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LEAD POISONING IN THE  
SMELTING AND REFINING  
OF LEAD



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## CONTENTS.

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<b>Lead poisoning in the smelting and refining of lead:</b>	<b>Page.</b>
Introduction.....	5-17
Dangerous processes in the smelting and refining of lead .....	6-8
Dust and fumes.....	9-11
Sanitary equipment.....	11
Medical care.....	11
Disadvantages of a shifting force .....	11, 12
Prevalence of lead poisoning in the industry.....	12-14
Prevention of lead poisoning in the smelting industry.....	14-17
Construction.....	15
Sanitary equipment.....	15
Dust prevention.....	16
Prevention of fumes.....	16
Control of the workmen.....	16
Medical supervision.....	16, 17
Processes used in lead smelting and refining in the United States.....	17-49
Handling the ore.....	17, 18
Crushing and sampling mills.....	19, 20
Transporting ground ore.....	20, 21
Smelting.....	21, 22
Furnaces used in lead smelting and refining in the United States....	22-46
Ore hearths.....	23-27
Smelting in reverberatory furnaces.....	27
Reverberatory furnaces for roasting.....	27, 28
Mechanical preroasters .....	28, 29
Huntington-Heberlein pots.....	29-31
Continuous sintering machines .....	31-33
Blast furnaces.....	33-37
Tapping floors .....	37-39
Prevalence of lead fumes and dust on charge and tapping floors..	39-41
Settling furnaces.....	41
Softening and refining furnaces.....	41-43
Drossing, remelting, and desilverizing kettles.....	43
By-product or residue furnaces.....	43, 44
Retorting and cupelling furnaces.....	44-46
Liquating furnaces.....	46
Flue-dust system.....	46-49
Heat and exertion.....	49, 50
Relative dangers of breathing lead dust and of getting lead on food.....	50-53
Analysis of dust and fumes.....	52, 53
Poisons other than lead encountered in lead smelting.....	53, 54
Lead poisoning in the smelting industry in Great Britain, Germany, and Austria.....	54-57

<b>Lead poisoning in the smelting and refining of lead—Concluded.</b>	Page.
Lead poisoning in the smelting industry in the United States.....	58-81
Historical.....	58-61
Number and kind of cases found.....	61-64
Period of exposure and attack rate.....	64-66
Relative danger of different kinds of work.....	66, 67
Influence of the seasons.....	68
Method of collecting cases.....	68-71
Medical supervision.....	71-73
Sickness and accident insurance.....	73, 74
Character of employees.....	75-78
Housing.....	78, 79
Compulsory registration of occupational plumbism.....	79-81
APPENDIX I.—The solubility of lead sulphide ores and of lead sulphide in human gastric juice.....	82-84
APPENDIX II.—Regulations for the lead and copper industries, drafted by Lillian Erskine, special investigator for the New Jersey Department of Labor, approved by Ernst F. Eurich, consulting metallurgical expert for the State, and issued in the form of a circular letter to these trades by Lewis T. Bryant, commissioner of labor.....	85-87
APPENDIX III.—German regulations for lead-smelting works (June 16, 1905).....	88-90
APPENDIX IV.—French regulations relating to precautions against industrial lead poisoning.....	91-94
APPENDIX V.—Provisions for medical inspection and care in English, German, and French smelters.....	95-97

## LIST OF PHOTOGRAPHS.

	Facing page—
PLATE 1.—Sampling mill.....	19
PLATE 2.—Ore hearth or Scotch hearth.....	23
PLATE 3.—Ore hearth building in partial operation.....	24
PLATE 4.—Huntington-Heberlein pot.....	29
PLATE 5.—Belt of empty grates of a Dwight-Lloyd machine.....	32
PLATE 6.—Feed floor.....	34
PLATE 7.—Blast furnace during slag tapping.....	37
PLATE 8.—Tapping floor of a blast furnace in the American Smelting & Refining Co.'s plant at Murray, Utah.....	38
PLATE 9.—Matte tapping in the American Smelting & Refining Co.'s plant at Murray, Utah.....	38
PLATE 10.—Tapping antimonial slag from a furnace.....	38
PLATE 11.—Softening furnace in a refinery, with mechanical charging.....	42
PLATE 12.—Residue furnace or copper matting furnace.....	44
PLATE 13.—Fabre du Faur zinc distillation furnace.....	44
PLATE 14.—Pouring the rich lead from a retort into a cupelling furnace.....	45
PLATE 15.—Flue and bag house system.....	46

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## LEAD POISONING IN THE SMELTING AND REFINING OF LEAD.

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

### INTRODUCTION.

The last 15 or 20 years have seen great changes in the lead smelting industry of the United States. As transportation has improved, small and poorly equipped smelters<sup>1</sup> which had been built near the deposits of ore have been abandoned and the tendency has been to concentrate the work of smelting and refining in a few large plants, for it has proved cheaper to ship the ore to large centers where labor is abundant, than to do the smelting in the mining districts.

This change has resulted in a twofold advantage to the worker. In the first place, as these large plants are usually equipped with the latest and best machinery, the amount of handwork required has been materially diminished. In the second place, the conditions under which the employees work have been improved, for large, well-built factories are usually freer from dust and fumes than are those of the old type, and newer methods of manufacture involve economies, such as the saving of poisonous volatile products which used to be allowed to escape into the air. Along with the improvement in equipment, there has been in recent years evidence of a greater interest on the part of the managers in the health and safety of their workmen, and there is probably now no plant in the United States in which some effort is not made to lessen the dangers of lead poisoning as well as to prevent accidents. As a result of these changes in most places where lead smelting is an old industry, as in southeastern Missouri, Pueblo, Denver, Leadville, East Helena, Omaha, and South Chicago, the opinion is general among physicians and townspeople, as well as among the men in the industry, that lead poisoning is far less frequent and less severe than it used to be. As will be seen later, it is not possible to find much documentary evi-

<sup>1</sup> There is much confusion in nomenclature in the literature of lead smelting. In this report the Century Dictionary has been followed, which permits the designation "smelter" for the place in which the work of smelting is done. The term smelter is by many people used for the man who does the actual work and by others for the man who is engaged in the business of smelting lead.

dence of this improvement, yet the general impression is probably founded on fact.

The following is a list of the smelters and refineries that form the subject of this study:

American Smelting & Refining Co.:

Refinery, Perth Amboy, N. J.

Refinery, South Chicago, Ill.

Smelting and refining, Federal, MI.

Refinery, Omaha, Nebr.

Smelter, Pueblo, Colo.

Smelter, Leadville, Colo.

Smelter, Denver, Colo.

Smelter, Murray, Utah.

Smelter, East Helena, Mont.

International Refining Co.:

Refinery, East Chicago, Ind.

Smelter, Tooele, Utah.

United States Refining Co.:

Refinery, Graselli, Ind.

Smelter, Midvale, Utah.

American Metals Co.: Smelter, Salida, Colo.

St. Joseph Lead Co.: Smelter and refinery, Herculanum, Mo.

Picher Lead Co.: Smelting, roasting oxides, subliming white lead, Joplin, Mo.

National Lead Co.: Smelting, subliming white lead, Collinsville, Ill.

Hoyt Metal Co.: Smelting and refining scrap lead, Granite City, Ill.

Balbach Co.: Smelting and refining scrap lead, Newark, N. J.

Goldsmith Bros.: Smelting and refining scrap lead, Chicago, Ill.

These 20 plants have an average daily pay roll of 7,500 men. The methods they employ vary quite a little according to the character of ore handled, and the difference in hygienic conditions seems to depend more upon the different methods used than upon different standards in the management. Only two plants were found in which neglect and indifference were conspicuous, but no plant was found in which every obvious precaution had been used. There is a general average of fairly good conditions and fairly active interest in the safety of the men, without any strikingly good instance and with few shockingly bad ones. As far as could be determined in this investigation the smelting and refining plants which have the greatest incidence of lead poisoning are those in which unusually dangerous processes are used. Two exceptions, however, were found to this rule, one a smelting plant and the other a refinery, which, without using processes any more dangerous than the others, have yet a much higher proportion of lead poisoning because of carelessness in management.

#### **DANGEROUS PROCESSES IN THE SMELTING AND REFINING OF LEAD.**

It may be well to give at the outstart a very brief outline of those processes in lead smelting and refining which are attended with more or less risk to the health of the men engaged in the industry. Roughly,

there are three processes or groups of processes in which dangerous conditions may be found: (1) The preparatory processes, such as crushing and screening the ores; (2) roasting and smelting processes; and (3) refining the metals secured by smelting. The kind, degree, and sources of danger differ in these different processes.

As a preliminary to all these processes the ore must be received and unloaded, an operation which may be very harmful, reasonably safe, or anywhere between these extremes, according to the kind of ore received and the precautions observed. The danger of handling ore depends chiefly on its dustiness, but also partly upon the chemical nature of the ore, for some compounds of lead are more soluble than others in the fluids of the body.

The ore of the Missouri and Illinois smelters is chiefly sulphide ore, but farther west larger or smaller quantities of oxides and carbonates are also smelted, both of which are more soluble and poisonous than the sulphide. Usually these ores reach the plant in a decidedly moist condition, and the work of unloading ore cars is not at all dusty and therefore involves but little danger.

After the ore has been stored for some time, it may become very dry and dusty. The mill in which the ore is crushed, sifted, and mixed with other ingredients is almost without exception a very dusty place, and mill hands get lead poisoning very frequently. The danger here is from dust and is greater or less according to the chemical nature of the ore and according to the care exercised in handling it. Attached to the crushing mill is the sampling mill where samples of ore are ground fine for analysis. This place must be kept clean, because if dust were allowed to blow about no sample would be pure. However, although no accumulations are allowed on floor or table, the small mills and sieves and the iron plates (known as bucking boards) must be cleaned after each sample and this is done by shaking and by brushing off the dust with a dry brush. This dust has been ground as fine as possible and sometimes the air of the room is quite cloudy with it. The sampling room is generally recognized as a fairly dangerous place to work in.

The ground ore, more or less dry, goes through many processes of roasting and smelting which will be described in detail in the body of this report. In these processes the risk to the men comes from the handling of dusty lead compounds and from the fumes which escape when lead or lead ores are heated. Melted lead is not dangerous as long as it is kept below a dull red heat,<sup>1</sup> but at this point fumes begin to be formed and in roasting and smelting it is raised to temperatures far above this. The men who transport the ore and the roasted

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<sup>1</sup> The exact point at which lead fumes begin to form and escape has been determined by L. Lewin (*Zeitschrift für Hygiene und Infektionskrankheiten*, 1912, vol. 73, p. 154) to be between 850° and 900° C. (1,562° to 1,652° F.) for pure lead and at 750° to 800° C. (1,382° to 1,472° F.) for lead with as much as 5 per cent zinc in the mixture.

products and who charge the furnaces are exposed to dust chiefly but more or less to fumes also. The men who tend and discharge furnaces are exposed especially to fumes.

In a refinery the processes are essentially like those used in smelting, for the by-products of refineries must be smelted and so must the lead scrap and dross which is worked up in many of them.

Throughout the process of roasting and smelting, fumes are evolved which contain enough volatile lead compounds, chiefly oxides and sulphates, to make their recovery economically desirable. As a consequence of this, an elaborate system is usually provided of steel and brick flues, dust chambers, and bag houses. The flue dust which collects is very fine and powdery and rich in soluble lead salts, and if the ore smelted contains arsenic this also is found in the flue dust. Flues must be cleaned out at intervals, sometimes once a month, sometimes only once a year. The bag house contains long bags of wool or cotton suspended from the roof and fastened over holes in the floor. The lightest of the flue dust passes into the tops of these bags, being drawn in by suction, and is deposited there. Then the bags must be shaken at least once daily to make the dust fall. In some plants men are obliged to go in every day and shake them by hand, in others they simply work a handle from outside which does the same thing mechanically. In two plants the air current is reversed and a vacuum created, which makes the bags collapse and shakes the dust into the dust chamber below. This dust chamber also must be cleaned out at intervals. Flue dust is very dangerous to handle, especially in those plants which smelt ore containing large quantities of arsenic.

Always the flue and bag-house work is regarded as about the most dangerous in the plant and always some effort is made to protect the men doing it, but the degree of effort made varies widely. In some plants care, the lavish use of water, and the introduction of mechanical devices have done a great deal to lessen the danger of the work, but there are others in which the manager seems content to admit that it is a bad job and to rush it through as fast as possible, employing his least useful men on the work. One of these managers stated in confidence that his annual flue cleaning in January, 1913, resulted in the poisoning of 40 men. His whole regular force in the smelter numbers only 350 men.

There are several processes in smelting and refining which are attended with little if any risk to health, provided ordinary cleanliness is observed and provided the work is not carried on in close proximity to fumes and dust from other processes. Therefore a well-managed plant will have several fairly safe departments and the dangerous departments will be strictly supervised and the men carefully watched. In a carelessly managed plant all departments may be dangerous to work in.

## DUST AND FUMES.

Most of the plants visited are fairly new and some are of very recent construction. The buildings of the more modern ones are large and high, well supplied with natural ventilation, if indeed they are not too open, and with ample space so that there is no crowding. The introduction of machinery to take the place of hand labor is general, and there is an increasing effort to save the lead fumes, which, when they are allowed to escape into the air, are the most potent cause of lead poisoning among the workmen. Even in the old plants, dark and crowded and dirty as they are, there is some evidence of recent improvements, and in some instances the old plant is being abandoned for one of modern construction. On the whole, it is certainly true that conditions are continually improving in this industry. However, there is not one plant in which no fumes are allowed to escape, not one in which there is a complete system of hoods and exhaust ventilation. Nor is there one plant which is kept as free from dust as it might be. The majority have at least one or two inexcusably dusty departments and some plants have hardly a single clean place. In both these respects, fume prevention and dust prevention, American smelting plants leave much to be desired. Yet it is dust and fume that are responsible for the great majority of cases of industrial plumbism, and their control should be a simple matter compared to the complicated engineering problems which have been successfully solved by smelting experts.

In a refinery there are special dangers which are not encountered in a smelter, and which come from the nature of the material worked up in a refinery. To a certain extent this is clean bullion from a smelter, and that, of course, is safe enough to handle, but many refineries work up, aside from the bullion, quantities of scrap lead and some work up nothing else. This stuff is handled much more carelessly than ore or concentrates, and as a usual thing such a refinery is a very dirty place, the most dangerous and dusty materials being shoveled and dumped without the least precaution. The mere fact that smelting is not done on so large a scale seems in the smaller refineries to lead to carelessness in the matter of fumes as well as of dust, and the only smelting furnaces found with absolutely no provision for protection against fumes were in refineries.

