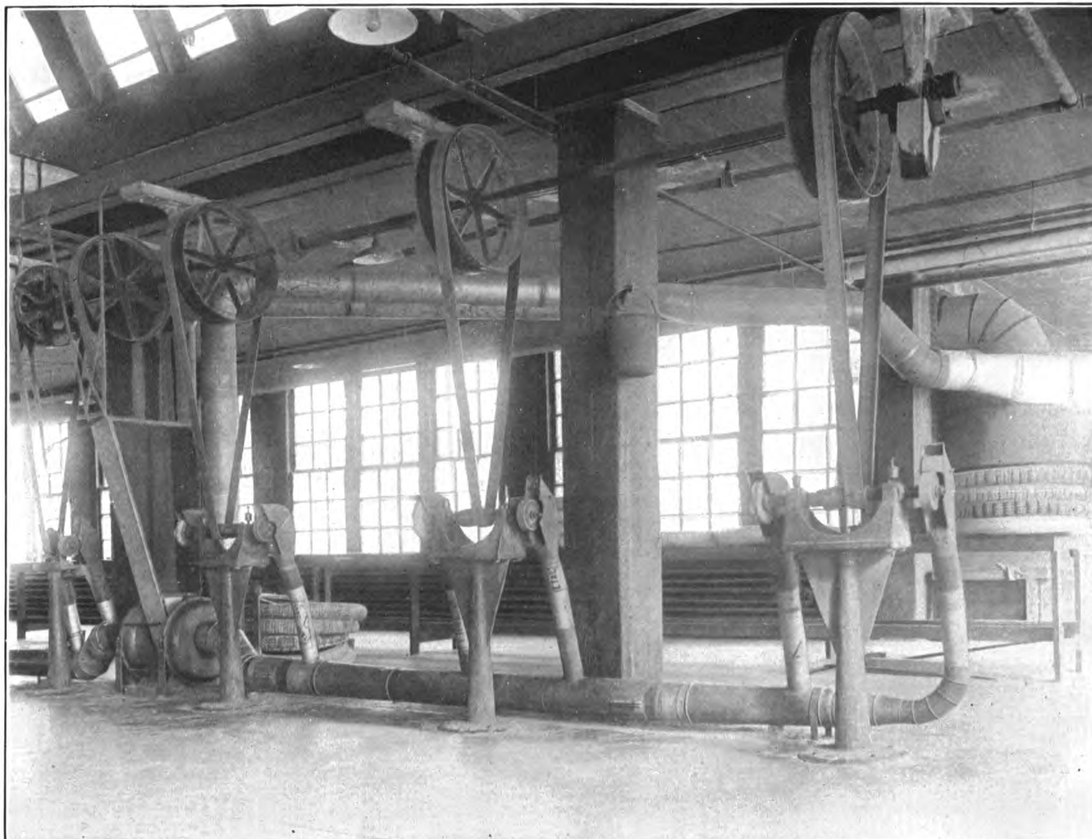

PLATE 5.—MACHINE FOR BUFFING TREADS.

These machines have down suction and a large pipe to carry off dust.

but there seemed to be absolutely no draft at all and the dust lay thick on the tops. Dry sweeping added to the evil, and so did the large wheels and belt at one end of the room which served to keep the dust stirring.

BUFFING AND GRINDING.

After the lead salts and the antimony sulphide have been thoroughly incorporated with the rubber, there is probably no further danger from them in the ordinary handling which takes place in the factory, except in roughening the surface or "buffing," and in grinding up old rubber for "shoddy." A good deal of rubber dust is produced by some kinds of buffing in tire building, but for the most part this dust is not light or dry. It tends to stick together and to fall to the floor instead of flying around, but when there is a great deal of it, when it is allowed to accumulate on the floor and other surfaces, it seems to dry and to be caught up by drafts and blown about, so that in neglected factories the buffers may be seen covered with rubber dust from head to foot. Buffing at a machine which has no air exhaust to carry off the dust is both dirty and dangerous. The usual method of buffing tires is to place the tire on a revolving wheel and hold a file against it as it turns, but in one New Jersey factory the workman slipped a tire around his body and over one shoulder and held it against a revolving file. He and four others were working in front of a window and around them were fully three bushels of rubber dust, which represented the accumulation of four days. In another factory 38 men were buffing tires in the same room at machines provided with hoods, but with so weak an exhaust that none of the dust was carried off. Tumbling or polishing toy balls, also, is productive of a great deal of dust if it is not done in well-closed machines. Hard-rubber dust is much lighter and fluffier and drier than soft-rubber dust, and parts of a hard-rubber factory may be very filthy if the dust is allowed to dry, but this dust is not really as dangerous as the dust produced in tire building, because hard rubber contains little if any lead. The polishing and buffing of hard rubber are always done wet; otherwise the heat produced would be too great.

The grinding of old rubber may be carried on under dust-tight covers, or it may be conducted so that a great deal of dust escapes. Old tires and rubber shoes contain lead compounds and should never be ground without precautions against dust. Most of the better rubber factories now have good exhaust systems in connection with both buffing and grinding.[1] Two samples of rubber dust, one produced by buffing outer tubes of tires, the other by grinding tires for rubber reclaiming, were submitted to the Bureau of Standards of the Department of Commerce for the determination of the presence of lead in such form as to be soluble in the human stomach. Several rubber

[1] See Plates 5 and 6.

chemists had given their opinion that the lead in the process of vulcanizing became so thoroughly incorporated with the rubber that the gastric juice would be prevented from acting upon it. The report from the Bureau of Standards shows that this is not true. The so-called "Thorpe" test was applied to this rubber dust, namely, digestion in 0.25 per cent hydrochloric acid at body temperature for 10 hours. The results showed that the first sample of dust contained only 0.74 per cent of soluble lead, but the second sample of dust contained 6.45 per cent. As lead soluble in the solution of hydrochloric acid used would be soluble in gastric juice also, this test shows that rubber dust may contain a dangerous proportion of lead which is capable of being absorbed by the human stomach.[1]

CEMENT MAKING.

After compounding is over the fumes of aniline continue to be given off to a certain extent, especially when the rubber is heated, but the dangers of the work from now on are due chiefly to the use of the petroleum distillates, of coal-tar benzol, and of carbon disulphide and tetrachloride. On account of the fire risk, naphtha, gasoline, and benzol are kept in a separate room, usually in a little building some distance from the factory. Here the rubber cement and the solution of rubber for dipping and spreading are made in large revolving churns which are usually tightly closed. In a few small factories the mixing is done by hand, a man armed with a large paddle stirring the mixture in an open barrel for hours at a time. Ample ventilation is a necessity in the churn house or the fumes would grow heavy enough to catch fire, but the odor of naphtha in these rooms is almost always strong enough to be decidedly disagreeable. There is little trouble from poisoning among the cement men, however, the reason probably being that no one is obliged to stay in the room steadily; it is enough if the worker enters from time to time to inspect. That the air can be kept perfectly fresh, even when large quantities of cement are made, is shown in one or two very well managed factories, such as a large shoe factory in New Haven and a factory for dipped and molded goods in Ohio,[2] in both of which it is impossible to detect any odor of naphtha in the churn rooms.

The filling of small cans of cement for the trade is carried on sometimes in the churning room, sometimes in a room next to it. Such cement is very apt to contain benzol and carbon disulphide, the fumes of which are much more poisonous than the fumes of naphtha. Carbon disulphide may be an ingredient of other cements also. For instance, in one plant such a cement was being used on the inner ply of tire casings. The greater the variety of cements used the more often the vats must be cleaned out, and cleaning is always a bad part of the work in this department.

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[1] See case described on page 55.

[2] This room is shown in Plate 7.

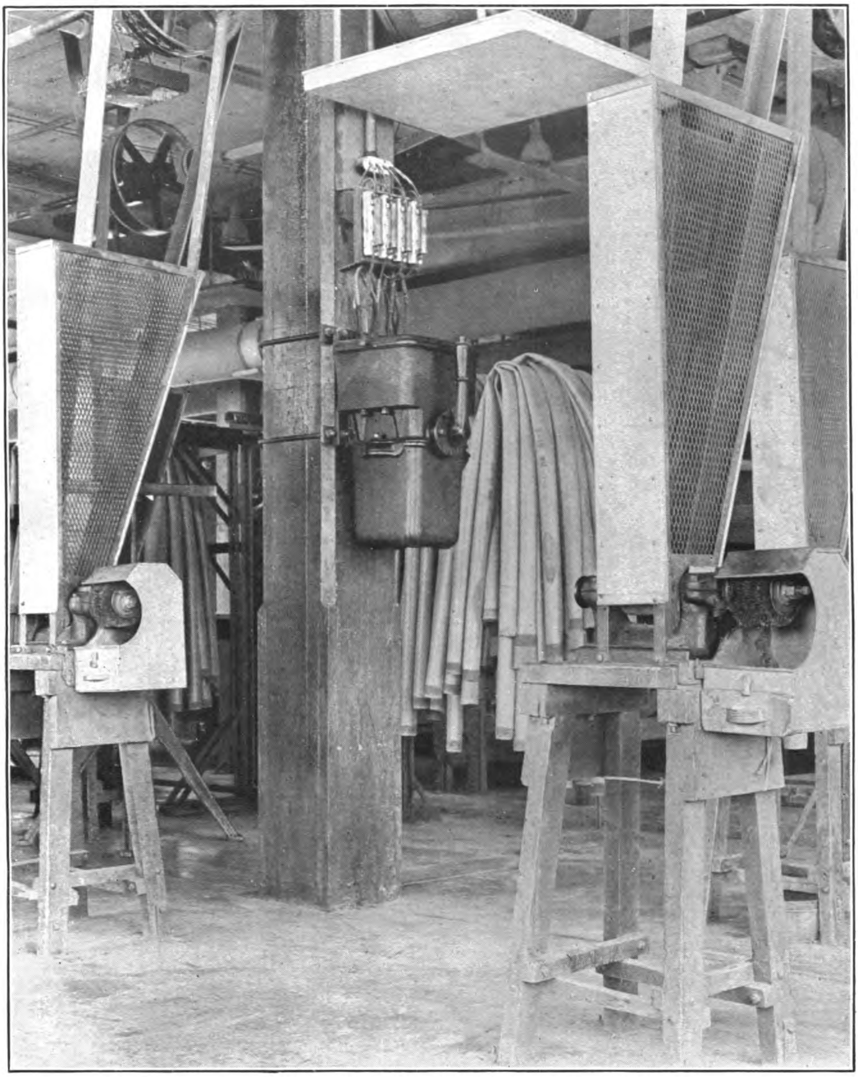

PLATE 6.—MACHINE FOR ROUGHENING ENDS OF INNER TUBES.

Two stiff, revolving brushes guarded by hoods are seen here. The fragments, which are spongy, not dry, are collected in the bottom of the hood.

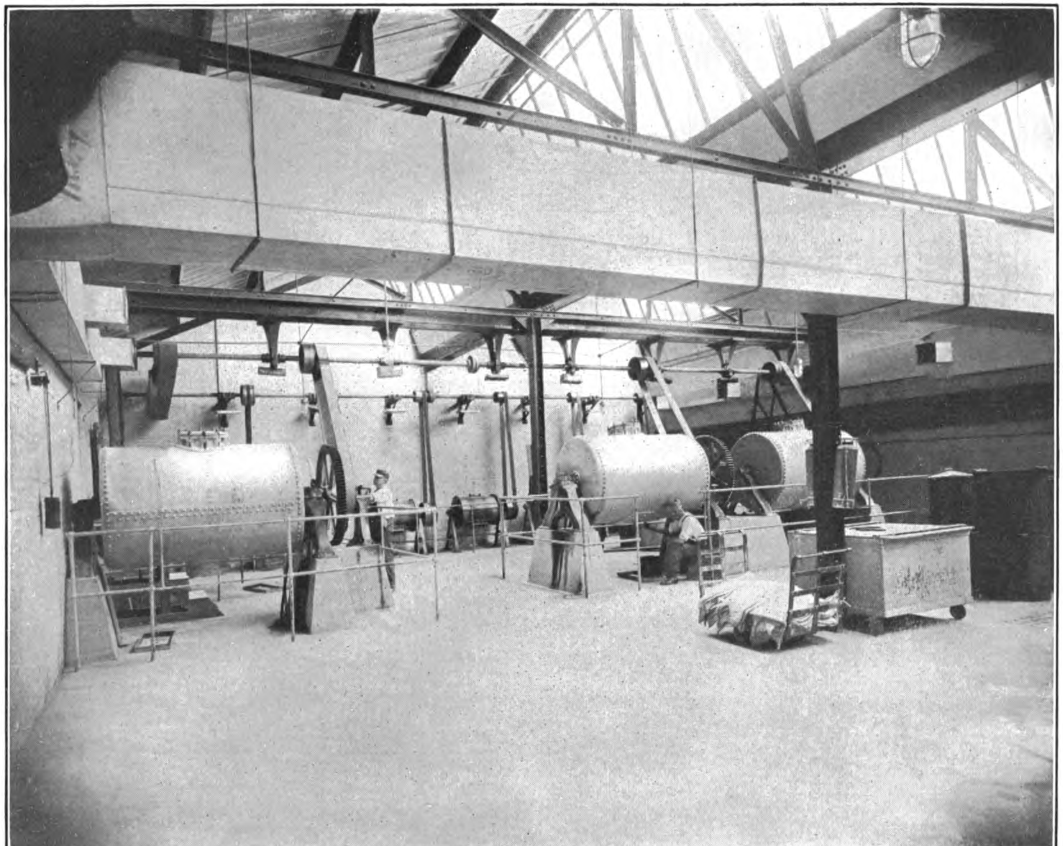

PLATE 7.—CEMENT CHURNING ROOM.

An excellent cement churning room. Artificial ventilation is installed and there is no perceptible odor of naphtha.

The work of filling small cans with cement, mentioned above, is done by hand and requires no skill, so that young lads are often found doing it. This is unfortunate, as carbon disulphide is especially harmful to young people. Their employment in occupations involving exposure to its fumes is forbidden by law in both Germany and Great Britain.

CEMENTING.

The largest quantities of cement are used in the making of dipped and spread goods. The making of calendered rubber clothing, rubber footwear, and medical supplies requires less, but still a decidedly large quantity, and so does the making of tires. Mechanical goods require less cement and hard rubber none.

Rubber cement is used to join together the seams of rubber footwear, toys, raincoats, hot-water bags, tubing, the different layers of tires, and a multitude of other articles. It is a paste of rubber in naphtha or in a mixture of naphtha with certain proportions of benzol, which dries more quickly than naphtha. The proportion of rubber and solvent varies greatly in different processes. Cement is sometimes as thin as a thin soup, or it may be thick enough to handle with a trowel. It is carried from the churning room in large cans, usually but not always covered, and the foreman pours or scoops out portions of it into tin cups or small cans for the use of the cementers. This may be done neatly and the cans carefully covered afterwards, or there may be a great deal of spilling over the floor, and the cans may be left open all the time. On the table beside each worker is a cup with cement and usually one with benzine as well, for edges of rubber can be made to adhere by means of pure benzine or benzol, and in making rubber tubing and inner tubes one of these liquids is sometimes used in place of cement.[1] The cups used by the women hold about half a pint, those used by the men in cementing clothing and tires may hold a quart or more. In one raincoat factory the men use large shallow open pans of cement about 12 inches in diameter. The cement is applied with paint brushes, or sometimes with the fingers. Benzine is often applied with a sponge. In cementing belting in mechanical rubber factories, the men sometimes sit under the table along which the belting is passing, and paint on the cement, a bad method because naphtha fumes are heavier than air and are worse near the floor than at the height of a man's head.

Often there may be as many as a hundred and fifty or two hundred men and girls working with cement in one large room of a footwear or clothing factory, but the rooms are usually abundantly provided with windows with a cross draft. Seldom was the air found to be unpleasantly contaminated with naphtha fumes, and frequently they

[1] See Plate 8.

were barely perceptible. The workmen say that in heavy, hot weather work in these departments may be very trying, but though these investigations were made during May and in the early part of June, when the weather was fairly hot, and again during very cold weather in November and in February, conditions in cementing rooms were found to be almost invariably good. It is probable, however, that in simply passing through a room one can not estimate the effect of the fumes as they are experienced at the workbench during a 10-hour day.

The air is usually better in the rooms where women only are employed than where men are working, for the men seem to feel the discomfort of the fumes less or else they are more afraid of cold air and drafts. In one great double room on a cold autumn day 400 men and women were working with cement, every window closed and no artificial ventilation. The air was very heavy and oppressive, but in another cementing room with about the same number of women only, the windows were open and conditions much better.

The workmen sometimes complain of very disagreeable and sickening fumes from benzine when they are obliged to pour benzine over two sheets of rubber which have stuck together in order to soak them apart.

If there is much trouble from the naphtha fumes, and the very general provision of first-aid rooms for the girl cementers seems to indicate that there is, it is strange that there has not been more effort to prevent evaporation of the cement and naphtha. In only three factories have cups with covers been provided. In all the others the idea seems not to have occurred to anyone, or else it has been rejected as impossible. Of course, it is perfectly simple to make a tin cover so shaped as to allow the brush to enter without removing the lid. In one factory the lids are shaped like a shallow funnel with a hole just large enough to let the brush pass through. In another factory the cups have little tin valves to protect the openings. There is absolutely no difficulty in the use of such covers and it is hard to understand why they are not found everywhere. There will always be some naphtha in the air from the cement that has been smeared on the goods, but at least one important source of air contamination has been removed when the cups are covered. The superintendent of one tire factory where the naphtha cups have been provided with "floater lids" said he saved enough gasoline during the first week of their use to pay for the making of the covers.

The largest shoe factory in the country has installed a machine for cementing inner soles. The strips of rubber are placed on a traveling belt and pass under a cement brush along a closed runway which extends the length of a large room and which is connected by means of fans with the air-exhaust system. By the time the end is reached

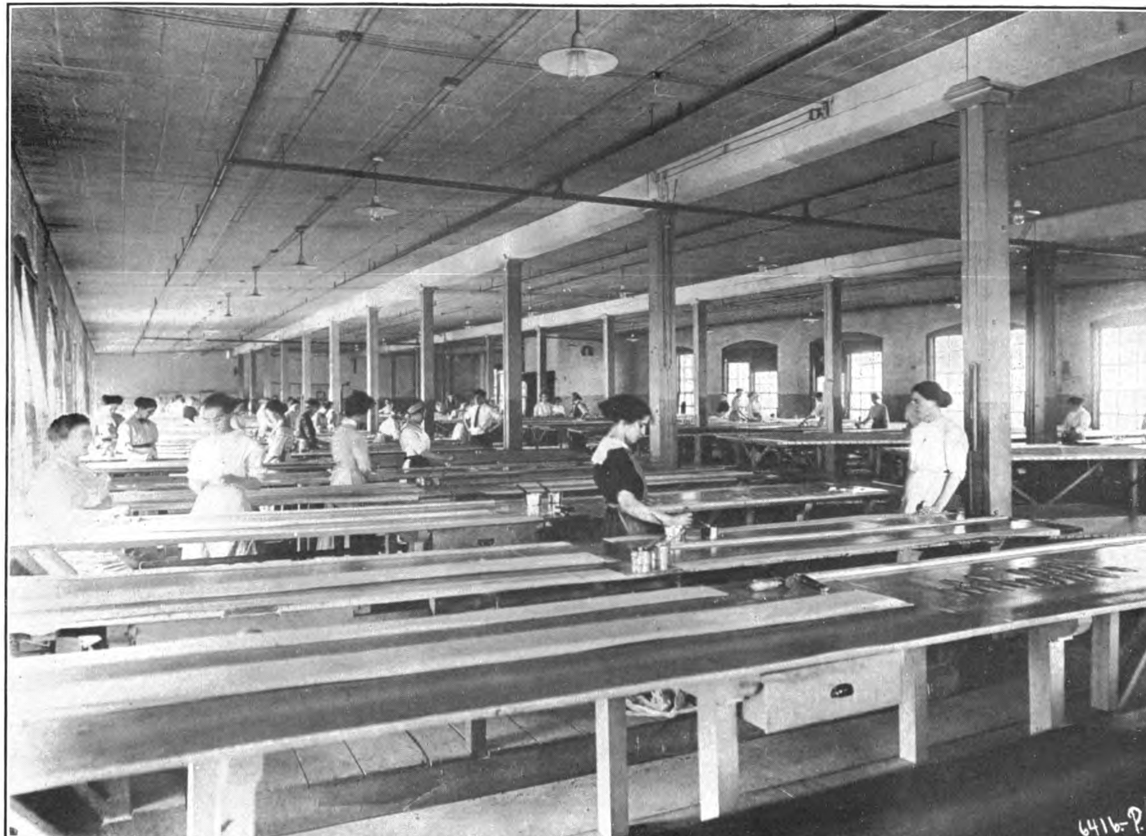

PLATE 8.—CEMENTING INNER TUBES AND VALVE PATCHES FOR TIRES.