It must not be forgotten that, in addition to the evils of dust and fume, men working in lead smelters and refineries are subject to extreme heat and to rapid changes of temperature, while at the same time their work calls for great physical exertion. This is not true of all the men employed, but it is true of a far larger proportion than is the case in such industries as the making of white lead, the glazing of pottery and tiles, or the painter's trade. Smelting resembles more closely the enameling of sanitary ironware, for there also the men

are exposed to lead-laden dust, to great heat, and great exertion. It is worth noticing that among these enamelers the incidence of lead poisoning was found to be about 21 per hundred. In smelting, all the furnace men and their helpers are exposed to great heat and to rapid cooling off. As to overexertion, Sommerfeld<sup>1</sup> says that physical overstrain is a decided factor in smelting work, especially in unloading ore, transporting ore, charging furnaces, breaking up roasted ore, repairing and cleaning furnaces, loading bullion on cars, etc. Not only the arms, but the muscles of the back and shoulders are used to their utmost. Physical fatigue is one of the predisposing causes to plumbism.

The managers and superintendents of these smelters and refineries appreciate the danger of lead dust and fumes. Indeed, there is a much more intelligent attitude toward the hygienic problems of this industry among the men in charge than is found in some of the lead industries, but there is too much insistence upon the responsibility of the workman for his personal cleanliness and too little on the responsibility of the management for the conditions under which the man works. As we shall see further on, bodily cleanliness is not nearly so important an item in the prevention of lead poisoning in the smelting industry as it is in the white-lead industry, or in the making of red lead or storage batteries, or in pottery glazing, where the men handle and are smeared with soluble lead salts. Hand and face washing and bathing are absolutely essential in those industries to prevent the men carrying large quantities of poisonous lead into their mouths with food or tobacco, but the amount of soluble lead that clings to the smelterman's hands is relatively small. In this trade, as in sanitary-ware enameling, it is dust that is the dangerous element, and under dust is included the excessively fine suspension of poisonous lead salts which make up the fumes from heated lead and lead ores. If all the lead which sticks to the hands and face and body of a smelter employee at the end of his day's work should in some way reach his mouth and be swallowed—practically, of course, this could not occur—it would not equal in amount what he breathes in if he is working in an atmosphere of lead fumes.<sup>2</sup>

In spite of the admitted danger from dust and fumes, foremen and physicians often explain the frequency of lead poisoning in a smelting plant on the ground of the men's carelessness in washing, and one often hears them say that if a man does not use a nailbrush when he washes his hands the lead which has gotten in under his nails will poison the food he handles. Now, it is certainly difficult to see how such a thing could take place, or how even with the greatest carelessness the lead on the back of the man's hands could possibly poison his food. This does not mean that eating food with unwashed hands

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<sup>1</sup> Leymann's *Bekämpfung der Bleigefahr in der Industrie*, p. 40. Jena, 1908.

<sup>2</sup> See p. 51.

should be permitted. It is of course dangerous, yet curiously enough the superintendents and physicians who insist most upon this danger are the ones who have provided practically no washing facilities for their workmen.

#### SANITARY EQUIPMENT.

Compared with the prevention of dust and fume, the provision in this industry of good wash rooms, shower baths, and lunch rooms is of minor importance, but it is important enough to make it a matter for surprise when we find that out of these 20 plants only 8 had at the time of this inspection an equipment which was at all adequate and that 3 of these are in Illinois where the law requires it. A striking instance of carelessness is the keeping of drinking water in open buckets, which, although an obviously dangerous practice, is not uncommon.

#### MEDICAL CARE.

All of the plants covered in this study employ physicians to attend cases of illness as well as of accidental injuries among the men. The service rendered by these physicians may be classed as good in the majority of cases; indifferent in some instances; poor in a few. The insurance system, by which the worker secures the right to medical treatment, varies somewhat in the different plants; but, except in two cases, the doctor is always chosen and appointed by the management and holds his position at its pleasure. In the two exceptional places, the men have a voice in deciding whether or not the physician is rendering good service and whether or not he shall continue to serve; but in 15 plants, though the physician is paid wholly or in greater part through sums deducted from their wages, they have no share in either his selection or retention. The plants in Illinois bear all the expense of medical and hospital care and do not charge the men anything. This is in accordance with the Illinois law.

The details of the insurance systems followed in different plants are given later. In general, it may be said that with a very few exceptions the expenses of sickness and accident are borne in large part, if not entirely, by the workmen, who have, however, no voice in saying how the money shall be expended and no means of redress if the medical care furnished is insufficient or indeed worthless.

#### DISADVANTAGES OF A SHIFTING FORCE.

The men employed in this industry are for the most part of foreign birth, with a varying proportion of American born, who usually hold the more highly skilled positions. The work is for the most part unskilled or at the most semiskilled.

It is a shifting class of labor everywhere, excessively so in New Jersey, perhaps a little better in the Middle West, and still better in

the West, but unsatisfactory everywhere. A certain amount of seasonal shifting is probably good for the men. In the spring, large numbers of them leave the smelter to take work on farms or beet fields or in railway construction and road work, coming back after four or five months decidedly benefited by this change to healthful outdoor work. Still it remains true on the whole that the more shifting the force, the greater the amount of lead poisoning. A new lot of men means a certain proportion of oversusceptible ones who can not be weeded out until they have demonstrated their susceptibility by an attack of acute poisoning. It also means awkward, bungling work, which results in the clogging of flues, the escape of fumes from improperly managed exhausts, injury to furnaces requiring repairs—in short, danger to fellow workmen as well as to the man himself. Repair work in a lead smelter is always dangerous because it always involves dust, and the more the force shifts the more repairs are needed. Then, too, it is impossible to expect that a foreman will take much pains in teaching his men how to avoid the dangers of the work if he has to instruct a fresh gang every month.

Lead smelting in the United States has one good feature not found in the industry in foreign countries: It does not employ boys or very young men. In Austria and Germany, it is evident that men under 20 are frequently employed in such work. Thus, in the model German smelting plant, the Friedrichshütte (together with the Walter Croneckhütte) in 1911 there were 132 men under the age of 20 out of a force of 803.

It is not hard to see why labor shifts so much in this industry for the wages paid are low,<sup>1</sup> the work is heavy and dangerous to health, the heat exhausting, and the sulphur fumes very disagreeable. Hours are not excessive. Three shifts of eight hours each are the rule everywhere except in and near Chicago, and contract work makes possible an even shorter day for men engaged in certain tasks. On the other hand, a seven-day week is universal.

#### PREVALENCE OF LEAD POISONING IN THE INDUSTRY.

There are no sources from which can be gathered full data as to the prevalence of lead poisoning in this industry and though an effort was made to ascertain the facts from hospital records and from interviews with physicians, druggists, priests, and workmen and their relatives, it has been impossible to get more than a partial estimate of the number of smelter employees who fall victims to industrial plumbism every year. Physicians can rarely give actual lists of cases, and it is unsafe to accept general statements as to the number of cases seen yearly by them, because some of the men might have visited more than one physician, and in the end, have gone to a hospital, so that the same case

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<sup>1</sup> See p. 76.

might be counted more than once. The list has therefore been limited to individual cases gathered from hospital records, from the written notes of doctors, and from the statements of the men themselves.

From these sources 1,769 cases of lead poisoning were found that had occurred in 19 lead smelting and refining plants during the year 1912. The twentieth, a newly erected refinery, had not been in operation long enough for cases of poisoning to develop among its 100 men. These 19 factories employ about 7,400 men, that is, 7,400 represents the sum of their average daily pay rolls. It does not represent the actual number of men who have entered and left, or still remain in the employ of these 19 plants.

The cases of lead poisoning were secured from the following sources: Hospitals, 347; physicians' records, 1,320; reported by laymen, 102. If it is considered safer to exclude those which came from non-medical sources, we shall have 1,667 cases among 7,400 men, or a little more than 22 for every 100 employed. The hospital cases alone give a rate of almost 5 in 100 employed, which is larger than the rate in Great Britain for all cases,<sup>1</sup> but these 347 men from the hospital records belong to only 9 of the 19 plants. The other 10 plants furnished no hospital records at all.

It may be objected here that the statement above as to the large numbers of men who pass in and out of the trade every year shows that many more than 7,500 were employed in the lead smelting in 1912. This is true, but it is obvious that it would be unfair to count all the men who enter and leave the industry, no matter how short their stay. An experience of a few days should not count in the same way as an experience of months. Were we to attempt such an estimate as that, a badly-managed plant with men coming and going might show a lower rate of lead poisoning than a well-managed plant with a steady force.

Moreover, it is also true that 1,769 does not nearly represent the full number of cases of lead poisoning that occurred in 1912. Only 2 of the 20 plants have a full medical record to show; in others the record was only partially complete, in still others only the scantiest information was available, and in 4 plants no information at all could be obtained. To take a few instances: 1 smelter employing 275 men and another employing 250 men had records of the hospital cases only. Naturally, many sick men prefer not to go to the hospital, especially if they are married and have their own homes. In another case—a large refinery employing 650 men—the physician refused to give any information or to allow inspection of the records of the hospital to which the company sends its sick workmen. All that could be learned of the situation was gained from the records of two outside physicians, who had seen some 120 cases in the course of the year. It is evident

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<sup>1</sup> See p. 54.

that this was only a small proportion of the men actually poisoned, for all the workers were paying \$1 a month to the company's sickness insurance fund, and the greatest number of them would certainly go to the doctor for whose services they had already paid.

It might be supposed that the Illinois smelters would have furnished full and satisfactory reports, since the law requiring a monthly medical inspection of all employees and a report of the cases of lead poisoning to the chief factory inspector's office went into effect more than two years ago. As will be seen later, however, this source of information has failed completely in the case of the three largest Illinois plants, owing to an unwillingness on the part of the doctors to send in full reports.

Considering how little information it was possible to obtain in many of the plants, it does not seem an exaggeration to say that the number of cases found falls far below the truth, and that the record for the smelting industry in the United States for one year is at least 1,657 (or 1,769) men poisoned among 7,400 employed.

#### PREVENTION OF LEAD POISONING IN THE SMELTING INDUSTRY.

The statistics of the British factory-inspection office and those from one or two plants in Germany and Austria show that lead smelting can be carried on without as much danger to health as exists at present in American smelting plants. To understand where the fault lies, one must study the methods used in the United States and see where the avoidable dangers are to be found. An admirable standard for the sanitary conduct of this industry may be found in the work of the late Richard Müller,<sup>1</sup> which was published in 1908 and awarded a prize by the International Association for Labor Legislation. Müller was not a physician, but an engineer, who had nineteen years' experience in the management of a large smelting and refining works, the Emser Blei und Silberhütten. He speaks, therefore, not as a theorist, but as a man who has tried out the measures he advocates. He has learned by experiment where the dangers in this industry lie, and how they can be controlled without detriment to the practical working of the plant and without increasing the cost of the output.

Müller emphasizes the danger from dust in transporting, grinding, and sifting leady substances, charging furnaces, repairing, sweeping, cleaning out flues, etc., and the danger from fumes whenever lead is melted. "Every shop superintendent should look upon any quantity of lead dust or fume as potentially dangerous, and should rather run the risk of doing too much to guard against it than of doing too little." He holds the management almost entirely responsible, for though most workmen are careless and disobedient, their carelessness

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<sup>1</sup> Die Bekämpfung der Bleigefahr in Bleihütten. Rich. Müller, Jena, 1908.

and disobedience can give rise only to occasional cases of lead poisoning. If a plant has repeated trouble, a continual succession of cases of lead poisoning, then it is the surroundings under which the men work that are at fault.

According to Müller, a smelter or refinery can be made so free from poisonous lead that only the oversusceptible will run the risk of becoming poisoned. The two essentials in such a plant are cleanliness and forced ventilation. These are the principles of construction and maintenance that he lays down.

#### CONSTRUCTION.

The character of the building has an influence on the conduct of the men, for dark, low-ceiled rooms do not inspire ideas of cleanliness. The buildings must be very roomy, light, well ventilated, the walls clean, and the floors smooth and hard. The walls should be white-washed at short intervals, partly for the effect on the men, partly because that is much the safest way of getting rid of the dust. As to ventilation, it must be ample, but one must not depend on windows and doorways to carry off fumes. On the contrary, a too open construction admits wind and drafts which disturb the exhaust system. Flues will work well only when the air inside is warm, and they are incapacitated by drafts of cold air. A plant with very open construction may have more fumes and dust than one which is better inclosed.

#### SANITARY EQUIPMENT.

Proper washing facilities, including warm water, soap, and towels, as well as a clean lunch room, should be provided for the men and their use made obligatory, but Müller believes that ordinary soap and the usual methods of hand and face washing are quite sufficient, and that it is foolish to insist on elaborate scrubbing and the removal of the last particle of dust deep in the folds of the skin. Lead which will not come off by ordinary washing with soap will hardly poison the man's food no matter how he handles it, and "personal cleanliness on the part of the workmen is not nearly as important as cleanliness of the shop." He has seen plants with fine bathhouses and model workmen's homes which had failed to reduce their rate of industrial plumbism because dust and fumes still persisted in the works.

The lunch boxes brought to the works should be kept in the lunch room, though this is hardly a matter of real importance. Far more important is it to see that the drinking water is not kept in open pails. Bathing facilities are desirable, chiefly because they train the men in habits of bodily cleanliness. Müller thinks that only insignificant quantities of dust cling to the bodies of men employed in a well-managed smelter, and that two baths a week are quite enough. For flue dust men, however, daily baths should be compulsory.

**DUST PREVENTION.**

Dust must be prevented by dampness, by sprinkling; there is no other possible way. Where material can not be handled wet, exhaust ventilation must be installed, but such work must always be regarded as dangerous and must be carefully supervised; only strong and well-tested men should be employed there. But in almost every part of the work dusty products can and should be dampened, and for this purpose an abundant and easily managed water supply is essential. Floors should be sprinkled so often that they will be always a little damp and dry sweeping should be absolutely forbidden.

**PREVENTION OF FUMES.**

All fumes should be carried off by exhaust ventilation, for the least escape of fumes is dangerous, and natural ventilation is too variable and uncertain. It must be remembered, however, that no exhaust system will render safe a furnace which is always getting out of order.

Neither against dust nor against fumes can one trust to the protection of respirators. Anyone who has ever worked with filters and has tried to drive air through and keep dust back knows how thick a filter and how strong a force is required. It is impossible for a workman to get enough air through a really effective dust filtering respirator. Like the British factory inspection department, Müller prefers to a respirator a simple muslin bag tied over the mouth and nose and washed daily.

**CONTROL OF THE WORKMEN.**

Discipline should be inflexible; half-hearted cooperation on the part of foremen is fatal to any system. All protective devices should be so arranged that the men will have more trouble in getting them out of the way than in using them, for it is impossible to make the whole force reasonably careful. Every increase in the force or change in the personnel increases the danger of lead poisoning, for new men may prove oversusceptible and may sicken under conditions not dangerous to ordinary men. Emergencies and accidents are frequent in lead smelting and always involve risk, but with a healthy lot of men a certain amount of risk can be encountered without harm, while if there are oversusceptible men they will succumb. No man who has been once leaded should be employed in the worst kinds of work.