The open cans of cement and benzine stand on the tables. The room is spacious and has ample natural ventilation.

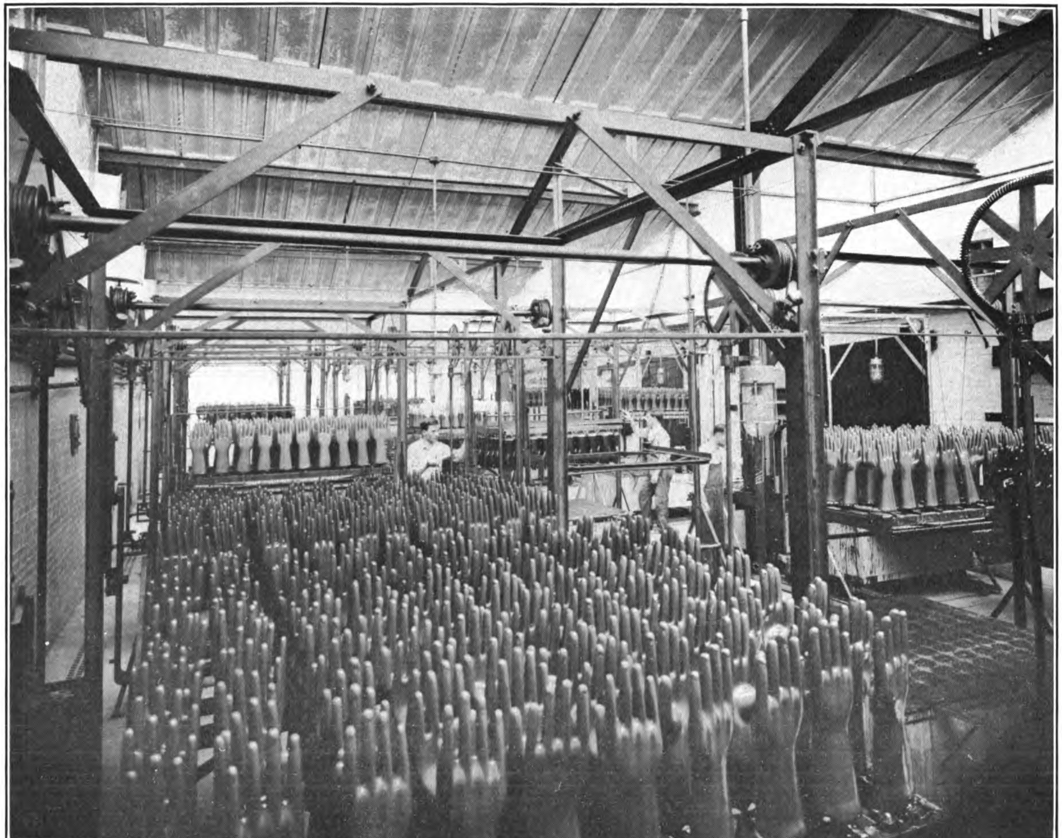

PLATE 9.—DIPPING ROOM.

A very good dipping room. The tanks of rubber solution, one of which can be seen in the lower right-hand corner, are closed when not in use. The vent for the vapors can be seen in the floor on the left.

the naphtha has evaporated sufficiently. Another mechanical device for the application of cement was seen in the making of rubber-coated thread for cord tires. The thread passes through the rubber solution and dries inside a small warm room which is provided with an air exhaust.

DIPPING.

Much more trouble from benzine fumes is experienced in dipping and spreading than in cementing. Goods made by dipping are the seamless rubber gloves, nipples for nursing bottles, finger cots, toys, face masks, plain bathing caps, and balloons. Celluloid or wooden forms are dipped in a solution of rubber in benzine and allowed to dry, then dipped again and again until a thick enough layer of rubber has been formed, when it is thoroughly dried and vulcanized. Naturally, in drying there is always a great deal of benzine fume given off, for the drying consists in the evaporation of the benzine.

The largest factory for dipped goods has a big dipping room with windows upon three sides, but these are not used for ventilation since the process requires a fairly even heat of 90° F. (in some places 98°). Also, since the vapors of naphtha and benzol are heavy, window ventilation would be of little use and the only proper way to get rid of the fumes is by down suction. In this plant the floor is slatted, warm air is driven in from above and drawn down through the openings in the floor. There are long tanks, some of which are filled with a solution of pure rubber in benzol for making surgeons' gloves, and others with compound rubber in naphtha for lower-grade goods. A rack filled with forms of gloves or balloons is dipped by machine very slowly into a tank, lifted up with its thin coating of rubber, allowed to drip for awhile over a pan, then inverted and swung to one side to dry, and the tank covered until the next dipping. The forms are dipped nine or ten times and each time the tank is left exposed from 7 to 10 minutes. About 10 tanks can be managed by one man, who moves from one to the other, leaving the drying forms behind him. In this particular plant there are four dippers on the day shift and four on the night shift, one inspector, and two men to fill the tanks and clean them out. In spite of the artificial ventilation the air here is heavy with fumes and the heat renders it still more oppressive.

A better dipping department than this is found in the second largest factory for dipped goods.[1] Here an elaborate system for artificial ventilation has been installed, to control not only temperature and change of air, but humidity also. The quality of the dipped goods can easily be injured by too rapid evaporation on dry days and by too slow evaporation on humid days, so that it is a matter of commercial importance to keep the humidity of the air constant at

[1] See Plate 9.

the right degree. Fortunately this is also a great advantage to the workmen, who suffer far more from the naphtha fumes on heavy, damp days. In this particular plant the dipping is done in three separate rooms, lighted from the ceiling, cement floored, white walled, and absolutely clean. Only two men work in each room, taking charge of 12 tanks apiece. The temperature in the rooms for compound rubber is only 80° F., for pure rubber 90° F.

Only three factories with extensive dipping departments were found, and all of these had artificial down-draft ventilation. In smaller departments in other factories natural ventilation is depended upon and no particular precautions are taken. The dipping room is not even completely separated from the rest of the plant in several places, and not only are the naphtha fumes allowed to escape into the factory, but the cold curing of these dipped goods, to be described later, is done in such a way as to add to the contamination of the air of the dipping room.

SPREADING.

Spreading is one method of making waterproof goods; that is, of covering a strip of cloth with a layer of rubber. It is not as common in the United States as calendering, which means passing the cloth and very thin rubber sheeting between heated rolls which press the rubber into the fabric. In spreading, a solution of rubber is used, a more or less thick paste with naphtha as a solvent. It is customary in this country to put the fabric and paste first through a frictioning machine, which rubs in the paste till the cloth is thoroughly impregnated, and then less spreading is needed. This method is not used in Europe, we are told, and therefore the goods must be passed much oftener through the spreading machines.

A spreading machine consists of a table with heated rolls over which is suspended a spreading knife in such a way that it almost touches the outermost roll.[1] The fabric passes under this knife, and as the workman places against it a portion of the rubber dough the knife spreads it over and presses it into the cloth, which then passes on along the spreading table over steam-heated pipes, the heat making the naphtha evaporate. All the solvent in the paste must be driven off in this way and, of course, it is driven into the air of the room, unless some artificial means of removal has been provided. Fortunately the fire risk from naphtha vapors is sufficiently great to insure at least abundant natural ventilation in rooms where this work is done, yet in spite of open windows the air is often heavy with fumes, which on murky, damp days are said to be extremely trying.

Spreading is done in 11 of the 35 factories, but in only 3 are there as many as 10 men employed in such work. Conditions in these rooms vary a great deal according to the weather. For instance, in a Mas-

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[1] See Plate 10.

sachusetts factory, which was visited on a fresh, clear day in May, the air in the spreading room was not at all disagreeable, even though there were 10 machines in the room, the ceiling was low, and the only ventilation was through windows. However, the foreman said frankly that in hot, heavy weather conditions in the room were almost unbearable.

Only two of the eleven have artificial ventilation, and of these one has it in one of its two spreading departments but not in the other. The better of these two factories, a plant in New York, was visited on a very hot day in June, and even then the air in the large spreading room was excellent. The ceiling of this room is high, the cement floor perfectly clean, and there are large windows on opposite sides of the room. Instead of placing long hoods over the spreading machine, exhaust pipes have been installed, for it was found that the hoods caught the hot air and prevented it from rising to the ceiling and that the temperature of the room after the hoods were introduced had been raised from 98° F. to 106° F.

A process somewhat similar to spreading is used in the making of very light rubber shoes, called "zephyrs." The cloth shoe is dipped in a solution of rubber in naphtha, dried over heat, and then a rubber sole cemented on.

PRINTING.

Printing rubber cloth is another process which involves exposure to naphtha fumes. This was seen in one plant only. The pattern in imitation of cloth is printed on rubber goods in a regular printing press. The colors are mixed with naphtha, and as the cloth travels along through the press it dips into a long narrow trough of naphtha under the roller. There was one man at work at the press. He said that he usually felt the effect of the naphtha for an hour or so at the beginning of the morning, then grew accustomed to it, but felt it again when he went out into the open air at the end of the day's work. His food often tasted of it.

VARNISHING.

Finally naphtha is used in the varnish for rubber boots and shoes. This contains turpentine as well, and rarely acetate of lead. Here again the risk from fire is great, and the work is carried on in special fireproof rooms, which are not always, however, well ventilated. The varnish is kept in large open tanks, and the racks of shoes are dipped into it and then set aside on a drip board to dry.[1] There may be a dozen such tanks in one room, and they are almost always left uncovered when not in use, though one would suppose that the loss from evaporation would be great enough to be considered. Opening out

[1] See Plate 11.

of this room is the hot chamber or furnace in which the varnish is dried and from which heavy fumes escape when the finished shoes are taken out. For cloth-topped rubber shoes the varnish is applied with a paintbrush.

VULCANIZING.

There are many ways of vulcanizing or curing rubber in the United States, but the methods fall under two main heads, heat vulcanization and the Parkes process. In heat curing, flowers of sulphur are mixed with rubber and other compounds and chemical action is brought about by heat, which may be applied in the form of steam or dry ("open heat"), with mechanical pressure, as in the case of molded goods, or under gas pressure or without pressure. In the Parkes process the sulphur is applied to the surface of the rubber in the form of sulphur monochloride. The sulphur monochloride may be in vapor form or liquid and may be pure or mixed with some rubber solvent.

In general it may be said that heat curing is always used for tires, molded goods, mechanical rubber, medical supplies, except gloves, and hard rubber and footwear. The Parkes process is used for balloons, finger cots, and colored bathing caps. Both methods are used in the curing of rubber clothing, gloves, toys, balls, nipples, rubber sheeting, and rubber dam. The inner tubes of tires may also be cured by either method. Almost always the method used for splicing these inner tubes, as it is called, is to roughen the surface of the two ends by buffing, then paint over the roughened parts with a mixture containing sulphur monochloride and join them together. In one factory, however, the sulphur monochloride is not used and the inner tubes are heat cured.

The tendency in the United States is to give up the Parkes method and to use heat curing even for rubber dam and for colored goods. Vulcanization by means of the sulphur monochloride with carbon disulphide can in any case be used only for thin goods, for the penetrating power of the mixture is not great. Aside from this, however, the method is said by many American chemists to be uncertain and unreliable, especially in a climate with such extremes of temperature as ours. Even in England we are told that steam curing is beginning to take the place of the cold cure. Seeligmann, Torrillon, and Falconnet[1] say that the Parkes method is not only bad for the workmen, but deteriorates the goods, and the factory inspection report for 1910 states that the use of carbon disulphide in vulcanizing has been practically abandoned.

For heat curing, especially dry heat, lead in some form is usually added as an aid and an accelerator of the process. Aniline also may

[1] Seeligmann, Torrillon, and Falconnet, India Rubber and Gutta Percha, London, 1903, p. 136.

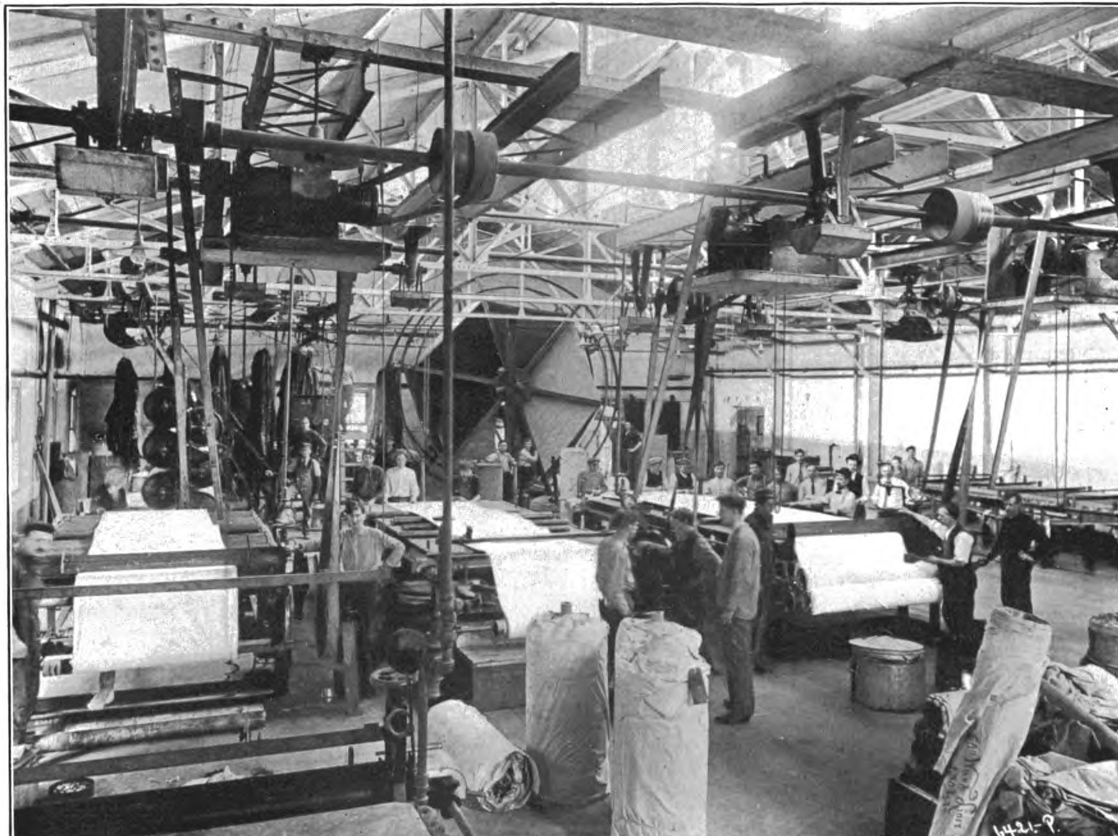

PLATE 10.—SPREADING.

The cloth passes under a long knife, which is hung at one end of the "spreading" table, and then along over heated rolls. A can of rubber dough or paste stands near, and the spreader (seen best at the right-hand machine) scoops out the dough and drops it along the edge of the knife, which spreads it and presses it into the fabric. There is only natural ventilation in this room.

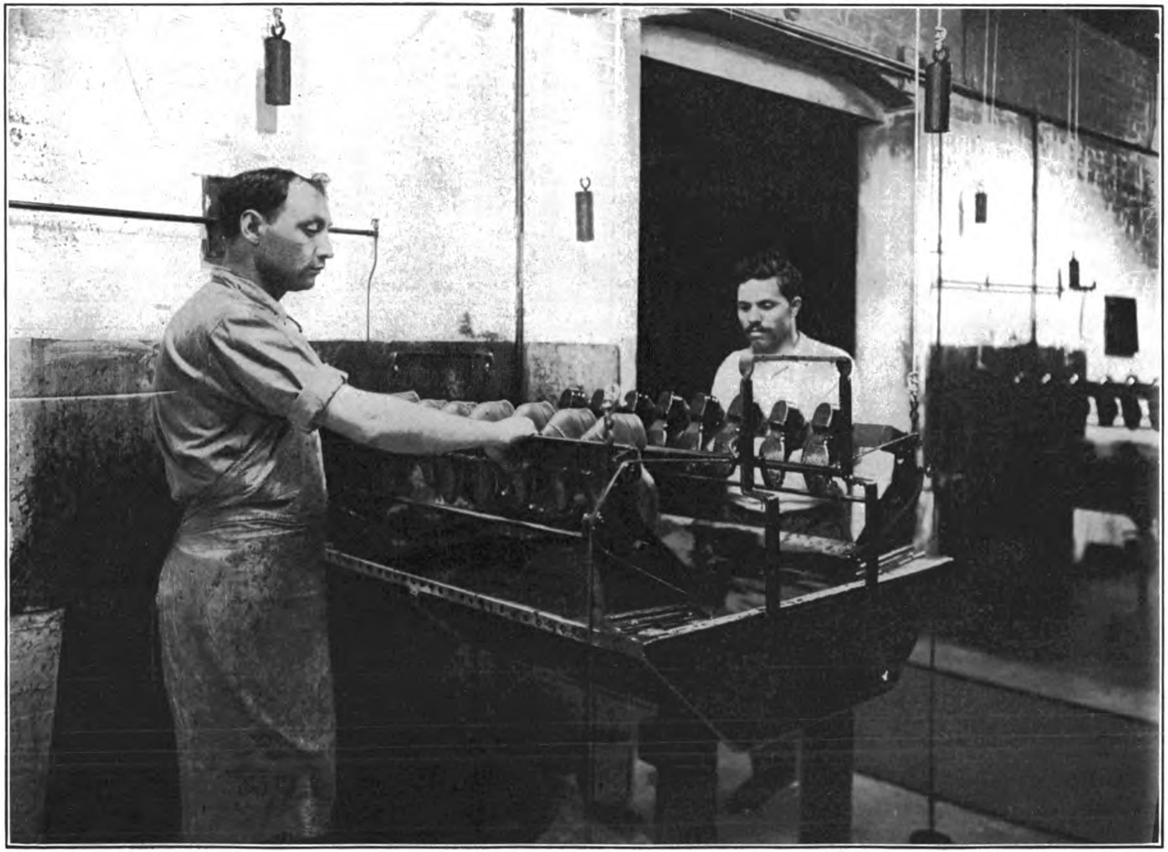

PLATE 11.—VARNISHING SHOES.

Varnishing shoes is effected by dipping racks of them into a tank of varnish.

be used, though many rubber chemists are skeptical of its value.[1] It is, however, steadily gaining ground, especially in the tire industry, and there are rubber chemists who claim that by the use of aniline and magnesium salts the lead compounds are rendered unnecessary.

In two factories aniline has been replaced by "aniline salt," and a large number of other organic substances are coming into use for the same purpose (see p. 34).

HEAT VULCANIZING.

Goods that are to be vulcanized by steam must first be wrapped or laid in beds of talcum or placed in molds to keep their shape. For dry heat this is not needed, but in both processes it is necessary to powder thoroughly all surfaces to prevent them from adhering while they are hot. Soapstone, talcum, or pumice is used in steam curing; flour or corn starch may be substituted in dry curing. In certain processes enormous quantities of such powders are used. Hot-water bags are sometimes filled with talcum and then laid in it; rubber tubing is always plentifully sprinkled and then placed on a talcum bed. Rings for jam jars are so thoroughly powdered that the girls handling them have to wear caps to protect their hair. The sifting and scattering of this soapstone or talcum or flour are productive of enormous quantities of dust and usually there is not the least effort made to lessen it. Even in factories otherwise well supervised the talcum rooms are sometimes covered with the white powder, which then must be swept up and sifted and used again. Everyone in the room is covered with the powder. This is, of course, simply bad management. In several of the better plants no dust is allowed to fall on the floor and no sifting is necessary. The so-called dust room may be perfectly clean if only proper care is taken.