**MEDICAL SUPERVISION.**

Like most practical men, Müller does not rate very high the advice which is given by medical experts. He advises superintendents to do their own inspecting and to insist on a report from the foreman as to pallor and loss of appetite among the men. Two very thorough medical inspections in a year would, he believes, be of more value than 12 superficial monthly examinations.

To sum up, the prevention of lead poisoning is in the hands of the superintendent. "The workmen can be blamed only after all that is possible in the way of cleanliness has been carried out in the plant."<sup>1</sup>

## PROCESSES USED IN LEAD SMELTING AND REFINING IN THE UNITED STATES.

### HANDLING THE ORE.

Lead ore from the mines must be first crushed and screened to the proper size for roasting and smelting. Sometimes this is done at the mine and the ore which comes to the smelter is in the form of concentrates, chemically unchanged but in shape for roasting or smelting. In the Western States the grinding is done at the smelter. The ores from these States contain lead sulphide, sulphate, oxides and carbonate. Missouri ore is almost all sulphide, galena, though it is doubtful if any smelting plant, even those in the Mississippi Valley, handles exclusively sulphide ore. There is almost invariably some so-called "scrap" smelted also and in some smelters and in almost all refineries scrap is a very important element. This scrap is lead refuse of all kinds and dangerous to handle, the danger increasing in proportion to the dustiness.

The sulphide of lead has been generally held by physiologists to be quite insoluble in the human body and therefore free from poisonous effects. It has been stated to be the one compound of lead which has no effect when taken into the stomach. Practical smelting experts, however, receive this statement with some skepticism. Müller reports a case of lead poisoning in a man who had been exposed to sulphide ore only, and experts in this country state that they have had no reason to believe this ore harmless, though long exposure is usually necessary before poisoning takes place. Our belief in the harmlessness of galena was shaken when it was discovered that during the year 1912, 25 cases of lead poisoning had been treated in the Alexian Brothers hospital in St. Louis and that the men, all foreigners, had come from the lead belt of southeastern Missouri, from Desloge chiefly, though a few came from Bonne Terre and Flat River. There is but one small smelter at Desloge, none in the other places. An investigator sent to the spot reported that though he could not trace the individual cases, inasmuch as about 1,000 foreigners are employed in the mines of the Desloge district, he was able to make sure that none of them had been employed in the smelter, for the workmen there were all Americans and knew each other. Bonne Terre and Flat River have concentrating mills

<sup>1</sup> For regulations adopted in Germany and France for the control of the lead-smelting industry see Appendixes III and IV, pp. 88 to 94.

but no smelting. These 25 cases of lead poisoning were serious enough to require hospital care and among them was 1 case of palsy and 1 of lead psychosis.

It was evident, then, that the lead poisoning had been contracted in the course of work in mines or concentrating mills where sulphide ore only is handled, and it was evident also that a long exposure is not always necessary, for these men were not a permanent body of employees but migratory, not staying long enough to be really known in the community.

To clear up this question of the solubility of lead sulphide it was suggested to Dr. Carlson and Dr. Woelfel, of the Physiological Department of the University of Chicago, that they subject these ores to laboratory tests, using for the purpose human gastric juice which they were able to procure from a case of gastric fistula. Similar experiments on the solubility of the basic carbonate and the basic sulphate of lead had already been made by these investigators and are reported in Bulletin No. 120 of the Bureau of Labor Statistics, pages 22 to 32.

The account of their experiments is given in the appendix.<sup>1</sup> It will be enough to state here that they showed the sulphide in galena ores to be soluble in the human gastric juice and therefore poisonous. To the objection that the lead in the ore may not all have been in the form of sulphide we may point to their report on the solubility of chemically pure lead sulphide, which they found to be even greater. This is in accord with the experience of Etz,<sup>2</sup> who found precipitated lead sulphide more soluble than galena.

In a plant where the ore concentrates arrive in the cars in a damp condition, as is almost always the case, the work of the unloading gang is free from risk. It is later on, after the ore has been stored for some time, that it may have grown dry and dusty and a good deal of trouble may come if it is shoveled and dumped without sprinkling down the dust. In one smelter where this is done six men went to the doctor with lead poisoning within two months, all of them having been engaged in handling ore.

Much worse than in any smelter is the condition in the corresponding department in a refinery, for all refineries handle more or less dross and scrap and some of them make a specialty of just this sort of work. This means that the storage bins are filled with very poisonous lead refuse, white lead and red lead, the dusty fragments of old storage batteries and dusty dross skimmings, material which is dangerous to unload, to transport, to mix, and to charge into furnaces. Four of the older refineries have stuff of this sort piled up all over the place, so that hardly one room is clean and safe.

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<sup>1</sup> See Appendix I, p. 82 to 84.

<sup>2</sup> Leymann, *Bekämpfung der Bleigefahr in der Industrie*, p. 4, Jena, 1903.

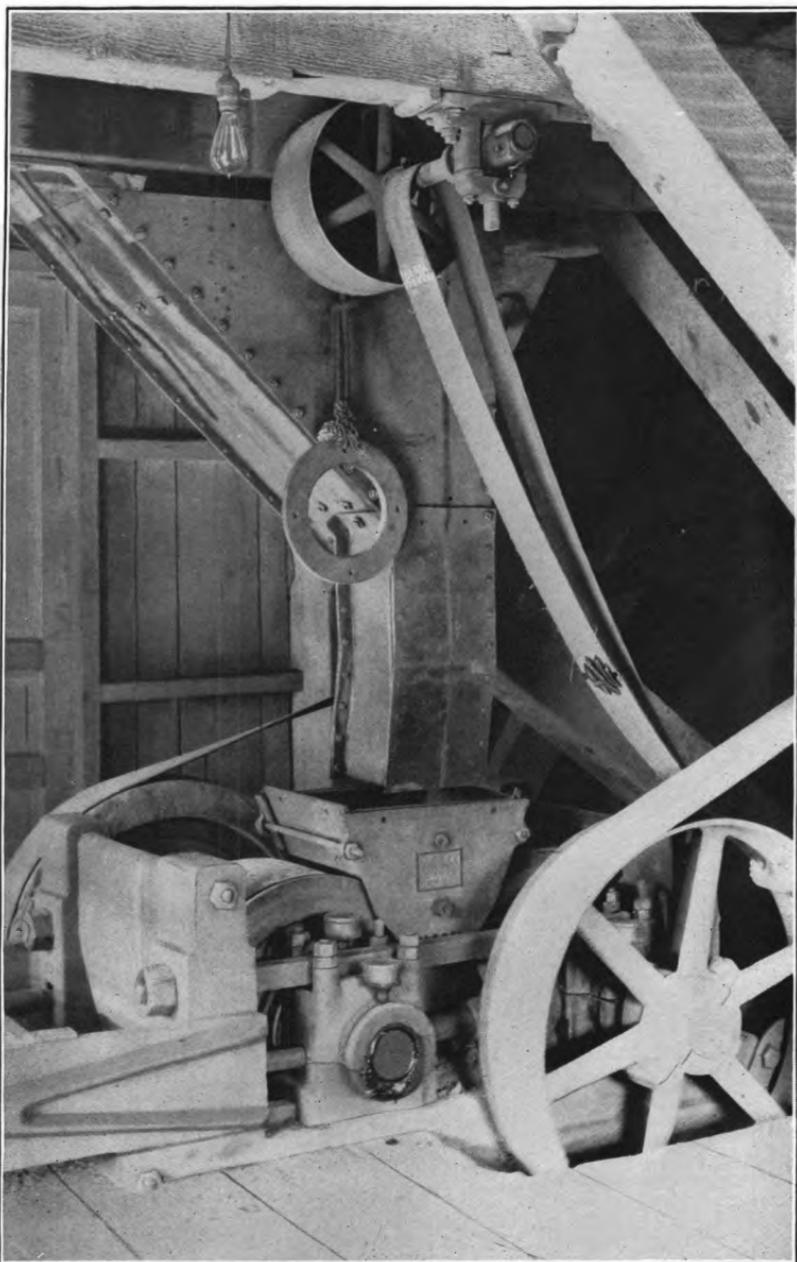


PLATE 1.—SAMPLING MILL.

The ground ore comes down this chute and falls into the hopper. There is no protection against the dust which flies everywhere, falling on the belts and being scattered through the room.

## CRUSHING AND SAMPLING MILLS.

These are almost always poorly constructed buildings with old, rough, dirty wooden floors, with accumulations of ground ore in the corners or sometimes covering the whole floor. Still finer dust clings to the walls and all projecting surfaces, and the air is often so dust laden that after a couple of minutes' exposure the leaf of one's notebook is quite gritty with dust. In many places the crushed ore is carried to the ore beds or weighing hoppers by a traveling belt which usually passes uninclosed through the building and lets quantities of dust spill as it passes along. The illustration (plate 1) shows another method, which is equally detrimental. Crushers and screens leak, chutes are open, the ore shoveled in at the dump is often much surrier than it should be, and the ground product of the mills is often discharged in such a way as to allow clouds of dust to escape. It would seem as if prevention of such conditions were simply a question of care and attention, not of elaborate and expensive mechanical devices, but in the absence of ordinary care the mill which is crushing anything but sulphide ore is a dangerous place. The excuse for leaving everything open is said to be the danger of clogging, which necessitates getting at the mechanism easily.

A description of two mills will serve to illustrate the difference that attention to cleanliness may make.

No. 20. The ore here is largely sulphide from the Cœur d'Alene district. There are two mills—an old one in which matte was being washed, and a new one which was crushing ore. The old building had old wooden floors, but they were clean. No dust was perceptible in the air and very little on projecting surfaces, a fact which was explained by the well-inclosed crushers and the installation of a spray above the discharge to the traveling belt, which served to dampen the ore as it left the crusher. The new building is better constructed with a clean cement floor, but there was more fine dust here on projecting surfaces, perhaps because ore grinding is dustier than matte grinding. There is a separate lunch room connected with this building and the men were lunching there at the time. Near it was a very well-equipped wash room, with accommodations for 14 men. It was provided with soap machines, paper towels, good basins, and hot and cold water.

No. 15. The ore handled here is two-thirds sulphide and one-third oxidized ore, with about 5 per cent pure carbonate. The mill was excessively dusty. The manager said that as samples of the ore are taken at once for analysis, all the ore could be dampened and none need be handled dry, but all that was seen going into the crushers during this visit was quite dry. The air in the first floor of the mill was so thick with dust that one could feel the particles in one's mouth, and clothes and notebook were powdered in a few minutes.

Most of it came in puffs and showers from the traveling belt. Heaps of dust lay in corners, though the center of the room had been swept and was damp at the time. The second story was also dusty, but not as bad as the first. There are no washing facilities at all in this mill and no lunch room.

The "plate room," where samples for analysis are mixed, is always scrupulously clean, because if dust were allowed to blow about, the different specimens of the ore would become mixed and great inaccuracies might result. The process of mixing and separating out the sample, which is done on a floor covered with smooth iron plates, is quite free from dust. Then this sample goes to the "bucking room," where it is ground in small mills, sifted by hand, and usually ground to extreme fineness on an iron "bucking plate" by means of a long-handled hammer with a large and heavy flat piece of iron at the end, which is known as the "bucker." The finely ground samples are mixed thoroughly in tumbling boxes or by tossing the powder to and fro on a piece of oilcloth.

Most sample mills leak more or less while they are grinding, and there is always an escape of dust while the powder is being poured in or taken out. There is some dust from bucking and from mixing and there is a good deal of very fine dust when the bucking boards, tumbling boxes, and mills are brushed clean to prepare for a new sample. Conditions are so nearly equal in all the sample mills seen that it is needless to describe specific instances. The danger from the dust varies according to the nature of the ore that has been ground and sifted.

In an ore sampling mill for western ores the average monthly payroll is 30 men. The physician's report for this plant was as follows: October, 1912, no cases of lead poisoning; November, 4 cases; December, 7; January, 1913, 4; February, 3; March, 1; April, 1; May, 2; June, 2; July, none; August, 2; September, 1; total, 27 cases in one year.

#### TRANSPORTING GROUND ORE.

Before being smelted, ores of different compositions are mixed, the purpose being to secure a compound containing chemical elements which will react upon one another in such a way as to facilitate the smelting process. A "charge" or mass of ore prepared for smelting must contain these different ingredients in a certain fixed proportion, otherwise it will not smelt properly. Mixing the charge is an important part of the preparatory processes.

There is a great deal of difference in the way the crushed ore is handled between mill and furnace and consequently in the amount of dust to which the workers are exposed. In one plant all the ore was decidedly wet at the time of inspection. The ore beds are out in the open with clean, damp cement walks between the two rows

of beds; trapdoors through which the ore is dropped to a car below are placed at intervals, thus making a very safe and clean method of loading. In another plant the separate ingredients for the charge are placed in weighing hoppers in a damp condition and discharged from the bottom of these hoppers on to a traveling belt. This also is an excellent and safe arrangement because everything is kept damp and there is no dust either at the discharge from the hoppers, or at the cylinders where the mixing is done, or at the discharge from the cylinders. A similar arrangement in another plant, however, is inexcusably dusty because of careless management. Here the air was clouded with fine dust and every projecting surface was thickly covered with it. The place looked as if it had never been cleaned. The dry ingredients for the charge drop from large weighing hoppers to the belt, which discharges them at a dump leading to the mixer, a large hole in the floor covered with a grate. Here a man was stationed to control the discharge and rake and push it through the grate. The whole place was enveloped in clouds of dust. This man was interviewed later and said that he was quitting because the familiar symptoms of lead poisoning had begun to appear and he recognized them, as he had been leaded before. He also said that all of the five men who had previously held this job had left for the same reason.

A very excellent arrangement was seen in a fourth plant where by an ingenious device some discarded Brückner cylinders have been converted into receptacles for ore and for the other ingredients needed in the furnace charges. Weighing hoppers regulate the discharge of these ingredients to a traveling belt which passes under them. The process is free from dust and practically automatic.

#### SMELTING.

After the ores have been ground and mixed, they are ready for the furnace processes. There are three groups of these: (1) Roasting, pre-roasting, and sintering; (2) reduction or smelting proper; (3) refining processes, such as dressing, desilvering, and the like. The purpose of roasting is to drive off sulphur, antimony, and arsenic, or any other ingredients which are either volatile in the first place or are rendered so by a preliminary heating. The oxidized mixture thus obtained is then ready for smelting, after which the refining processes are used to free the lead from all traces of the other metals which may have been mixed with it in the ore.