Boys are often employed in the dusty work, especially in the wrapping of tires and in the tubing department, where they are powdered like millers. The rubber tubes are laid on long tables covered thickly with talcum and are cut into lengths. In one New Jersey factory an effort is made to protect the boys who do this work, and a long flue with canvas sides and an exhaust at the end to carry off the dust has been built over the cutting table. There is an electric light inside,

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[1] The action of lead in vulcanization and also of the organic compounds, such as aniline, was explained recently by Eugen Seidl in the Gummizeitung, vol. 25, p. 710. By the addition of moderately large amounts of lead oxide vulcanization may be completed in half or less than half the time required when lead is not used. The addition of some organic substance like phenol to a mixture of lead oxide and sulphur causes a vigorous reaction with great evolution of heat, and a still more vigorous reaction is caused by the addition of aniline or its homologues. The heat evolved is due to two causes: First, the reaction of sulphur upon an organic substance (aniline) with the formation of hydrogen sulphide; and, second, the reaction between hydrogen sulphide and lead oxide with the formation of lead sulphide and water. It is evident, then, that litharge and aniline accelerate the process of vulcanization by promoting reactions which generate heat in the vulcanizing of rubber.

and the boys work through a small opening made by raising a flap of curtain.

In curing by steam and pressure there is a source of lead poisoning which seems to have escaped attention, the making of lead molds for molded goods. These goods are rubber articles which are shaped and vulcanized simultaneously by means of steam heat applied under great mechanical pressure. Strips of rubber are placed in hot molds, these are closed and pressed together, and the heat is great enough to melt and mold the rubber into the proper shape.[1] For large objects of simple shape, such as hot-water bags and fountain syringes, steel molds may be used, but they are very expensive and it is cheaper to use soft metal when the shape is complicated, the decoration elaborate, and the fashion likely to change. Hard-rubber goods, druggists' supplies, toys and balls, plumbers' rubber, matting, gaskets, heels and soles are all cured in lead molds. These molds are made in the factory and the old ones are melted up so that the lead can be used again. In one druggists' supply house there are four kettles of lead and two of a mixture of lead, zinc, and tin, and 12 men are employed making molds. The kettles of melted lead are a source of danger unless hooded, for fumes of lead oxide escape when the workmen stir, skim, and ladle out the lead. An additional danger arises when the lead skimmings are thrown onto the floor, where they are ground to dust, which contaminates the air.

PARKES PROCESS.

This process is usually called cold cure, or acid cure, and vapor cure.

No matter how carelessly heat curing may be done, the risk to health is slight, but in cold curing the danger to health is great enough to cause the Europeans to class the rubber industry among the dangerous trades. As already stated, in cold and in vapor curing rubber is vulcanized or cured by the application of sulphur monochloride. Three methods of applying the sulphur monochloride are in use in the United States: First, exposing goods to the vapor, which is called the vapor cure; second, dipping them into a mixture of sulphur monochloride and some rubber solvent, known as the cold or acid cure; third, painting the surface with such a mixture. The first method is applicable only to very thin goods, for the vapor does not penetrate far. Dipping is used for somewhat heavier goods; painting only for the ends of inner tubes of tires and for horseshoe pads. Twenty-four of the thirty-five plants visited use one or more of these methods of vulcanization. The eleven factories in which no cold curing is done manufacture footwear, clothing, mechanical rubber, insulated wire and cables, and hard rubber.

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[1] See Plate 12.

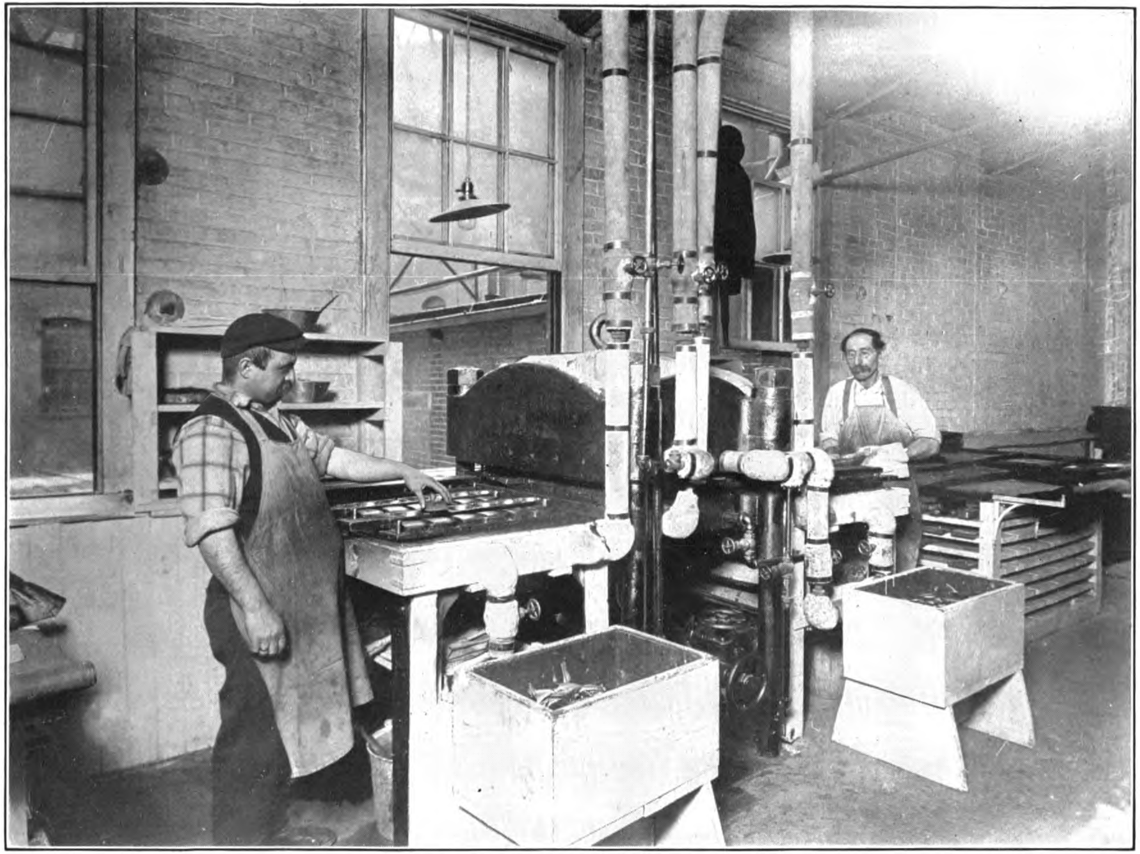

PLATE 12.—MOLD CURING.

The rubber articles to be vulcanized (in this case heels for shoes) are placed in leaden molds and subjected to heat under a hydraulic press.

Vapor cure.

This method is rarely used in the American rubber industry. In vapor curing the objects to be vulcanized are spread out or hung up in a chamber which is warmed by coils of steam pipes. Shallow receptacles filled with sulphur monochloride, or more often with a mixture containing a small portion of it, are placed on the floor of the warm chamber, which is then closed and the vapor, the evolution of which is hastened by the heat, is allowed to act upon the rubber. When the pure sulphur monochloride is used it is generally placed in a small cabinet opening into the vapor room and the fumes, mixed with the proper proportion of air, are drawn into this room by suction.

At the completion of the process the further action of the sulphur monochloride is stopped by driving in steam or vapors of ammonia or sometimes simply by opening up the airing chamber. In three factories the sulphur monochloride is used pure and here there is, so far as we know, no danger to the workmen. In another, benzol is the diluent used. This is not free from danger, but is decidedly less dangerous than carbon disulphide, which in the other three plants is mixed with sulphur monochloride in the proportion of 20 parts of the former to 1 of the latter. One of these factories has a vapor chamber built inside a large room, with no direct connection with the outer air. At the completion of the cure the workmen open the door opposite a window and wait five minutes before going in, but this is not nearly long enough to clear the air. It was easy to smell the characteristic odor of these vapors as one approached the factory, though the vapor room is on the third floor, and the odor was very strong in the neighborhood of this room. The vulcanizers here work the full 10-hour day. In a second factory vapor curing is carried on in two small basement rooms opening on a narrow courtyard between the factory buildings. No one is exposed to the vapors as long as the process continues and the men are cautious about entering before the vapors have cleared away, but the only way to get rid of them is to open windows and doors and that means that the fumes spread in the narrow courtyard and enter the windows of the ground floor. In the third factory the work is better managed. There is a small separate building on the roof into which are put reels of rubber dam and racks of pure rubber gloves. Saucers filled with the carbon disulphide mixture stand on the floor, and when the cure is completed live steam is turned into the room to drive out the vapors. Two workmen are employed here for about two or three hours a day.

Vapor curing is the cheapest method of vulcanization in labor and in equipment, but it can be used only for the very thinnest goods, such as surgeons' gloves, rubber dam, bathing caps, finger cots, babies' bibs, barbers' aprons, and the poorer grade of clothing.

Cold cure or acid cure.

In cold curing or acid curing, rubber gloves, balloons, toys, nipples, and so on, stretched on forms, are dipped in a vulcanizing solution which consists of the sulphur monochloride and some rubber solvent, almost always carbon disulphide, and then set up to dry. There is a great deal more carbon disulphide used in this process than in vapor curing, and the fumes are more likely to do harm because, coming from open tanks and from drying goods, they are more widely diffused than the fumes produced by the other method. In vapor curing, if simple precautions are taken, nobody need be exposed to fumes, but in dipping they can not be escaped unless the process is carried on mechanically under cover. There was only one factory in which a very dangerous method was found in use which is described as that used in British factories. In the English report already referred to on dangers in the rubber industry,[1] it is stated that rubber cloth is vulcanized on a machine similar to a spreading machine, the cloth passing over rolls, dipping into a long trough filled with carbon disulphide and sulphur monochloride, and then being taken off and hung up on crossbeams to dry. This method of curing was found in a rubber-clothing factory in New England.