Ordinarily these three processes are quite distinct, a separate furnace or group of furnaces being used for each. In the case of simple lead compounds, like galena, the roasting and smelting may be combined in one operation, for which only one furnace, either an open hearth or a reverberatory furnace is used. More commonly, however,

roasting is carried on in one or more furnaces designed for this use only.

In the course of the present investigation, the following furnaces were found in use, divided as indicated among the three groups of processes:

- I. Preparatory roasting:
  - Hand-rabbed reverberatory furnaces.
  - Mechanical preroasters—
    - Godfrey furnace.
    - Holthoff furnace.
    - Wedge furnace.
  - Roasting and sintering furnaces—
    - Huntington-Heberlein pots.
    - Dwight-Lloyd machines.
- II. Smelting processes:
  - Open or Scotch hearth (combines roasting and smelting).
  - Hand-rabbed reverberatory furnace (combines roasting and smelting, but is almost obsolete).
  - Blast furnace, with, in some cases, a settling furnace in addition.
- III. Refining processes:
  - Softening and refining furnaces.
  - Drossing, remelting, and desilvering furnaces.
  - By-product furnaces.
  - Retorting and cupelling furnaces.
  - Liquating furnaces.

The technical details in the following description of the different furnaces used in lead smelting and refining in the United States were prepared by H. B. Pulsifer, of the Armour Institute, Chicago. His description is supplemented by specific instances seen in the course of this investigation.

#### FURNACES USED IN LEAD SMELTING AND REFINING IN THE UNITED STATES.

At the present time a great variety of furnaces exist in the lead industry as practiced in the 20 plants which form the subject of this study.

In the preparation of the ores and intermediate products for actual reduction the old hand-rabbed reverberatory is still used to a slight extent, in particular for roasting lead mattes. The Brückner cylinder, which for a very few years flourished as an improvement on reverberatory roasting, has disappeared entirely. The Huntington-Heberlein process of pot roasting, the next roasting innovation after the Brückner, is still largely used side by side with the more recent innovations. The Midvale converters are a mere variation of this process and, hygienically considered, are practically the same thing. A method which is coming into general use now for preparing ore for the blast furnace is down-draft, sinter-roasting by means of the Dwight-Lloyd machines. For preroasting the Godfrey or Holthoff



PLATE 2.—ORE HEARTH OR SCOTCH HEARTH.

This is protected by a double hood, the flaring outer hood coming over the work plate, but not over the lead well, to the right, nor the car for gray slag, to the left. The photograph was taken purposely during an interval when there was no slag on the work plate, so that fumes would not obscure the view.

furnaces are commonly used, but Wedge furnaces, patterned on those used in copper smelting, are being introduced.

In the actual reduction of the ores to metallic lead the ore hearth, first used in England about the middle of the seventeenth century, is even to-day used on a large scale and with only little change in furnace construction. The reverberatory furnace, whose climax came about a century ago in England, is all but extinct with us now, only a couple of furnaces being in use in just one plant. The blast furnace is our main device for winning metallic lead; it has had a great development and appears firmly fixed in its preeminent position. In the plants about the country we can find blast furnaces of every capacity from 30 to 250 tons per 24 hours. The smaller of these furnaces have not much increased capacity over furnaces used for centuries, but their construction and operation show the result of the general improvement in blast furnaces.

In the refining of the bullion made in the blast furnace quite a variety of reverberatory furnaces exists. Softening and refining is done in furnaces holding from 50 to 300 tons, both practically identical in construction. Reverberatory furnaces are also used for liquating and for working up matte and antimonial slags. Fabre du Faur tilting furnaces (retorts) are used to distill the zinc from the silver crusts; the American modification of the English cupellation furnace is widely used to win the doré (silver and gold) from the rich lead. Large, open cast-iron kettles are commonly used for remelting, drossing, and desilvering.

The degree of danger to which the worker is exposed differs materially according to the furnace at which he works and to the precautions taken to safeguard him from dust and fumes. In the following pages descriptions will be given of the furnaces seen in use, and of the conditions actually prevailing in the plants visited.

#### ORE HEARTH.

These furnaces, commonly known in America as Scotch or open hearths and in Germany and Austria as American hearths, are considered first as being the oldest device and involving the simplest process still in use for smelting lead.

The usual hearth is a cast-iron box, 4 feet long, 18 inches wide, and 1 foot deep; it rests on a base or legs with its top about waist high. About the hearth box and resting on it is a three-sided water jacket, also of cast iron, while above is always an inner hood to catch most of the fume and in addition a broader, more spreading hood may be placed over both men and box. (See plate 2.)

Two men work the hearth; they throw on the fine ore and coke with a shovel; they stir the charge with pokers and toss the hot slag, first out onto the work plate or apron, then into a receptacle at one

side (which may contain water) and drain out the melted lead into a pot at the other side. Almost without intermission the work goes on during the shift. Whenever the fire blazes up well through the smoothed-off mass, the latter must be stirred and restirred and thrown back, and more ore and coke added, and after a rest of a few seconds the whole operation must be repeated.

The blast comes into the hearth through a row of holes in the back just above the level of the lead which practically fills the box. Before the lead quite overflows one of the men banks the channel at one corner of the work apron and with his shovel pumps the lead up over the edge so that it will run down into the side pot. A little coal fire burns under this pot to keep the lead hot till enough has accumulated for the helper to mold it into 100-pound bars. Such is smelting at the ore hearth. One plant has 30 of these hearths, another has 24, a third has 16.

The work is hard and hot for the hearth man and his helper. In order to make full wages a man has to work assiduously. He has to stand up to the flame and red hot charge and keep the hearth in condition all the time, for it will not make even standard extraction if at all neglected. In winter it is not so bad, but in summer no man can stand it continuously for many days. Usually the work is divided into three shifts of eight hours each and the piecework is paid for on the assumption that the man is working eight hours. There are no pauses for lunch; if the man stops he does it at his own loss. If he wishes to wash his hands and sit down and eat his lunch, he must do it knowing that the hearth will stop producing during that time. Many do not eat at all while at work, especially if they are troubled by the sickishly sweet taste of lead; others stop for a few moments now and then to eat, but not to wash. It would be hard to say which is worse, exposure to lead fumes with an empty stomach, or eating lead soiled food.

About 50 per cent of the lead from the charge is recovered from the ore hearth as metallic lead, about 35 per cent goes into the gray slag and the rest into the fumes, which means that smoke from the lead pot, the slag pot, and from the furnace itself are all rich in lead. If there were only one hearth in a plant the men would get the fumes from only that one, but with a row of hearths each man gets the smoke from all the hearths. At every visit paid to an ore hearth building the air was found to be cloudy with lead fumes. (See plate 3.)

A brief description may be given of two ore-hearth buildings. In the first (No. 8) 180 men are employed in three shifts of eight hours each. This does not include the unskilled laborer who brings the ore and coke to the hearths and who is outside of the building more than he is inside. The furnaces are built in a long row under a shed which is open on three sides, supposedly for better ventilation. Over each

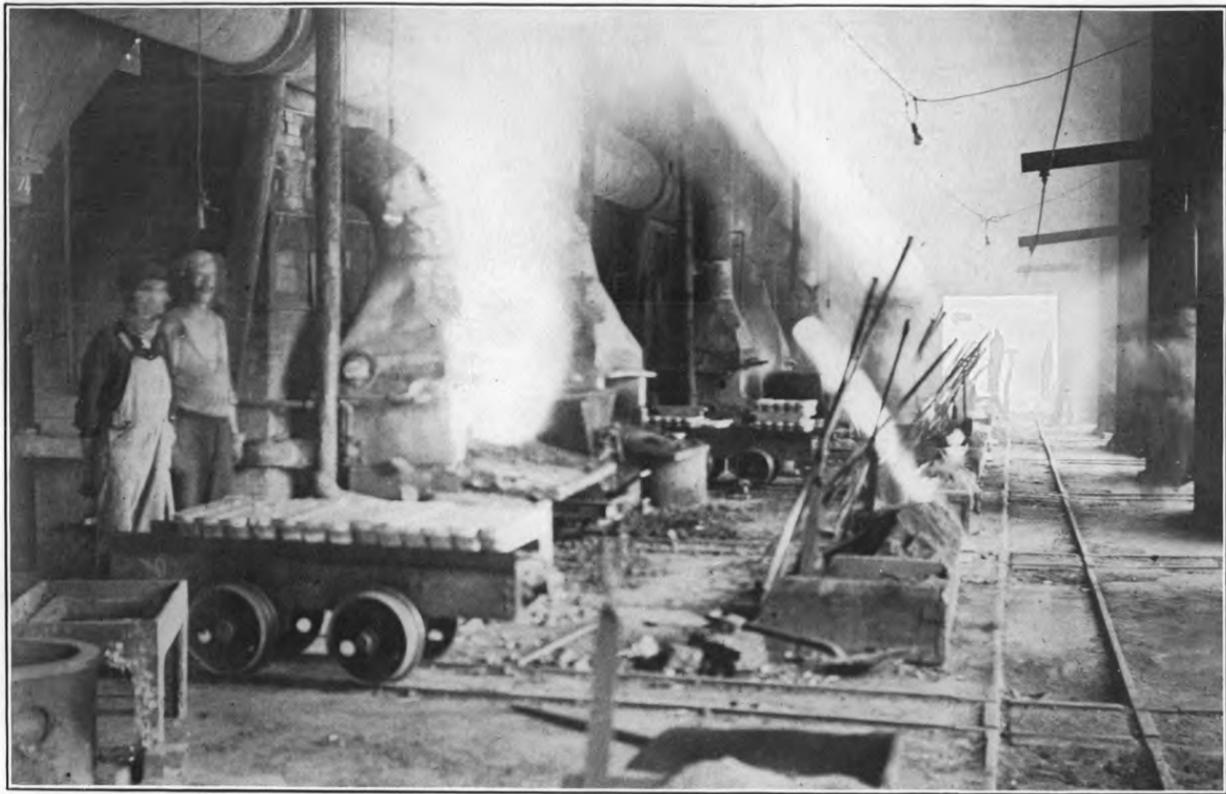


PLATE 3.—ORE HEARTH BUILDING IN PARTIAL OPERATION.

Not all of the hearths were working, but the presence of fumes is evident enough.

hearth is a double hood, the outer one projecting far over the hearth and designed to catch all of the fumes from the work plate. Nevertheless the gusts of wind from outside drove some of the hearth fume out into the room and all the dense white clouds which came from the lead slag as it was thrown out into the skip car escaped into the room. There is no water in this car. The manager does not attempt to work the hearths for more than about 70 per cent of their usual output in the summer months, for the men simply can not endure the heat and exertion. The hearth men are said to earn \$3.50 to \$3.75 a day, the helpers \$2.50 to \$3.

In spite of the fact that there is careful medical supervision of these men, and that the ore-hearth men suspected of plumbism are suspended from work by the doctor, the rate of lead poisoning is said to be very high. The men are skilled workmen and earn higher wages than they can at other work in the plant; consequently they object very strongly to being shifted to safer departments, even concealing their symptoms from the doctor as long as possible for fear he will make them stop work.

No. 9. There are 24 open hearths in a long building, the sides of which can be opened for ventilation, and also closed on windy days. Each hearth has a hood with a strong exhaust, but not nearly all the fume from the hearth passes up under it, and that from the slag all escapes, because it is outside the edge of the hood. There is more fume in the air here than in No. 8, because the hood is single and not as wide nor effective. Another quite unnecessary source of contamination of the air was seen in the openings into the flues through which the workmen can put their tools and clear out accumulations of dust. In the intervals between cleanings these holes are supposed to be kept closed, but at least three were open at the time of the visit and sending out little white puffs of smoke. Also in between pairs of furnaces there are hoppers attached to the flues, in order to collect at once the heavier flue dust while the lighter passes on to the bag house. Every day the "nipple" of each hopper is unscrewed and this dust allowed to fall into a truck below. This adds lead dust to the lead fumes and increases the danger of work at the furnaces. Negroes are employed here and both American and foreign born whites. The force shifts surprisingly in spite of the good wages paid. At a second visit to this plant, after an interval of three years, the foreman pointed out as an "old hand" a man who had been there when the first visit was made. He and two others were the only ones left of the men who had been there three years ago.

All of the hearth men who were interviewed complained of the heat, the fumes, and the driving pace. It is doubtful whether there is any one piece of work in the smelting of lead which is as dangerous

to health as the ore-hearth work, unless it be the handling of flue dust. Three of the 20 smelters visited use ore hearths, and as they have in addition blast furnaces and large flue systems, it might naturally be expected that they would have more serious trouble from lead poisoning than the other 17 plants. This seems to be the case.

Concerning two of them, we have no accurate report to depend upon, yet even with the very imperfect lists available, the number of cases of serious plumbism is startling. In the third, a thorough medical examination had been made of a part of the force just prior to the inspection and the doctor's records were freely shown.

Taking the cases discovered in all three plants we find that, as compared with the average smelter, they have an undue proportion of lead poisoning and especially of its severer forms.

PROPORTION OF EMPLOYEES AND OF CASES OF PLUMBISM IN 3 ORE-HEARTH PLANTS AS COMPARED WITH TOTAL IN THE 19 PLANTS VISITED IN THE UNITED STATES.

[One newly erected plant is not here included.]

	Employees.	Number of cases of--			Number of fatal cases.
		Plumbism.	Encephalopathy.	Palsy.	
In 19 plants.....	7,400	1,769	41	35	16
In 3 ore-hearth plants.....	1,000	397	29	19	9
Per cent of whole number in the 3 ore-hearth plants.....	13.5	22.4	70.7	54.3	56.3

Smelters which have ore hearths have over five times their proper proportion of encephalopathy (convulsions, delirium, insanity, etc.), and about four times their proper proportion of palsy, for as they have but 13.5 per cent of the men employed in smelting, they should have only that proportion of encephalopathy, palsy, and death. This excess may be due in part to the employment of Negroes<sup>1</sup> on the hearths in one plant.

The most detailed foreign report on the use of ore hearths in the smelting of lead is that given in the Austrian commission's report.<sup>2</sup> What is here called the Scotch hearth and by the Austrians, the American hearth, is described in the chapter on the smelter at Gailitz. As far as one can tell, the work is done in the same way as it is in this country and the risks are the same, but the Austrians take the matter far more seriously than we do. Recognizing that heat, exertion, and exposure to fumes are inevitable at the ore hearths, they take the one obvious precaution and reduce the hours of work. At the time the report of the royal commission was written the following system was in force in the Gailitz plant and was made compulsory by the rules established in 1910. On each 12-hour shift four men are

<sup>1</sup> See p. 63.

<sup>2</sup> K. K. Arbeitsstatistisches Amt im Handelsministerium: Bleivergiftungen in hüttenmännischen und gewerblichen Betrieben, I Teil, pp. 21-27. Wien, 1906.

employed, working in pairs for two hours at a time, then changing off with the other pair of men for two hours, and so on, making six hours work for each man during the 12-hour shift. The shifts are also so arranged that a 24-hour rest period divides one working period from the next. For this, three relays of men are needed, working as follows: Shift A, from 6 a. m. to 6 p. m., Monday; B, from 6 p. m. Monday to 6 a. m., Tuesday; C, from 6 a. m. to 6 p. m., Tuesday; and A, again, at 6 p. m., Tuesday. In this way the men of shift A work for six hours on Monday and then rest until Tuesday evening. Such excessive care is considered by the Austrians only reasonable in view of the enormous risks involved in the work. That the precautions are justified can be seen in the records of Gailitz, where in 1889 there were 14 cases of colic among 61 men, but in the two years, 1902 and 1903, not one case among 49 men.

The danger in ore-hearth work is first from the fumes in the air; second, the danger from dust. Compared to these the danger from unwashed hands is negligible and the best appointed and best managed bath house and dining room will have little effect on the incidence of lead poisoning in this department. It is a question of dust and fume control.

#### SMELTING IN REVERBERATORY FURNACES.

These naturally followed the ore hearth in the evolution of this branch of metallurgy. In the United States the reverberatory has had its day. Ore treatment by this appliance required too much manual labor and fuel; no mechanical device has been invented to replace the manual labor, because of the peculiar and varied conditions which must be met with during the heat on each charge.

Ore is dropped into the furnace through a hopper over the top of the roof; the furnaceman spreads the charge about, rabbles it at intervals, regulates his fire, and finally gets the fused residue out. The reduced lead has meanwhile run out into its pot, and just before the shift ends the lead is molded into 100-pound bars.

Working the charge is arduous and requires a training not at all fostered in this country. There is but 1 of the 20 plants in which such a furnace is in use.

#### REVERBERATORY FURNACES FOR ROASTING.

Ore hearths and reverberatories for smelting have been mentioned first because they are the oldest methods and require no preparation of the material before it is put in the furnace. But for blast furnaces most material does require preparation, and this brings us to the furnaces used for the purpose of roasting and "sintering" (agglomerating) the ore, preparatory to smelting it in blast furnaces.

The long, hand-rabbled reverberatory has seen many decades of service in roasting and agglomerating lead ores and mattes. The

furnace is merely a long, narrow, closely covered floor, with a firebox at one end, on which the fine ore is spread, stirred, pushed along toward the hot end, and finally poked through to the buggy below. The whole contrivance is made of brick; 60 feet is a common length, 14 feet is an ordinary width, and the arched roof is not much more than 2 feet above the floor at the height of the arch.

The ore or matte is dropped into the furnace from a hopper over a hole in the top of the arch near the far end of the furnace. At this back end, where the charge is first spread, the furnace is not very hot and the easily fusible charge does not melt as it would at the hot end. Gradually the charge is worked forward toward the hot end of the furnace, but it is continuously losing sulphur, or roasting, until finally it can be heated pretty hot and suffer strong desulphurization before final discharge.

Spreading, stirring, and moving the charge is heavy and hot and exacting labor. But the work does not drive the men as hearth work does, since there is no way to check up piecework as when the lead is weighed up at the hearth and each man is paid according to the amount he has extracted.

There is likely to be some dust about the battery of reverberatories, and a bad fume usually comes from the freshly drawn charge of roasted material. After this has cooled it is shoveled and placed in trucks, in which process dust is raised. Only two plants were found in which this method of roasting still persists, and it is said that these are soon to abandon it.

#### MECHANICAL PREROASTERS.

Owing to the easily fusible nature of all leady material which has to be roasted, mechanical roasters were slow in making headway. They have made great progress in the metallurgy of copper, but with lead, only the Godfrey and the Holthoff furnaces have found much use; until very recently the Wedge furnace, a modification of the furnaces used in copper smelting, has been introduced. These types of furnaces require scarcely any attention; in fact, during the natural running of the furnace it has only to be oiled, the fire kept up, the hopper above filled, and the roast taken away whenever a car is filled. The furnaces make scarcely any outside dust or fumes. Cleaning and repairing will be mentioned in connection with the same work on all types of furnaces.

In most of the plants visited the mechanical roasting department was clean and free from perceptible fumes except when some accident to the working of a furnace caused it to smoke for a time. The charging is usually mechanical, and the discharge of roasted material often takes place under a spray of water which eliminates all risk of dust. When the work is carelessly done and dust and fumes

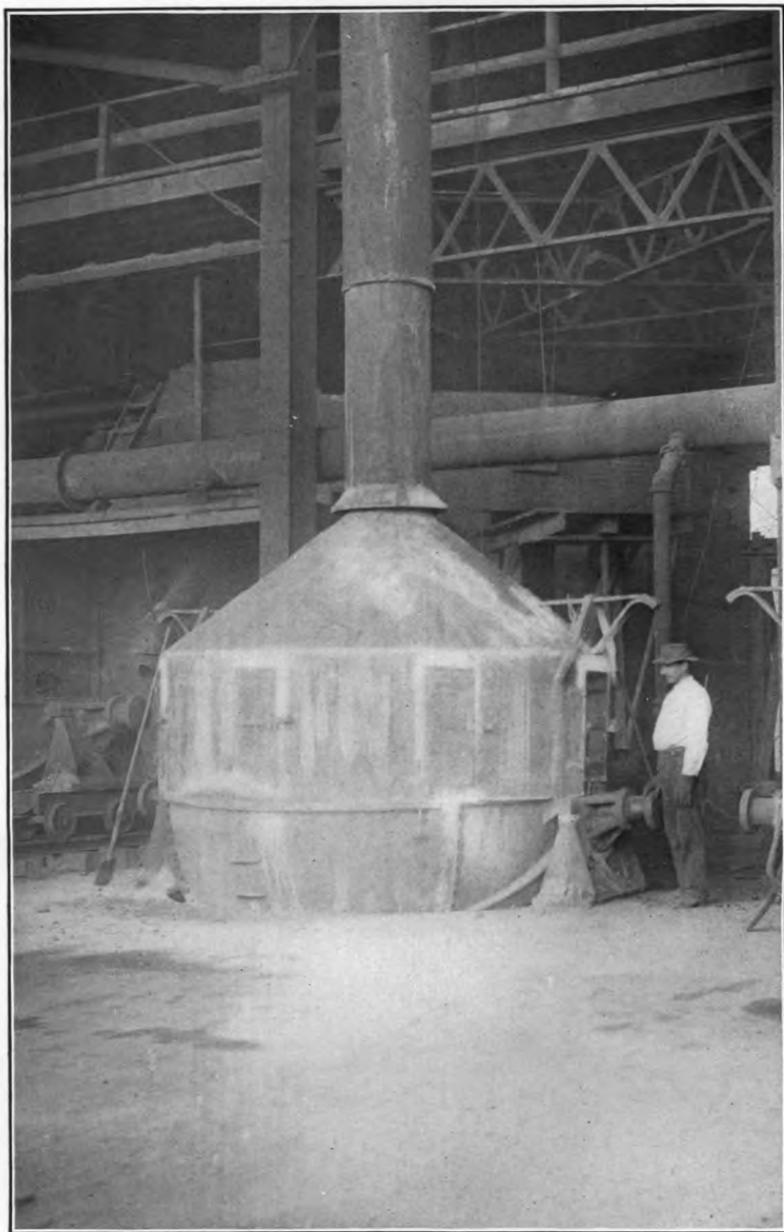


PLATE 4.—HUNTINGTON-HEBERLEIN POT.

The pot is the lower half, the upper half consisting of the great hood and flue which is fitted over the pot during roasting. The windows in the side are opened for raking from time to time. When roasting is complete the hood is lifted off, the pot caught by a crane, tipped over, and the smoking charge dumped and crushed.

are permitted there is danger, because both fumes and dust from prerosters contain oxide of lead.

#### HUNTINGTON-HEBERLEIN POTS.

This method of roasting and sintering ores was developed in Europe and introduced into this country in 1905. The general design of these furnaces is shown in the accompanying illustration (plate 4). The charge to be roasted is placed in a huge cast-iron pot which has a false bottom. If the first layers of the charge are red-hot, the roasting begins the moment the blast is turned on beneath the grate; otherwise a coal or coke fire must be started in the bottom before the charge is dumped in.

As the blast is forced into the pot and the gaseous products of the roasting must pass away from the top of the pot, it is necessary to provide a hood and an abundant draft in order to work about the pot at all. The charge in the pot usually has to be poked at intervals, thus necessitating opening the doors of the hood to see in and use the poker.

The charging of the pots need not be bad work, for the charge should be moist to roast best, and this keeps down the dust. Of course, when the pots are charged with dry, fine material it is a dusty task, and still worse when the charge is red-hot.

The discharging of the pots is an extremely unsatisfactory part of their use. The charge is hot, smoking, and dusty; it may be dumped out by simply turning the pot or by lifting the whole pot and turning it over in mid-air. In any case clouds of fume and dust fill the air surrounding the workmen and the craneman who is controlling the mechanical hoister. The breaking of the big cakes of sintered ore (called "the button") is a part of the dumping and no really satisfactory method of dumping and crushing has yet been devised. Usually the cake drops from a height and breaks into great masses, then a crushing stone is lifted by machinery and dropped on it repeatedly, and finally the men break up the refractory masses by hand and shovel the coarse mass into the crusher or into trucks for the crusher. This is almost always one of the most dangerous places in a smelter.

The following description of this part of the work was given by a metallurgist who has had practical experience in many departments of smelting:

An updraft plant (H. & H. or converter roaster) operated at capacity may be a perfectly agreeable place at times and at others it may be a veritable hell. One day the air may be clear and the flues carrying off every noticeable puff of smoke that rises; another day there may be a high wind with the flues laboring to get even part of the gases through and the place a smokehouse, with the men shirking as much as possible, and only now and then dashing in to turn a valve or hook a chain or give the charge a jab. The craneman has the worst of it, for he can not get out of the way. If superintendents and managers had to endure their own upblast plants, they would have been replaced long ago.

German factory inspectors comment on the danger of breaking the roasted ore from these pots. In a certain smelter in the Wiesbaden district<sup>1</sup> the number of cases of lead poisoning increased from 33 among 459 men (7 per 100) in 1910 to 65 among 587, or 11 per 100, and the inspector attributed the increase partly to the introduction of Huntington-Heberlein pots, necessitating the dusty work.

Huntington-Heberlein pots are found in 6 of these 20 smelting plants and as the converter roasters in Midvale, Utah, are essentially the same, there are 7 plants which have from 8 to 60 pots apiece. Usually they are placed out in the open air, but in East Helena the winters are so severe and the snowfall so heavy that a closed building is necessary. In all these plants there is some dangerous fume in the working of the pots and always there are quantities of dust. Indeed, in one very clean and very carefully managed smelter, the breaking up of the roasted cake from these pots is the dustiest and most dangerous piece of work in the whole place. It would seem to the ordinary observer that it was possible to do away with hand labor in the breaking up of the roasted ore and in conveying it to the crusher, but the problem has not yet been solved. Everywhere one sees men working in a cloud of dust and sulphur fumes, breaking, shoveling, and pushing the fuming, dusty masses to get them into the crusher. Spraying the mass of sintered ore with water is the rule in most places, especially to wash off the "fines," the powder that has escaped the caking process, but the water does not really soak in far, and the inside of the cake is still dry. In one of the Colorado smelters no sprinkling was used in winter because the men are said to object to the steam which it generates.

Although dust is the great danger in this work, fumes are not absent. All pots leak when the wind is in the wrong direction. This smoke is stated to contain only 10 per cent of lead, the rest being SO<sub>2</sub>, but 10 per cent of lead in a state of fine division is an appreciable quantity. Müller regards these fumes as decidedly dangerous. He also finds more lead on the men's hands here than in most work. Of two men employed in breaking up roasted ore, which had been well sprinkled, one had 0.605 g. of lead (estimated as sulphate) on his hands at the end of the day's work, the other had 0.643 g. However, Müller had had no case of lead poisoning in this department in his plant for 13 years because of a thorough use of sprinkling and a strict attention to the men's cleanliness.

Laureck<sup>2</sup> gives statistics for lead poisoning among the chargers of the Huntington-Heberlein pots and the breakers of roasted ore in the royal Friedrichshütte in Tarnowitz.

<sup>1</sup> Jahresbericht d. Gewerbeaufsichtsbeamten u. Bergbehörden, 1912, vol. i, p. 490.

<sup>2</sup> Kraukheiten der Arbeiter in Blei-, Silber-, Zink und Quecksilberhütten, by P. Laureck. In Weyl's Handbuch der Arbeiterkrankheiten, p. 39.

CASES OF LEAD POISONING AMONG CHARGERS OF HUNTINGTON-HEBERLEIN POTS AND BREAKERS OF ROASTED ORE IN THE ROYAL FRIEDRICHSHÜTTE IN TARNO-WITZ, AND RATE PER 100 EMPLOYEES, BY YEARS, 1902 TO 1904.

Year.	Employees.	Cases of lead poisoning.	
		Number.	Rate per 100 employees.
1902.....	250	58	23.2
1903.....	267	59	22.1
1904.....	232	24	10.3

This shows that the work even after the installation of improvements was still dangerous, and short periods of work are recommended for the breakers, alternating with the chargers.

#### CONTINUOUS SINTERING MACHINES.

A great deal of experimenting has been done to improve the up-draft method of roasting and sintering and eventually a system has been devised which depends on suction down through the charge. The inventions of Dwight and Lloyd consist in making the operation continuous. This is known as sinter-roasting by Dwight-Lloyd machines, a method which is being generally adopted for roasting and sintering work.

In this operation the well-mixed and moistened charge is fed to a moving grate through the bottom of a hopper; the grate moves slowly forward bearing its 4 or 5 inch layer of mixture over the edge of a suction box and under a flame playing down from above. The flame is drawn by the suction down toward the charge, ignites it, and the gases pass downward into the suction box. During the passage of the ignited charge over the suction box the chemical and physical work is accomplished so that at the end of the machine the cake, which breaks off and falls into the car, is both roasted and sintered. The empty grate passes down along an endless belt and up again to the starting place. Meanwhile the gases and fume go from the suction box through the flue to the fan and then away to the big flues and bag house.

Not only has this process cheapened and improved the work in every metallurgical sense, but the conditions of operating can be made far superior from the hygienic standpoint to those of any other similar process. This comes from the fact that a positive suction at all points of the active operation may be made to draw all gas, fume, or smoke into the machine and not permit it to escape and poison the workmen. At the end of the machine where the smoking cake breaks off arrangements can also be made to suck in any fume still persisting. The influence of external conditions on the evolution of

fume has been guarded against and the suction works no matter how the wind blows.