Nine of the thirty-five factories cure goods by dipping in tanks containing the curing liquid. In one, the vehicle for the sulphur monochloride is carbon disulphide mixed with an equal part of tetrachloride, but in the others it is all carbon disulphide. In English, French, and German textbooks the proportion of sulphur monochloride to carbon disulphide in the Parkes process is stated to be 1 to 40 or 1 to 100. Pearson[2] says that the proportions used in American factories are 1 to 30 or 40, but for balls and balloons the proportion of disulphide may be even higher.

None of these nine plants has installed exhausts strong enough to keep the air of the dipping rooms clear of vapors, but in one the whole process has been made mechanical, and is done under cover. This is one of the smaller plants, the owner of which is also the manager. He said quite frankly that he had been forced to devise some method of protecting his men because he had had so much trouble from the fumes. The men suffered with headache and weakness in the arms and legs and some of them even "went silly." His arrangement consists of a small brick room quite separate from the rest of the factory and containing a closed cabinet which holds a small tank of the curing solution and is ventilated with a strong exhaust. A rack of gloves or other goods is placed inside this cabinet and the door closed. By means of a handle outside the rack is

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[1] Home Office, Interim report of Departmental Committee on Certain Miscellaneous Dangerous Trades, 1896 [C. 8149], p. 15.

[2] Pearson, Crude Rubber and Compounding Ingredients. New York, 1909, pp. 54, 55.

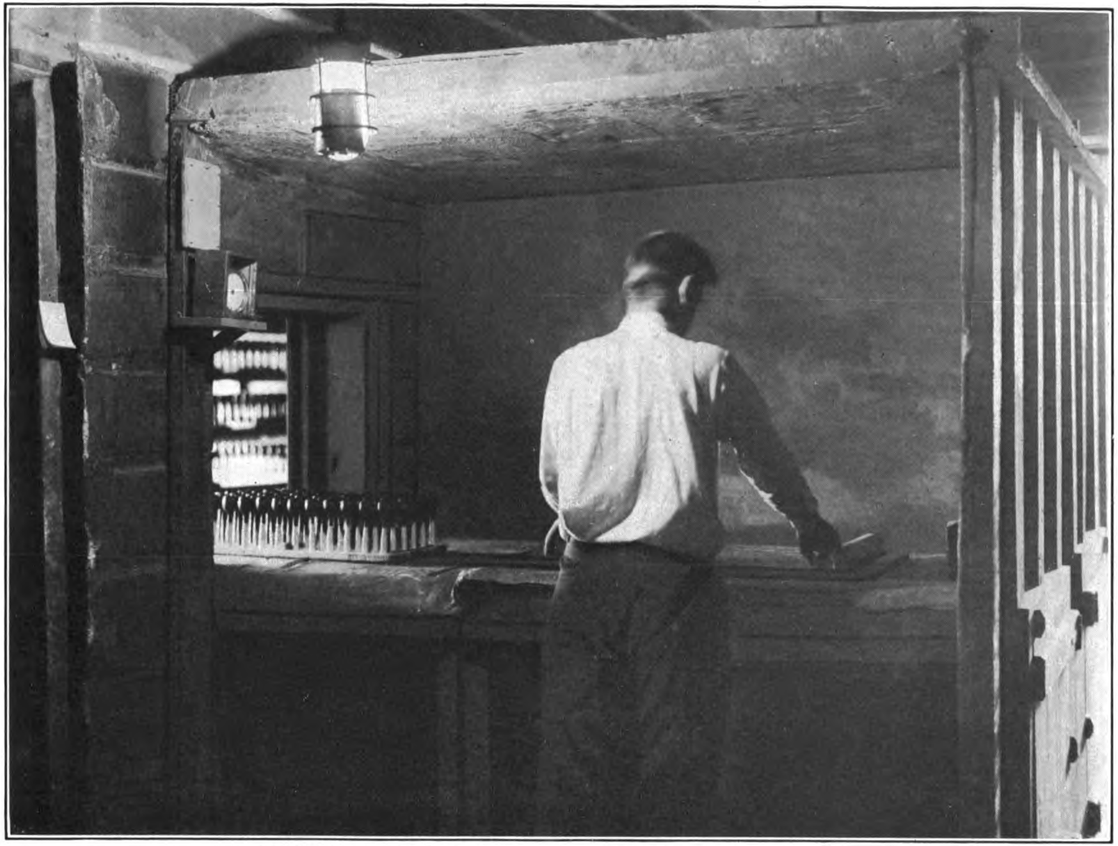

PLATE 13.—ACID CURING OR COLD CURING OF BALLOONS.

The workman has just submerged a rack of balloons in the curing solution. The tank containing the solution is placed in a large concrete trough. There is an air space between the two, and when the tank is uncovered to lift out the rack, the vapors from the solution are drawn down through this space and through a porthole to the exhaust fan seen in the next plate (Plate 14).

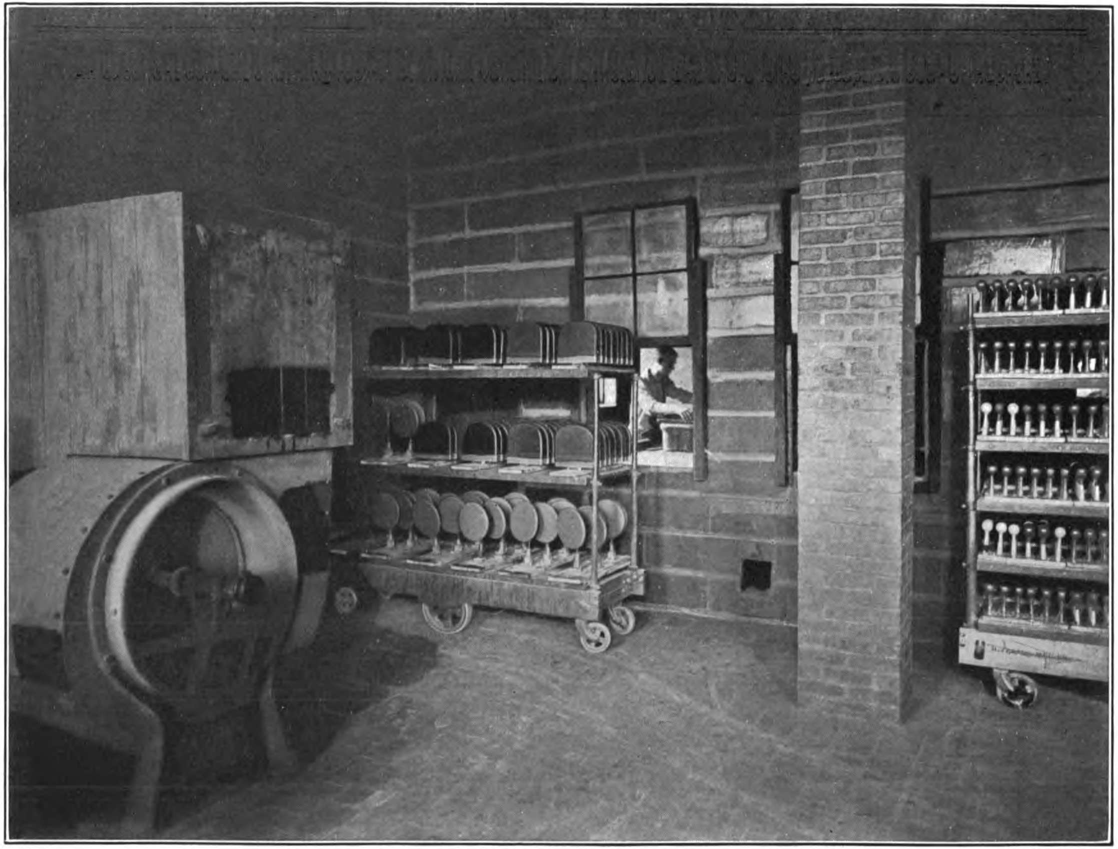

PLATE 14.—DEODORIZING ROOM.

The deodorizing room is next to the curing room. Freshly cured goods are pushed through the window and left here on racks until the vapors have all passed off. The exhaust fan for both departments is seen on the left.

inverted, lowered into the solution, then lifted, turned over, and left to dry. The whole process can be inspected by looking through a window in the side of the cabinet. If the rack is not removed till the goods are really dry, there should be no risk at all to the workmen.

Mechanical devices of this sort are used on a large scale in German rubber factories. Only this one was seen in this investigation, but in a large factory for dipped goods they are planning to inclose the "acid tank" completely and do all of the dipping mechanically. This factory already has a better cold-cure department than any of the others except the little one just described.[1] The room is separate and fumes are prevented from escaping into the rest of the plant. Goods are dipped in a tank placed under a hood, but the suction is down to vents in the floor, for these vapors are heavy. The dipped forms are put on racks and pushed to the other side of the room to dry, and a strong draft of air is driven in at the end of the room where the dippers work, and sucked out at the other end past the racks of drying goods. The air was surprisingly fresh in the neighborhood of the tanks. Here the carbon disulphide is mixed with an equal part of tetrachloride.

Little can be said in favor of this department in the other seven plants in which acid curing is used. The best is a tiny place where almost all the work is done in one room. Here the tank is set in a little chamber built into the wall, and behind the tank is a space for the rack of dipped goods to stand and dry. A fan is placed in the outer wall to carry off the fumes and a drop door closes the chamber off from the room. In all the others the work is done in such a way as not only to expose the workmen engaged in it to the fumes, but also to let fumes escape and contaminate the air in the rooms where women are "finishing" the cured goods.

Painting.

The third method, painting the mixture of sulphur monochloride over surfaces that are to be vulcanized, is used in splicing inner tubes for tires and in making hoof pads for horseshoes. This is used in 14 of the 35 factories. Two of them use carbon tetrachloride to dilute the monochloride, one uses benzol, two use twenty parts of benzol and two of carbon disulphide, and in two others the management refused to say what diluent is used, simply stating that it is not carbon disulphide. The other seven use the carbon disulphide. In several of these factories tube splicing is a department of minor importance and only two or three men are employed for perhaps part of their time, but in others fairly large numbers do this sort of work during a full working day. The German regulations forbid more than four hours' work in a day, and even this period must be divided into two parts, so that there shall be only two hours' continuous exposure.

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[1] See Plates 13 and 14.

In addition to the men who do the vulcanizing, an even larger number are employed near them and breathe the vapors which rise from the painted surfaces. In several plants an exhaust with a down draft is placed directly in front of the man and he holds the end of the tire over it so that the drip from his brush is caught as well as the fumes. In others not so much care is taken. The liquid is allowed to drip on the floor or is caught in an open jar, and the exhaust is too weak to be of any real benefit. It is unusual to find these splicing rooms separated from the rest of the factory so that the fumes will not contaminate the air of other rooms, but in any case the work is not as dangerous as the dipping of goods in carbon disulphide solution, for the quantity used is so much smaller. Still the German authorities consider the work dangerous enough to require that it be done under a glass cabinet furnished with an air exhaust.[1]

Summary of the use of the Parkes process in 24 factories.

Vapor cure	7
Diluents of sulphur monochloride used:	
Carbon disulphide	3
Benzol	1
No diluent	3
Dipping	9
Diluent used:	
Carbon disulphide in all factories, but one factory uses equal parts of tetrachloride.	
Painting	14
Diluent used:	
Carbon disulphide	7
Benzol	3
Two of these factories use one-tenth carbon disulphide.	
Carbon tetrachloride	2
Unknown	2

RUBBER RECLAIMING.

Very little can be said about this branch of rubber work. The essential features consist in grinding and washing the old rubber, getting rid of textiles by the action of acid or alkalies, and softening the rubber. Rubber grinding is dirty work, but the ordinary stock has about 4 per cent of moisture and the dust need not be great if care is used. Grinding hard rubber was extremely dusty wherever it was seen, the men employed in it looking like brown chimney sweeps. The ground rubber is put through warm rolls and comes out a sticky mass full of shreds of cloth. This goes into a digester, a huge autoclave, where it is treated with warm dilute sulphuric acid, or a mixture of sulphuric and hydrochloric acids, or, more often, with an alkali, sodium or potassium, to rot the cloth. In the Marks process

[1] Jahresberichte der Gewerbe-aufsichtsbeamten und Bergbehörden, 1911, vol. 3, 18, p. 3.

the ground scrap is heated with caustic alkali solution under a pressure of 100 pounds for 10 hours or more. This rots the cloth and softens the rubber. The rotting fluid is carefully washed out, the rubber shoddy dried and put into "warm-up mills," but from this point on the methods are secret. It is safe to say, however, that no reclaiming plant now trusts to heat alone to soften the rubber. Crude phenol or carbolic acid, tar, naphthalene, gasoline, kerosene, xylene, turpentine, and aniline are all used for this purpose, but it is impossible to say how they are used and how their use is safeguarded in the different plants. In some of these plants lead salts also are used in compounding the reclaimed rubber.

A case of lead poisoning which was described by an Akron physician is apparently an instance of the absorption of lead from rubber scrap. The man was a Hungarian and his history was very hard to get, for he spoke little English and could not describe his work clearly. It was, however, ascertained that he had worked six years in the reclaiming department of a large rubber factory, in the screening room. According to his account the beads from tires are ground up, treated with what he called "acid"—a general term among workmen for any unknown solution with an irritating effect on the skin—then sent to the screening room, where the scrap is dried, screened, and "cured." He was in the habit of climbing into the screens to work the rubber over. After 18 months' work he began to feel ill, and several times he was treated by the company doctor for acute colic before he came into the hands of an outside physician, who reported the case as one of chronic lead poisoning, with a lead line on the gums, pallor, constipation, and gastric disturbances.

SUMMARY.

Among the poisonous substances used in the rubber industry in the United States are litharge, sublimed lead, basic carbonate of lead, and red lead; antimony pentasulphide; aniline oil; petroleum, naphtha, benzine, etc.; coal-tar benzol; carbon disulphide, and carbon tetra chloride.

The industry is not, in this country, considered a dangerous one, for relatively few of the workers are exposed to a harmful extent to the poisonous dusts and vapors of these substances. A small number of employees who sift and weigh the lead salts and mix them with rubber run the risk of lead poisoning. An even smaller number of men engaged in compounding rubber and in reclaiming rubber scrap are exposed to the fumes of aniline oil. A few men handle the golden sulphide of antimony, which is used largely in compounding, and a few others use benzol as an ingredient of cement. Among those exposed to these poisons the rubber compounders and mixers show a high rate of lead poisoning. Aniline poisoning is far less frequent than formerly but still occurs.

A larger number of workers, including many women, are exposed to the fumes of petroleum, naphtha, and benzine in cementing rubber articles, but these fumes are seldom heavy. In making cement and in making spread and dipped goods heavier fumes of these compounds are produced, but only a few workers, all men, are engaged in these processes. Acute, severe benzine poisoning is rare, but chronic, mild benzine poisoning is probably very common.

A few men engaged in vapor curing use carbon disulphide in the form of vapor, a few others engaged in dipping use the liquid form, and a much larger number use it for painting the ends of inner tubes. Among the dippers carbon-disulphide poisoning is fairly common; it is less frequent, but still occurs, among those who use the disulphide as a paint or in the form of vapor. In a few factories carbon tetrachloride is used as a substitute for carbon disulphide; it is dangerous but less so than the carbon disulphide.

There need be little if any trouble from these poisons if proper precautions are taken by the employers. All that is required for the workmen's protection is the prevention of dust and fumes by means of closed receptacles and strong air exhausts, and the provision of washing facilities and clean lunch rooms.

American rubber factories, even those that are in other respects admirably constructed and managed, are, almost without exception, lacking in the proper protection of workmen against poisons. In consequence the industry is much more unhealthful in this country than it need be.

APPENDIX A.—ANILINE POISONING IN THE RUBBER INDUSTRY OF AKRON, OHIO.

By Rey Vincent Luce, M. D.

Aniline poisoning, which occurred fairly frequently among workmen employed in rubber factories, for a long time puzzled the physicians. The nature of the chemical compounds used by the rubber companies was then, as it is now, guarded with the closest secrecy, and although the cases of poisoning were well defined it was some time before physicians traced them to their source. The popular term "blue men" was applied to the victims because cyanosis of a more or less profound degree is the most prominent symptom.

As soon as the ætiological factor was discovered a more intelligent study of the situation was made possible, but this discovery was by no means a simple task. It was only after close inquiry and observation that physicians discovered that the "blue men" had in all instances been working with aniline or in rooms where aniline was being used. It was also discovered that poor ventilation and high temperature play an important part in the production of this form of poisoning. The men who worked in hot and poorly ventilated rooms were far more apt to manifest symptoms than the men doing the same sort of work in cool and well-ventilated rooms. The discovery of the cause made prevention possible, and now "blue men" are a rarity in the rubber factories. The workmen who are obliged to handle aniline or to breathe air containing aniline vapors have been taught that as soon as they notice the flushing of the face or suffer from severe headache, or nausea, it is time to seek the fresh air and to keep away from aniline for the rest of the day. If these instructions are obeyed, the premonitory symptoms usually disappear promptly. As far as can be ascertained, aniline poisoning has never resulted in a death at any of the rubber plants, although frequently it has produced most alarming symptoms.

The most usual symptoms of aniline poisoning, as it has been observed in this industry, are, first, a flushing and congestion of the face due to the vasodilator effect of the poison. Violent throbbing headache then comes on, chiefly occipital, and associated with this there is very likely to be nausea and vomiting. When the patient has been subjected to the inhalation of any considerable amount of aniline vapors, or when a quantity of it has been spilled on his body, there is a profound cyanosis and a more or less severe degree of prostration. The pulse becomes weak and thready and the temperature is frequently subnormal. There may be respiration of the Cheyne-Stokes type. Ringing in the ears, vertigo, and lancinating pains are common but less alarming symptoms. In a few cases epileptoid convulsions have been observed. One case of this kind is of particular interest. The patient, who was chief chemist to one of the large rubber companies, was found by his physician to be suffering from a severe degree of cyanosis, violent headache, and nausea. Shortly after the doctor arrived a violent convulsion, epileptoid in character, came on and after it the patient was greatly prostrated. He had never suffered from convulsions before. An interesting detail in this case was the effect produced by the administration of a vasodilator. The physician, unaware that his patient was suffering from aniline poisoning, administered inhalations of amyl nitrite, which promptly aggravated the symptoms and for some time following the administration the patient was in an extremely hazardous condition.

In the more severe cases of aniline poisoning, a few of the patients have lapsed into coma, the period of unconsciousness lasting from a few minutes to several hours.

A certain degree of tolerance seems to be acquired by workmen who have been exposed to aniline fumes for a considerable period of time, but if then they are suddenly exposed to larger amounts of the poison than they have been accustomed to, there is frequently a train of very serious after results. In such cases the poisoning has taken the form of a profound and persistent anemia, lasting many months but responding well to cessation of work and routine medication. A blood examination in these cases shows a severe hæmolysis (destruction of red blood corpuscles) and associated with this there is frequently a hæmoglobinuria; that is, the products of the disintegrated blood corpuscles are found in the urine.

The following is the history of a patient who was admitted to the city hospital of Akron in a state of unconsciousness which lasted nine hours. He was profoundly cyanotic. The pulse was 116, weak, fluttering, and intermittent. The temperature, rectal, was 97.6° F. The pupils were equal, but reacted sluggishly to light. The knee jerk was normal and there was no Babinsky reflex. Urine: Sp. g. 1024, trace of albumen. No sugar. No diacetic acid. No acetone. No casts.

Lumbar puncture. No evidence of pus, nothing of note microscopically. Pressure increased, Nonné negative, cell count normal.

Respirations 24. Chest negative.

The patient was put to bed and given inhalations of oxygen, and heart stimulants, aromatic spirits of ammonia, camphorated oil, digalen, and strychnine. The temperature remained subnormal for six hours. After nine hours he regained consciousness and was discharged the following day, feeling a little weak and slightly nauseated, but otherwise normal.

The following history was then obtained from him. At about 1 o'clock on the afternoon of the day before he spilled a can of liquid, the nature of which he did not know, over his clothes. He described the liquid as having a peculiar alcoholic odor and when it came in contact with his skin it produced a burning sensation. He said that the fumes were very noticeable and although he felt that something was wrong he kept on with his work for about two hours more. Then he began to notice that his cheeks were flushed and he was conscious of a severe palpitation of the heart, then dizziness came on and a violent headache, and shortly afterwards he became nauseated and vomited two or three times. He was taken to his home, where he became increasingly cyanotic and at about 6 o'clock in the evening he lost consciousness and was then brought to the hospital. He did not recover consciousness till 3 o'clock in the morning. Investigation showed that the liquid was aniline.