However, it is unfortunately very rare to find a Dwight-Lloyd installation in which there is no escape of fume, and it is impossible to find one without dust. There may be dust at the feeding point, there is almost always dust on the floor and fine dust on projecting surfaces. The down-draft at the roasting box is often insufficient and little white puffs of fume escape. In recognition of this fact the manager of the Midvale plant has placed a hood with a fan and up-draft at this point, and also at the place where the charge falls on the grate and where there is often quite a little dust.

A bad feature of the Dwight-Lloyd machines is the grate cleaning. The charge sticks more or less closely to the grate and after the roasted mass has fallen off the bits which still adhere must be chipped off or the next charge will not stick. The dustiness of this work varies greatly just as the stickiness of the charge varies greatly. Usually the grate cleaner stands under the machine and works at the traveling belt of grates as it comes down to pass up again. He uses an air hammer to chip off the roasted ore. The accompanying illustration (plate 5) shows a man engaged in this work under conditions more favorable than sometimes obtain. Often he stands below and works at the grates as they come down over his head. In one of these buildings the cleaning is done by means of a long-handled rod which lets the man stand farther off, but the best arrangement is a mechanical cleaner attached to the grate. This was being tested in the East Helena plant and seemed to work admirably. Grate cleaning may be entirely done away with if the charge can be so made up as to fall off clean from the grate. In the Murray smelter they had succeeded in doing this and, at the time the plant was visited, they were not cleaning their grates at all. In other plants they sometimes try to prevent the charge sticking by first covering the grate with lime, and though this means very dusty grate cleaning the dust is of course not poisonous. However, when lime is added to the charge, the resulting cake is very brittle and that makes conditions at the discharge bad.

The next danger point is at the discharge. If the cake comes off clear and falls far down outside the building into a car where a spray of water plays on it, nobody is endangered. This arrangement is seen in several plants. But in others a man must be stationed at the grate to push the cake off and even at the car below to receive the cakes. The enormous evolution of sulphur fumes makes the discharge a very trying place to work, to say nothing of the really dangerous dust, and unfortunately the sulphur fumes and the dust are sometimes allowed to enter the buildings, too.

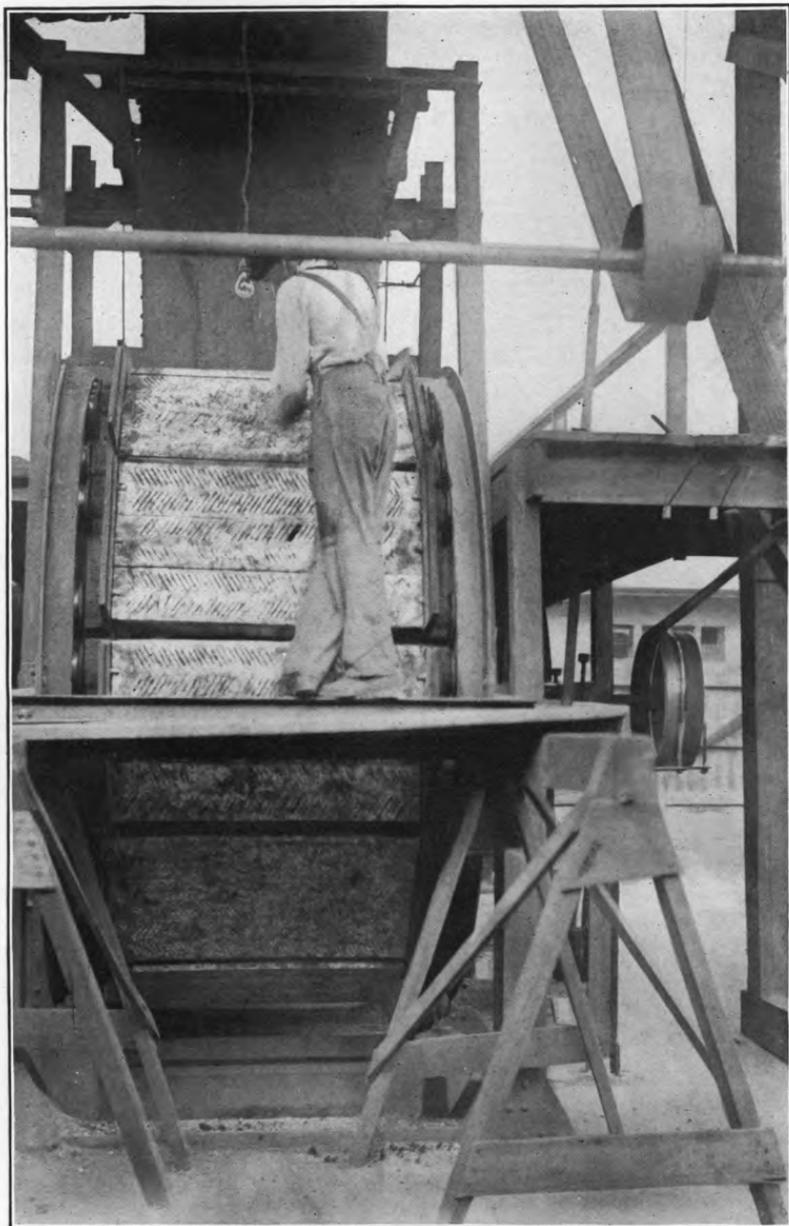


PLATE 5.—BELT OF EMPTY GRATES OF A DWIGHT-LLOYD MACHINE.

The roasted cakes have dropped off and the man is chipping off the fragments which still stick to the grates. This is a very much better installation than many, and the man is not so much exposed to the dust as he would be were he standing below.

The following descriptions give the worst and the best Dwight-Lloyd departments that were seen:

No. 17. The Dwight-Lloyd building is unusually free from sulphur fumes, but the floor is dry and dusty. The charge is damp and falls without any dust from a belt conveyor into a hopper. There is no apparent escape of fumes at the fire box. The cakes drop off more completely than in any other place and leave the grid so clean that no chipping is required unless the charge has been badly mixed. The discharge takes place outside of the building, the cake falling the distance of two stories to a freight car below, where a spray of water is playing. Nobody is required either at the discharge or below except to inspect from time to time.

No. 19. This is much the worst Dwight-Lloyd building in the country. The lowest floor is covered with flue dust because the flues running through here are emptied from hoppers. Heaps of it lie about waiting to be mixed into charges for the machines. The second floor where the empty grates pass down is extremely dusty. The grate cleaner stands under the belt of grates, cleaning them with an air hammer. As there are many machines in a row, the air is full of dust from this cleaning. On the upper floor, where the roasting goes on, the dust is thick, but there is very little  $\text{SO}_2$ . There is a hood over the flame, but it is only a fire box with no exhaust, and it is easy to see the fumes escaping under the edge. Out on a balcony near the discharge lie heaps of poorly sintered ore; two men stand on the balcony breaking apart cakes which have stuck together, and on a platform below stand two more men to detach the cakes and make them drop into a car below. No water is used here, and there was so much dust in the air that after half a minute out on the balcony the paper of a notebook was covered with dust. On the top floor the conditions are rather better, for there is no dust where the charge comes down on the grates. The floor, however, was very dusty. A man was eating his lunch up here and the lunch pails of the other men were standing all about. There is no water for washing in this building.

#### BLAST FURNACES.

The blast furnace is a tall, narrow shaft filled with charge; at the base air is blown in and the fire rages, the charge reacts and melts, and settles in a bath of several layers, while the gases, dust, and fume pass up through the charge and out of the stack. From the crucible below the shaft the melted mass is tapped out according to whether the lower layer of lead or the upper layer of slag is to be removed. Slag comes out at the top of the crucible level and any matte comes with it, while the lead is drawn off from the very bottom through a well which is sunk down to the bottom through the side of the crucible.

Blast furnaces may be small, round affairs smelting 30 tons a day, or any size up to the big rectangular furnaces which smelt 250 tons a day. The little furnaces may be kept in blast a few days or weeks and then allowed to cool down, but with the big furnaces it is a serious thing to put one entirely out of blast, and good economy demands that a furnace shall run for months or even years without fully drawing the fire.

A "slag-eye" is a small blast furnace built to volatilize lead. The temperature must be much higher, especially on the surface, than in an ordinary blast furnace, and, of course, there will be more fumes. As the air rushes in at the feed door, there is no escape of fumes here, but the slag, mixed with the lead which has escaped volatilization, flows out continuously into a settling basin, which fumes all the time. The lead sinks to the bottom and the slag overflows into a pot of water.

There are two points of special danger about a blast furnace: The charge floor, from which the charge or mass of prepared ore is emptied into the furnace, and the tapping floor, where, at different levels, the melted slag, matte, and lead are drawn off. At both of these danger points the risk from dust and fumes may be much lessened if the management is really in earnest about reducing this risk, but at both many dangerous conditions were found.

There are several methods of feeding or charging the furnaces. For little furnaces the charge is best shoveled in at the top of the shaft on what is known as the charge floor. The shaft usually has one or more openings with covers which can be taken away to let the men dump or shovel in the components of the charge and the coke for fuel. Large furnaces commonly have their flues leading away just below the level of the charge or feed floor, at one side or end of the furnace, and this leaves the charge floor quite free for the coming and going of big cars which bring the charge and dump it into the open shaft as the bottom of the car swings open. A feed floor of this kind is shown in illustration No. 6. Artificial drafts are supposed to hold the stream of furnace gas in the flue and to draw in a large amount of fresh air as well. In this way when all is working well the fume is led away to the bag house and collected to smelt again. Feed floors are bad when charges are dry, when fumes escape from the charge doors, and when fumes from the slag pot and matte kettle on the tapping floor below can come up through the floor or the windows and poison the air.

The following are some actual conditions seen on the feed floors in various plants:

*No. 2. Refinery, specializing in scrap and dross.*—There are two blast furnaces, charged from the second story of an old building, crowded and dark, with an old wooden floor. The place is very



PLATE 6.—FEED FLOOR.

An excellent example of a feed floor, such as is found in five smelters, although only three are as good as this. The openings to the furnaces may be seen in the runway for the cars. The mechanician controls from a distance the discharging of the cars.

dusty. Piles of crushed matte and heaps of dross and refuse lie about the charge floor, all dry and powdery. The feed door is large,  $4\frac{1}{2}$  by 3 feet, and is up about at the level of a man's shoulder, so that the charge must be lifted and shoveled in with the charge feeder's face right in front of the opening.

*No. 5. Refinery for western bullion.*—The blast furnace feed floor is fairly clean, the feeding doors are in the shaft at the level of the floor and when the door is open the inward draft is apparently good, yet there was bad leaking either from these doors or from cracks in the shaft, for the air was irritating and full of the odor of garlic, denoting the presence of arsenic or antimony. The charge feeders were shoveling briskly and stirring up quantities of dust, although the superintendent said there was no reason why the charges should not be thoroughly dampened.

*No. 4. Refinery for western bullion.*—There is only one blast furnace for working up scrap lead, dross, and flue dust. The room is full of very fine bluish lead dust because a dust chamber opens directly into it. Piles of all kinds of lead refuse lie about. The furnace is charged through doors in the stack from a platform, 12 feet above the floor, and the charge is dusty or damp as it happens. The storage bins are out in the open and if there has been rain the charge is damp, if the weather has been dry it is dusty. The furnace was being cleaned at the time, a frightfully dusty piece of work, so it was impossible to tell how the draft would work.

*No. 13. Large western smelter.*—The feed floor is decidedly bad, almost all the furnace doors leaking, one quite shockingly. The charges were dry and the feeders raised a good deal of dust, but it was said to be impossible to sprinkle in that weather, the thermometer being  $5^{\circ}$  below zero.

*No. 15. Large western smelter.*—The charge floor was bad, smelling strongly of garlic, yet the manager insists that there is no arsenic and only a small amount of antimony in the ore. There was an enormous escape of fume from the loosely hanging sheets which close the feed doors in the stack. The inward suction is good when the door is open, but the doors are so arranged that there is one on each side of a stack, and while charging is going on at one, clouds of fume pour out through the other. Thus one of two doors is leaking all the time. The charges were damp and the floor was clean.

*No. 19. Large western smelter.*—This was in a worse condition than any other feed floor visited, frightfully smoky and smelling strongly of garlic. The feed doors in the floor are large, about 4 by 10 feet, and only partially closed by ragged, broken pieces of iron which are not nearly long enough to cover the ends. Every furnace was leaking and one was simply belching forth fumes. Cars with charges run along a track over the furnaces. The feeders

stand beside the car, open the hopper gate and let the charge fall through, a good deal of it falling on either side of the door and having to be shoveled in after the car has passed on. This is a necessary feature of furnace feeding in some plants, in order to spread the charge properly. The condition on the floor was made unusually bad at the time of this inspection because one of the furnaces was being "trimmed off." The blast had been turned off this furnace, but it was still hot and fumes and dust were abundant. Sixteen men were working on the charge floor at the time.

Conditions on the feed floor are so dependent on the proper working of the furnaces that it is impossible to pronounce absolutely on any single plant unless it is visited repeatedly. The very best blast furnace is subject to accidents; none of them work well all the time. The following are plants in which the feed floor is very well constructed and at the time of the inspection everything was working normally.

*No. 10. Large Mississippi Valley smelter.*—The charges, well dampened, are conveyed in hopper cars to a large, open, clean feed floor, with charge doors in the floor. The whole process is automatic, the car stops over a charge door, the mechanic who stands at a distance opens the hopper door and the charge drops down. The down suction was excellent at the time and there was no escape of smoke, though the charge doors were all left open. The floor was scrupulously clean and well dampened.

*No. 17. Large western smelter.*—Here there is a similar arrangement of floor, only the charge doors are closed when not in use. The floor was clean and wet and there was no escape of fume during charging, which is automatic, but a strong wind was driving the smoke up from the tapping floor below.

*No. 18. Large western smelter.*—The feed floor here is like the two former, the doors being left open all the time. The down draft was good and there was no escape of fume from most of the furnaces, but two were smoking badly. The dumping of the charge is not automatic, but must be managed at the feed door and the man there must also shovel in the part of the charge which falls at the sides of the door. There were traces of garlic in the air. The floor was well watered in spots, yet at one end a man was sweeping it dry.