The rubber companies are at present doing everything possible to prevent aniline poisoning. Most of the work with aniline is being done under hoods and where hoods are not available thorough ventilation is provided and the men are warned against the danger of close contact with the poison.

APPENDIX B.—THE SOLUBILITY OF GOLDEN ANTIMONY AND CRIMSON ANTIMONY IN HUMAN GASTRIC JUICE.

By A. J. Carlson, from the Hull Physiological Laboratory of the University of Chicago.

The following tests were made at the request of Dr. Alice Hamilton with the view of determining whether the workmen in the rubber industry who handle antimony sulphides are in danger of poisoning. Antimony is a poison. The sulphides as handled by workmen in the rubber industry to-day, fill the air and are swallowed with the saliva. If they are sufficiently soluble in the digestive juices, chronic antimonial poisoning will result. So far as we are aware, tests of the solubility of the commercially important antimony compounds in human gastric juice have never been made.

The gastric juice used in these tests was obtained from the case of gastric fistula that furnished material for former tests of this character. (See Bulletins No. 120 and No. 141, Bureau of Labor Statistics.) The samples of "golden antimony" and "crimson antimony" were furnished by the B. F. Goodrich Co., of Akron. According to W. C. Geer, chief chemist of the Goodrich Co., these samples showed the following proportional composition:

PROPORTIONAL COMPOSITION OF GOLDEN ANTIMONY AND CRIMSON ANTIMONY.

	Free sulphur.	Calcium sulphate.	Metallic antimony.	Antimony trisulphide.
Golden antimony	17.0	66.2	22.8	32.0
Crimson antimony	15.0	48.7	36.1	50.7

Technic of experiments.

The tests were carried out as follows: 0.1 gram (1.623 grains) of the antimony was added to 50 c. c. of gastric juice, incubated for 10 hours at 38° C. and then filtered. To the clear filtrate some tartaric acid was added and hydrogen sulphide gas passed through it. The mixture was then warmed up to near the boiling point, and the excess of hydrogen sulphide removed by a stream of carbon dioxide. The precipitate was collected on weighed filter papers, washed with hydrogen sulphide water, dried at 100° C. for one hour, and weighed. The precipitate was then tested with strong hydrochloric acid for the presence of free sulphur. As all of the precipitate went into solution, it was concluded that it was all Sb_2S_4 and that no free sulphur was present.

RESULTS OF EXPERIMENTS.

[0.1 g.+50 c. c. gastric juice at 38° C. for 10 hours.]

Crimson antimony.		Golden antimony.	
Test.	Sb_2S_4 in solution.	Test.	Sb_2S_4 in solution.
1	0.0045 g. (0.073 grain).	1	0.0008 g. (0.013 grain).
2	.0048 g. (.078 grain).	2	.0010 g. (.016 grain).
3	.0038 g. (.062 grain).	3	.0009 g. (.015 grain).
4	.0040 g. (.065 grain).	4	.0007 g. (.011 grain).
Average	.0043 g. (.070 grain).	Average	.0009 g. (.015 grain).

The antimony compound dissolved by the hydrochloric acid of the gastric juice is in all probability the trisulphide (and possibly antimony oxides present), rather than metallic antimony. According to the analytical data sent us by Dr. Geer, of the Goodrich Co., our 0.1 gram (1.623 grains) portions of crimson antimony contained 0.05 gram (0.812 grain) of antimony trisulphide; the 0.1 gram (1.623 grains) of golden antimony contained 0.032 gram (0.519 grain) antimony trisulphide. If we assume, as seems highly probable, that all of the solvent action of the gastric juice was exerted on the trisulphide, our results show that with the amounts and kinds of antimony and with the quantity and character of gastric juice employed above, about 8 per cent of the antimony in the crimson and about 3 per cent in the golden antimony goes into solution. We have no explanation for the greater solubility of the crimson antimony.

It is clear from the above that crimson and golden antimony are soluble in human gastric juice. It is probable that this solubility is sufficient to be a source of danger to the health of workmen who are obliged to use these compounds in such a way as to expose them to the dust, or who handle their food or tobacco with hands smeared with them. The question must be conclusively settled by means of feeding experiments. In the meantime, such measures should be taken in the rubber industry as will protect the workmen from what is in all probability a real danger.

APPENDIX C.—FOUR STATE REPORTS ON THE HYGIENE OF THE RUBBER INDUSTRY.

New Jersey.

The first full report of the rubber industry in the United States with regard to its influence upon the health of the workers was published as long ago as 1886 by that pioneer in the field of industrial hygiene, the New Jersey Board of Health.[1] The description given (of the rubber-shoe branch only) is quite full and shows that the changes that have been made in the industry since 1886 have resulted in lessening the dangers to the workers. Compounding then as now involved the use of litharge, but a much greater amount of white lead was used then, and acetate of lead was commonly added to the varnish. Litharge was also an ingredient of the color used to mark the shoes. Lead poisoning is said to have been very common and practically all workers who had been several years in the factory showed the lead line on their gums. Much trouble was experienced also from naphtha fumes, especially when the rooms were hot. When "the racks come in loaded with boots and shoes hot from the ovens, with windows closed, the heat of the room becomes almost unbearable." Girls often were overcome and had to give up the work because of nausea, headache, impaired digestion, and loss of appetite. The varnishers are said to have had a particularly hard lot, for they were obliged to be in the factory from 4 in the morning till 7 or 8 in the evening. The conditions in the factory which formed the subject of the detailed descriptions are said to have been unusually good, so it is easy to see that decided improvement has taken place in the making of rubber shoes since that time. There was, of course, no cold vulcanization, as that is never used for the curing of footwear.

Massachusetts.

In 1907 the Massachusetts State Board of Health issued a report[2] in which the rubber industry is described. Fourteen factories employing some 9,000 persons, about evenly divided as to sex, were visited by the inspectors. In 11 of 13 factories only slight naphtha fumes were noted, in 2 they were quite perceptible. Some men who were employed on spreading machines, and also some girls were found who complained of the effects. In 6 factories where litharge was used no cases of lead poisoning could be found, but in 2 others it was said that cases occurred occasionally.

New York.

Appendix VIII of the Second Report of the Factory Investigating Commission of the State of New York, published in 1913, contains a section by C. T. Graham Rogers, M. D., and John H. Vogt, B. S., on lead poisoning in the rubber industry in that State (pp. 1118–1120). The dangers they find to be practically confined to the compounding and mixing departments. Five rubber factories are described. In one of them an apparatus was being installed for weighing the compounds and filling the containers under cover, with no escape of dust, but in the mixing room of this same factory no precautions against dust were found, and a sample of air taken at the time the compounds were being emptied into the mill showed that there was no less than

[1] Tenth Annual Report of the Board of Health of the State of New Jersey, 1886, pp. 195–200.

[2] Report of the Massachusetts State Board of Health upon the Sanitary Condition of Factories, Workshops, and Other Establishments Where Persons are Employed. Boston, 1907, pp. 110–113.

8 milligrams (0.130 grain) of lead to the cubic meter (35.3 cubic feet). In a smaller plant making tires, the compounding room was of the usual kind and none of the mixing mills had means for taking care of the dust created. Gloves were furnished the workers, but there were no special facilities for washing, and lunch was eaten in the factory. In a third factory, for electrical supplies (p. 1133), the air in the compounding room had 1 milligram (0.162 grain) of lead per cubic meter (35.3 cubic feet), and in the mill room 2.9 milligrams (0.047 grain). Four cases of lead poisoning were found here. A fourth factory (p. 1135) uses large quantities of litharge in the compounding, and here the air in the weighing room had 6 milligrams (0.097 grain) of lead per cubic meter (35.3 cubic feet). The air in the mixing room contained less, only 0.5 milligram (0.008 grain). But the workmen ate their lunch in this room without being able to wash their hands. Seven cases of lead poisoning were found in this department.

Ohio.

The State of Ohio has just published a detailed study of the industries in which there is risk to health and of the cases of occupational disease discovered by the investigators of the State board of health or reported by physicians.[1]

The section on the rubber industry (pp. 206–229) is full and very important, taking up the elements of varying temperature, dust, fatigue, hours of labor, opportunity for contracting communicable disease, as well as the effect of all the poisonous substances used in rubber manufacture. Sixteen bolting and compounding departments were investigated and 22 cases of lead poisoning were found, to which might be added 5 in which the diagnosis was tentative only. Twenty-one mixing mill rooms were visited and in 13 the risk of lead poisoning was found to be great. A positive diagnosis of lead poisoning was made in 22 cases and a tentative diagnosis in 4 more. Three cases of aniline poisoning were found among mixers, and 2 cases among compounders were reported but not seen by the investigators.

Dr. Hayhurst found much evidence of ill health resulting from benzine vapors, and he criticizes conditions in many plants where tire building is done without precautions against these vapors. Workers in these departments complain chiefly of headache, dizziness, and stupefaction. Anemia is often seen among them, due undoubtedly to the chronic effect of the benzine. In more than half the dipping rooms, also, the precautions against benzine fumes were inadequate. One positive and 2 tentative cases of chronic benzine poisoning were seen. Also in cement manufacture antiquated methods of health protection were found in four out of nine plants. Boys were often found working in these departments and many complaints of ill health were heard.

The risk of carbon disulphide poisoning in cold vulcanizing was great in 8 plants, the protective devices were fair in 6, and adequate in 1. Four cases of poisoning were found, 2 more were probable, and several suspicious. Four cases of poisoning from carbon tetrachloride were found in plants which are using this chemical in place of the carbon disulphide.

Dr. Hayhurst believes that there is a decided risk of lead poisoning in compounding and milling, a fairly large risk of benzine poisoning in dipping and in tire building, and a slighter risk of it in cement making and cementing inner tubes. Carbon disulphide poisoning is a decided risk in cold curing, and a small percentage of cases of aniline poisoning may be expected to occur in compounding and milling.

[1] Industrial Health Hazards and Occupational Diseases in Ohio, by E. R. Hayhurst, A. M., M. D., director of the division of occupational diseases, State board of health. Columbus, Ohio, 1913.

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