With good management the feed floor can be kept clean and free from objectionable fume and dust except during the "blowing out" of a furnace. This is an accident which may come so rarely as to be fairly negligible or so frequently as to be almost a part of the day's work. When the charge for some reason sticks to the side, forming what the workmen call "hangs" or "scaffolds," the blast of air from the tuyères forces a channel through and rushes up the stack, filling the feed floor with fume. This channel may be plugged up with siliceous material after the blast has been turned off,

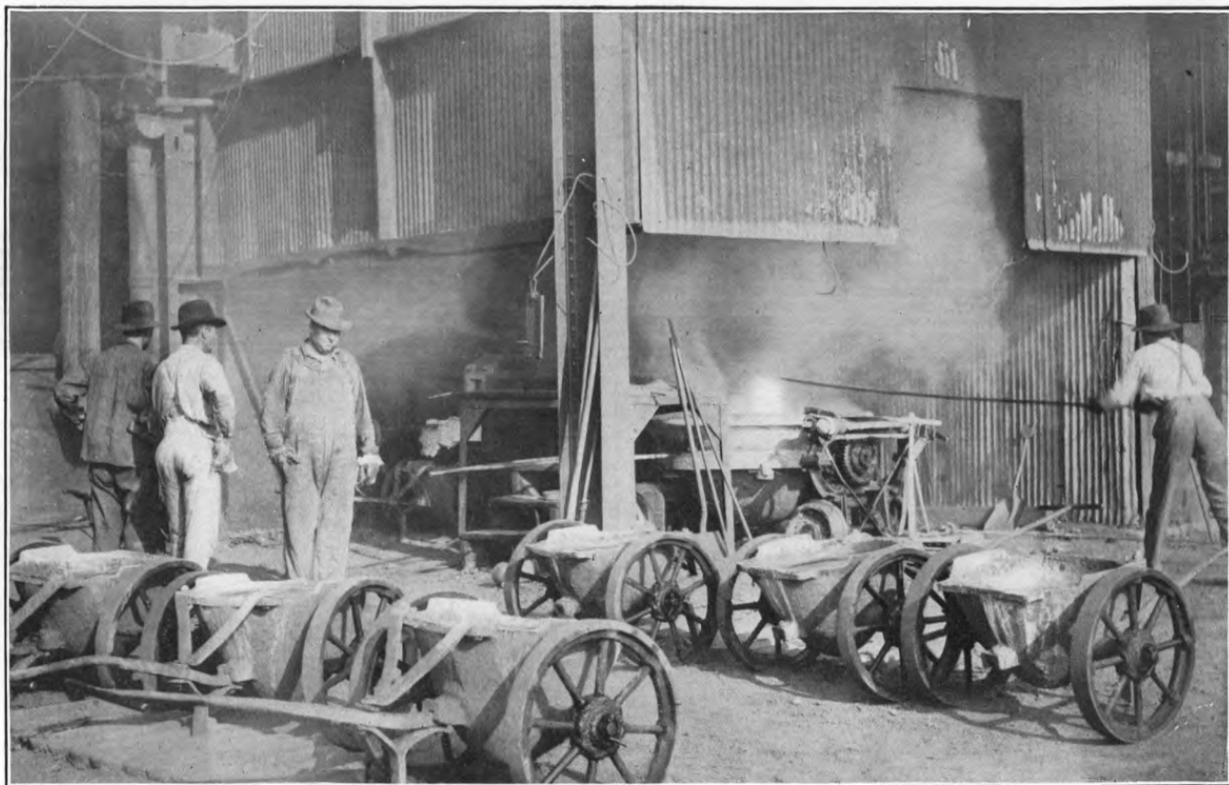


PLATE 7.—BLAST FURNACE DURING SLAG TAPPING.

or it may be necessary to stop work and dig out the "hang." Even when water is used digging is dusty, and often it is done while the furnace is hot to save time. This description of the work was given by a man familiar with furnace cleaning or "wrecking:"

All blast furnaces require more or less cleaning out after a run which has clogged the inside of crucible and shaft. This is one of the most disagreeable tasks in connection with furnace operations. It is often done with the blast merely turned off (cleaning breast and well) or with the furnace run down part way (cleaning "hang" in shaft) or with the end jackets out (cleaning shaft), and is inevitably a hot and dusty and arduous job. Hours spent in cleaning shafts are not easily forgotten. With bar and pick we pry and strike at the softer spots; then we get the big ram lined up and swing its 500-pound weight against the gad that pierces and cracks the crust inch by inch; the furnace walls are too hot to touch, the scanty platform sways and bends, clouds of dust and steam surge and blind and choke us with every lump that falls; every half hour the four men hustle out and four reliefs climb down and rush the job. Furnaces are usually pretty tractable, but blowholes and blowing outs, burn outs, and closed channels make them interesting enough every now and then.

#### TAPPING FLOORS.

On the tapping floor of a blast furnace, or at the front, are the furnace men, the tappers who draw out the lead, matte, and slag at intervals, the unskilled laborers who wheel the lead away, and in larger smelters the trainmen who take away by motor the kettles of matte and slag. The danger on the tapping floor is not from dust, but from fume. The lead runs out at a low red or a bright red heat, fuming always more or less, although the fumes are not nearly so conspicuous as those from slag and matte, and are therefore usually ignored by the men in charge. The lead pot is not hooded, though in some plants the molten lead is covered with slaked lime. The objection to a hood seems to be that it would get in the man's way when he skims off dross or poles out the channel to free it from dross.

Slag and matte as they run out into the settler or forehearth fume thickly. The accompanying illustration (plate 7) shows the extent to which the men are exposed to fumes during slag tapping, even when conditions are fairly good. Slag alone usually contains not more than 1 per cent of lead, but may contain 2 or 3 per cent, depending on the way the furnaces run; matte from 13 to 20 per cent. As matte fumes far more than lead, matte tapping is the most dangerous feature of this part of the work. It occurs about every 40 minutes and always dense clouds of white fume arise, lasting for several minutes. It is very rare to find the hood over the matte kettle at all effective in carrying off these fumes, and often there is no attempt to hood it at all. Even where there is a hood the train crew generally pulls the kettle out before it has stopped fuming and carries it off, spreading the smoke as it goes. Slag is tapped every 10 minutes or so. The fumes from this also are very abundant, but usually the slag kettle is better hooded than the matte. In the

case of those furnaces which are not provided with a settler the mixture of slag and matte must be taken at once before it has had time to cool and poured into the settling furnace. This means an enormous escape of fumes. The three illustrations immediately following (plates 8, 9, and 10) show the conditions under which tapping is carried on in some of the plants visited.

A few instances will serve to illustrate the way in which the work is carried on in different plants.

*No. 5. Large refinery for western bullion.*—The blast furnace is in an inclosed room with a low ceiling and little natural ventilation. Lead and arsenical antimonial slag are tapped here. There is no hood over the lead tap and over the slag tap there is a shaft running up to the roof, but without any exhaust, so it is very ineffective. The air was full of the odor of garlic.

*No. 13. Large western smelter.*—As one approaches the tapping floor great clouds of fume can be seen coming out from under the long roof. The floor is open on three sides and covered with a roof which has a wide stack over each tapping floor. These stacks are supposed to carry off the fumes and may do so fairly well in still weather, but on a windy day the fumes blow in all directions. A little additional protection is afforded by a shield of corrugated iron hung at one side of the runway and pot for slag and matte, but the whole construction is far too open to admit of any control of drafts and currents. The odor of garlic was strong, and the ore handled here is often rich in arsenic. There is no forehearth on these furnaces, so slag and matte run out into an open kettle and are wheeled off to the settling furnace while still hot and fuming.

Better conditions than this are found in some blast furnaces, but the tapping floor is not a safe place in any of the plants that were visited, and this is due partly to a very open construction which fails to shut out varying winds, and partly to the lack of properly fitted hoods with a system of exhaust ventilation. It is strange that even the most modern smelters have been built with dependence on natural ventilation to carry off fumes, although any ventilation expert will say that such an arrangement is at the mercy of wind and weather.

*No. 16. A large western smelter.*—This has a fairly good arrangement of hoods, one large hood covering trough, settler, slag car, and matte kettle. When tapping and when closing the tap, the man must go close to the furnace, but once the stream is started, he steps out beyond the edge of the hood. The fumes from both slag and matte passed up through the stack very completely, but it happened to be a still day, and the men say that on a windy day the state of things is quite different.

Other large smelters have equally good tapping floors, but all are open and are dependent for their successful working on the wind.

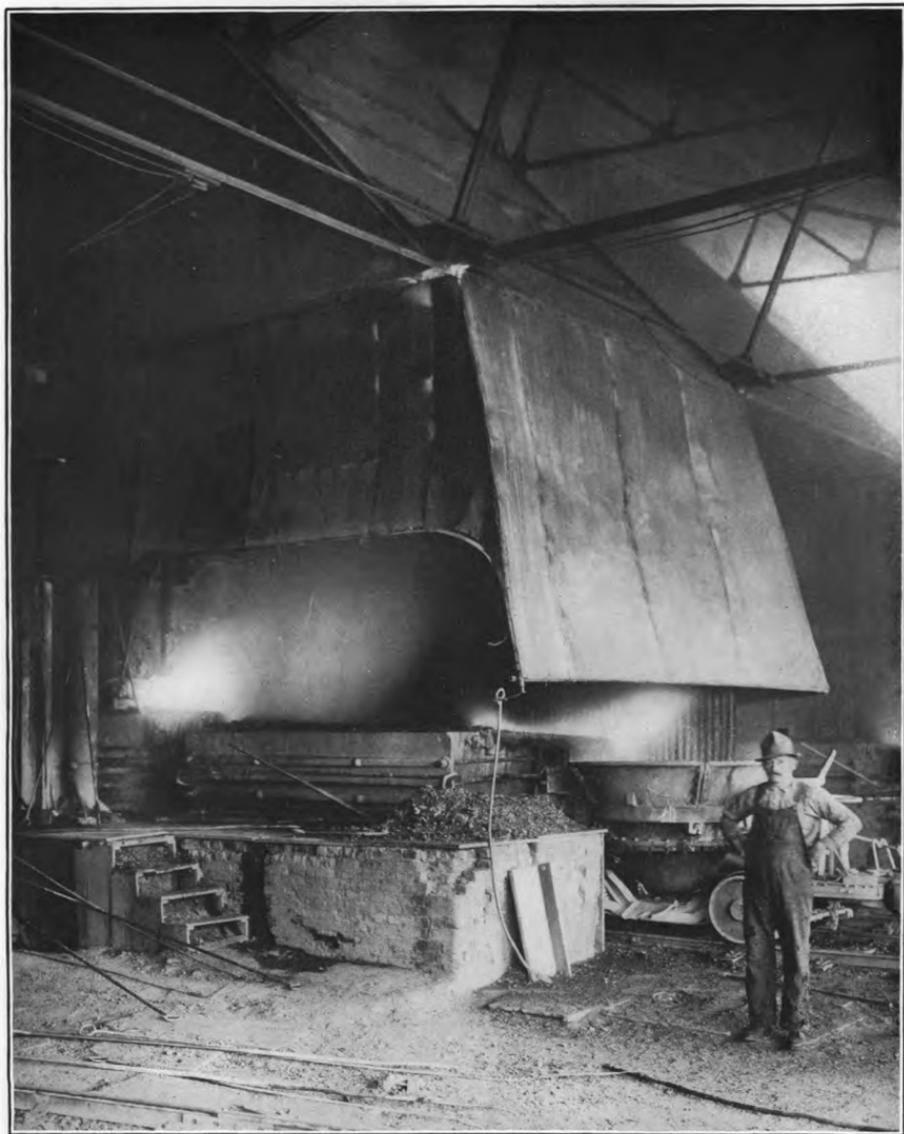


PLATE 8.—TAPPING FLOOR OF A BLAST FURNACE IN THE AMERICAN SMELTING & REFINING CO.'S PLANT AT MURRAY, UTAH.

The arrangement in the Midvale plant is exactly the same. Slag is pouring out into the forehearth and overflowing into the slag pot in front. The day being quiet, no fumes are escaping. This is, however, not the case at all times. When the wind blows in toward the furnace the tapping floor seen in the left corner may be thick with fumes. The side of the building facing these furnaces is all open.



PLATE 9.—MATTE TAPPING IN THE AMERICAN SMELTING & REFINING CO.'S  
PLANT AT MURRAY, UTAH.

This is on the other side of the same furnace. It is easy to see that though the hooding protection is adequate at times a puff of wind could easily scatter the fumes from this matte kettle. These hoods are, however, better than those in any of the other smelters that were visited except those at Midvale.



PLATE 10.—TAPPING ANTIMONIAL SLAG FROM A FURNACE.

The slag overflows into the second kettle; the lead settles in the first kettle with a small crust of matte on top. The hood can be seen at the top of the picture, too high up to be of any real use.

The consequence is that in all smelters the tapping floor is looked upon as one of the most dangerous spots, if not the most so. One plant in which careful records have been kept has more trouble here than anywhere, as is shown by the fact that 23 out of 54 blast-furnace men who were examined showed evidence of plumbism. In still another, 21 out of 65 cases of lead poisoning in the plant came from the front of the blast furnace, though the men here formed only one-sixth of the whole force. Refineries do not have so large a blast-furnace installation as smelters, but some of the worst conditions encountered on charge floors and tapping floors were in refineries. Five out of the seven worst instances are in refineries.

Two of the plants visited make sublimed white lead, basic sulphate of lead, in addition to their other products. The method employed is essentially smelting in Scotch hearths, collecting the "blue fume" from these hearths, and smelting it in blast furnaces of the type known as the "slag eye."<sup>1</sup> These are kept at a high temperature, especially on the surface, for the object is to cause as much volatilization as possible. The "white fume" from the slag eyes is collected in a bag house and consists of lead sulphate with a varying proportion of oxides.

As the three worst features of lead smelting, the ore hearth, the blast furnace, and the bag house are the essential elements in this process, it follows that the making of sublimed white lead is an extremely hazardous occupation. In both plants bag shaking is done by hand, and in both the packing of the light and fluffy powder is very dusty. The men look on the "paint" department as the worst place of all to work in. In one of these two plants 16 men in the sublimed white lead department had been recently examined and 5 were found to show signs of plumbism, while 11 had the lead line. In the other plant it was not possible to get any information from the physician, but 12 men were found who had recently suffered from acute plumbism. There are 45 men regularly employed in this department in the plant.

#### PREVALENCE OF LEAD FUMES AND DUST ON CHARGE AND TAPPING FLOORS.

Collis speaks of the dangers of both dust and fumes on the blast-furnace charge floor.<sup>2</sup> At one factory he found that three out of seven chargers had marked tremor, and one of these had extensor paralysis, while all seven had the lead line. In another factory partial blocking of the flue and escape of furnace fume on the charge floor resulted in three cases of lead poisoning. Collis quotes the analysis of the fumes at the tapping floor of a blast furnace which was given in the annual

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<sup>1</sup> For description, see p. 34.

<sup>2</sup> Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead. By Edgar L. Collis, M. B., H. M. medical inspector of factories, 1910, p. 7.

report of the chief inspector of factories and workshops in Great Britain in 1900. It was calculated that on this floor a man might in eight hours breathe in 7.38 grains of lead (0.478 g.)<sup>1</sup>

Hofman<sup>2</sup> gives the average lead content in the down comers of a blast furnace as 47½ per cent, and of the dust on the roof of a blast-furnace building as 27.1 per cent.

Müller places blast-furnace tapping in the class of greatest danger if fumes are allowed to escape, but if proper devices are installed it may be classed with the comparatively safe work. All fumes on the tapping floor, whether lead, slag, or matte, must be regarded as a menace. The managers of American smelters usually acknowledge the danger from matte fumes, but look on the fumes from the lead tap as negligible, because they are never very heavy, and in fact are visible only close to the pot. The fumes from the slag pot they consider practically safe, because there is supposed to be less than 1 per cent of lead in the slag. Both these opinions Müller regards as very erroneous. The fumes from the lead pot are practically pure lead oxide, and as for the slag pot the fumes contain a much higher proportion of lead than does the slag itself. He has found by analysis of slag fumes that there may be 12.3 per cent of lead, 8.7 per cent of zinc, and 4.2 per cent SO<sub>2</sub>.

Hofman<sup>3</sup> finds far greater quantities of lead than this in the fumes from a boiling slag pot which may contain no less than 41 per cent lead monoxide, 26.2 per cent PbSO<sub>4</sub>, and 4.8 per cent arsenious oxide.

Müller has also analyzed samples of dust which collected between the tap for lead and the tap for slag and found it to be 17.4 per cent lead.

Matte comes out under high pressure, very hot, giving off thick white fumes, consisting chiefly of PbS, which changes almost at once to PbSO<sub>4</sub>. Müller's analysis of these fumes gave 18.8 per cent lead, 10.9 per cent zinc, 5.9 per cent SO<sub>2</sub>. Matte fumes are, of course, worse than slag fumes, but not nearly so abundant, because matte is usually tapped every 40 minutes, while slag is tapped every 10 minutes.

Müller's comment on the hooding devices in use on tapping floors is that they are generally useless and expensive decorations. That those in his own plant are effective is shown by the decrease in the number of cases of lead poisoning, which fell from 10 among 30 men in 1897 to none during the 10 years from 1898 to 1908. When a visit was made to his plant in 1910 it was found that the tapping floor was in a well-inclosed and very clean building, with whitewashed walls, and that the dependence was upon artificial ventilation altogether. Over the lead tap and the tap for slag and matte a large hood was fitted, the edges of which came down to within 3 feet of the floor. This was connected with the flue system and there was a strong suction in the

<sup>1</sup> Great Britain, Annual Report of the Chief Inspector of Factories and Workshops, 1900, p. 438.

<sup>2</sup> H. O. Hofman. *Metallurgy of Lead*, p. 379. New York, 1899, 5th ed.

<sup>3</sup> *Loc. cit.*

shaft. A window in this hood allowed the workman to open and close the tap with a long-handled rod. The workman was not allowed to wheel away lead pot, slag, or matte till the contents had cooled to at least a dull red heat.

The statistics of lead poisoning among blast-furnace men in the great smelter at Tarnowitz show the effect of installing proper exhaust ventilation over the taps. The improvements were begun in 1888, but were carried out chiefly in 1890.<sup>1</sup>

CASES OF LEAD POISONING AMONG BLAST-FURNACE MEN IN THE SMELTER AT TARNOWITZ, AND RATE PER 100 EMPLOYEES, BY YEARS, 1887-88 TO 1891-92.

Year.	Number of employees.	Cases of lead poisoning.	
		Number.	Rate per 100 employees.
1887-88 .....	164	136	82.9
1888-89 .....	130	63	48.5
1889-90 .....	140	58	41.4
1890-91 .....	138	19	13.8
1891-92 .....	124	24	19.4

#### SETTLING FURNACES.

In place of a forehearth or settler at the mouth of a blast furnace, certain plants have installed a settling furnace for the separation of matte and slag. There are several disadvantages in this arrangement. Instead of the matte being tapped only at intervals of three-quarters of an hour, matte and slag are tapped together every 10 or 15 minutes, and the great open pot must be wheeled away red hot and fuming to be emptied at once into the furnace. No precautions against fumes at any stage, including the final tapping of matte from the settling furnace, are to be found in any of the three plants where this method is in use. In one, which is fortunately possessed of a careful and accurate medical adviser, it was found that 6 cases of lead poisoning developed in as many weeks among 36 motor men and furnace tenders engaged in transporting and handling the slag and matte.

Hofman's analysis of fumes from a reverberatory settling furnace for matte showed 31 per cent lead monoxide and 2.3 per cent arsenic.

#### SOFTENING AND REFINING FURNACES.

After smelting the lead is ready for the finishing processes, of which softening and refining come first. Reverberatory furnaces are used for this process. Hand charging of this type of furnace is becoming obsolete and in a modern plant the workmen have merely to place the bar of lead on a conveyor or run the already molten lead into the furnace through a pipe or spout. The accompanying illustration

<sup>1</sup> Die Bekämpfung der Bleigefahr in Bleihütten. Rich. Müller, Jena, 1908, p. 154.

(plate 11) shows one method of mechanical charging in such a furnace. The furnaces are emptied through tapping the lead out or by a siphon. During the process of softening and refining more or less fume escapes at the time of drawing drosses and skims and sometimes at the lead pot. The red-hot skim also fumes after it has been drawn out.

These are two instances of such furnaces:

No. 2. The softening furnaces for the removal of copper, arsenic, and antimony are in a dirty but fairly well-ventilated room. They are charged by hand from the front. A man standing at a distance of 8 feet holds a long-handled spade with its end resting on the edge of the furnace door. Two men come up in turn to the door, place a pig of bullion on the shovel and the shoveler pushes it into the furnace. There is no hood over this door, but the inward draft seems good. Later, when charging is over, the men open the door and rake the charge and during this process fumes escape. The lead runs out into the zincing kettles, the hot slag is skimmed off, and thrown on the floor. There is no attempt to avoid either fumes or dust.

No. 5. Here charging is done mechanically from a traveling belt. The furnace is first raised to a low heat and the copper removed, then to a much higher temperature. The doors are then opened and the furnace gradually cooled down. During this time white fumes escaped from the four openings and though their general direction was upward to the window in the roof some eddied down driven by the drafts of air in all directions. A man stood about 8 feet from the door and raked out the red-hot arsenical and antimonial skim which fell into a pot and splashed on the floor. This gave off thick white fumes as the man dragged it away and stood it at one side to cool. The furnace doors are left open three hours and the charge skimmed from time to time.

The same sort of furnace is used in refineries for melting old lead. The work in one of the largest of this class of refineries (No. 7) is done in a large, dark, ill-ventilated, and extremely dusty room, the floor of which is covered with heaps of dross and scrap. There are no hoods over the charge door or work door, and windows in the room are relied upon to carry off the fumes. Charges are mixed here and fed in by hand, and at least once an hour the furnace man opens the work door and rakes the charge. He stands about 6 feet away but well within the fumes which escape in great clouds and eddy around the room so that they are distinctly perceptible at a distance of 30 feet. The lead flows out at a bright red heat into an unhooded kettle.

There are two refineries in which an electrolytic process is used to obtain pure lead. The work in the battery room is dust free and not accompanied by risk, except such as might come from handling the lead sheets. The places where precautions are needed are at



PLATE 11.—A SOFTENING FURNACE IN REFINERY, WITH MECHANICAL CHARGING.

The pigs of bullion come down the closed chute to the charge door. In contrast to this excellent device is the carelessness which allows heaps of dusty dross to lie on the floor near the furnace.

the kettle where scrap lead is melted for the starting sheets, in casting the starting sheets, in melting up the old sheets and drossing the melting kettles, in working up the drosses in reverberatory furnaces, and above all in handling the so-called "anode mud," the product of electrolysis. This wet slime or sludge is said to consist of lead, silver, and gold in metallic form, with arsenic, antimony, and copper in compounds as yet undetermined. It must be treated in reverberatory furnaces, and in preparation for this it is dried in dust chambers. Transporting and charging this dry powder is very dangerous, and there are of course the usual dangers from the furnaces.

#### DROSSING, REMELTING, AND DESILVERIZING KETTLES.

Practically all lead plants have open cast-iron kettles for holding the lead to be melted, drossed, desilverized, or purified. The temperature has ordinarily no occasion to rise above some 450° C. (842° F.), the melting point of zinc. As this is below even a low red heat, there is practically no volatilization of metal and no production of fume, and therefore no source of contamination except what is to be expected from handling lead or leady materials. Lead may be charged into the kettles by hand, as in the case of bars and sweepings, or in huge slugs lifted by power; most frequently the already molten lead is run in through spouts or poured in from a lead pot. Kettles are emptied by a siphon or by a pipe from the bottom provided with a turncock. It is better to run the molten lead through a pipe rather than a trough, especially if it is at a red heat, when it may fume.

In one large refinery there are no hoods over the charge doors or work doors of the softening furnaces, and when the crust is skimmed and the lead allowed to flow out fumes escape into the room. The lead flows along a trough to the desilverizing kettle, which is at some distance away, and therefore the lead has to be at a fuming temperature or it would partly congeal before it reached the kettle.

Desilverizing may be, and in fact almost always is, so carried on as to be practically free from dust or fumes. The only danger is from the lead which clings to the men's hands and which is pure metallic lead or the oxide.

Oliver<sup>1</sup> says it is rare to find lead poisoning in a desilverizer, and Müller placed here his workmen who had had lead poisoning, considering it the safest part of the plant.

#### BY-PRODUCT OR RESIDUE FURNACES.

The material put in these furnaces is usually solid. It is first dumped into a hopper over the furnace, then let into the furnace through the roof. It is not unusual to shovel the charge in through

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<sup>1</sup> Dangerous Trades, p. 287.

side doors. The furnace is emptied by tapping out into slag pots, skimming through side doors, or letting the lead out through a well.

As can be seen by the illustration (plate 12), these by-products or residue furnaces may be a prolific source of fumes in the plant, for there is seldom much effort made to carry off the fumes from slag or lead.

The arsenic in many by-products is a real source of trouble. Men come in contact with it in a variety of ways, at the furnaces as fume or dust, but more especially in the handling of the stuff and in getting it from one place to another.

Matte roasting is carried on only in large quantities; if the quantity is small, the matte is shipped to another plant.

A copper converter for the recovery of copper from matte is a steel shell lined with refractory material with holes in the bottom, through which air is blown to oxidize and blow away sulphur and lead, leaving the copper. The converters are charged usually with liquid matte.

This "blowing" process is of course productive of an enormous amount of fume which contains lead as sulphate and oxide, and the three plants which use this process have not succeeded in catching and carrying off the dangerous fumes. In all three places the work is very bad indeed. On going over the records of one of these refineries it was noticed that the cases of lead poisoning rose suddenly in a certain year, and the reason given for this increase was that the copper converters were installed in that year. The following description will illustrate the conditions which are encountered by men employed in this sort of work:

No. 1. The converter room is large, with a high ceiling and traveling cranes. The air at the time was full of fumes, almost hiding the motor man in the crane. There are adjustable hoods over the doors of the converters; these are lowered when blowing begins and turned with the converter, but they do not catch the fumes, especially at the beginning of blowing. In this same room is a furnace for holding and settling matte for the converter. It is charged from the top, the opening is neither closed nor hooded, and fumes escape all the time.

#### RETORTING AND CUPPELLING FURNACES.

In the refining of lead these furnaces are an important link in the sequence of recovering the gold and silver. They are both quite neat in operation, and with proper draft and ventilation should give no offense. The rich amalgam of zinc and lead in chunks is dropped into the retorts in the Fabre du Faur tilting furnace and the condensers sealed on at the neck of the retort. At the close of the distillation, when the zinc has been volatilized, the condenser is removed and the rich lead poured out and wheeled to the cupelling

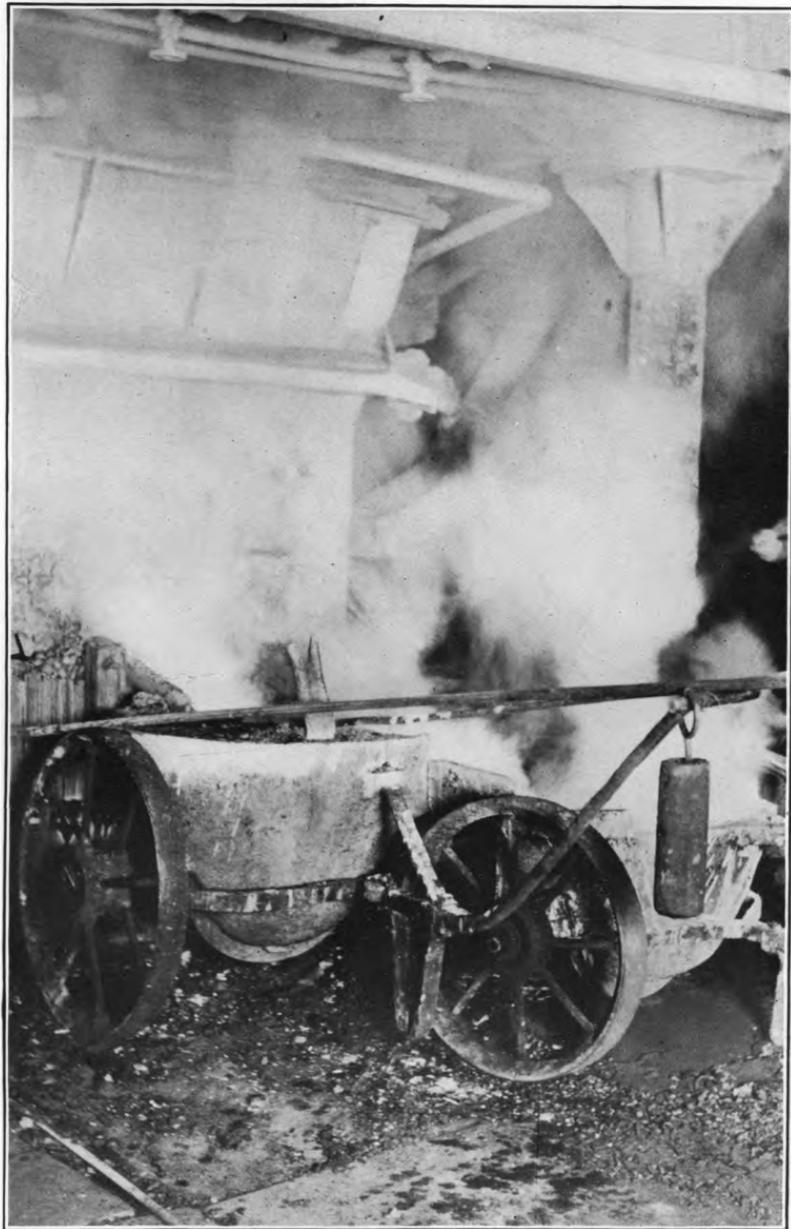


PLATE 12.—RESIDUE FURNACE OR COPPER MATTING FURNACE.

The lead drips from the well in front to the lead kettle. There is no hood here at all.

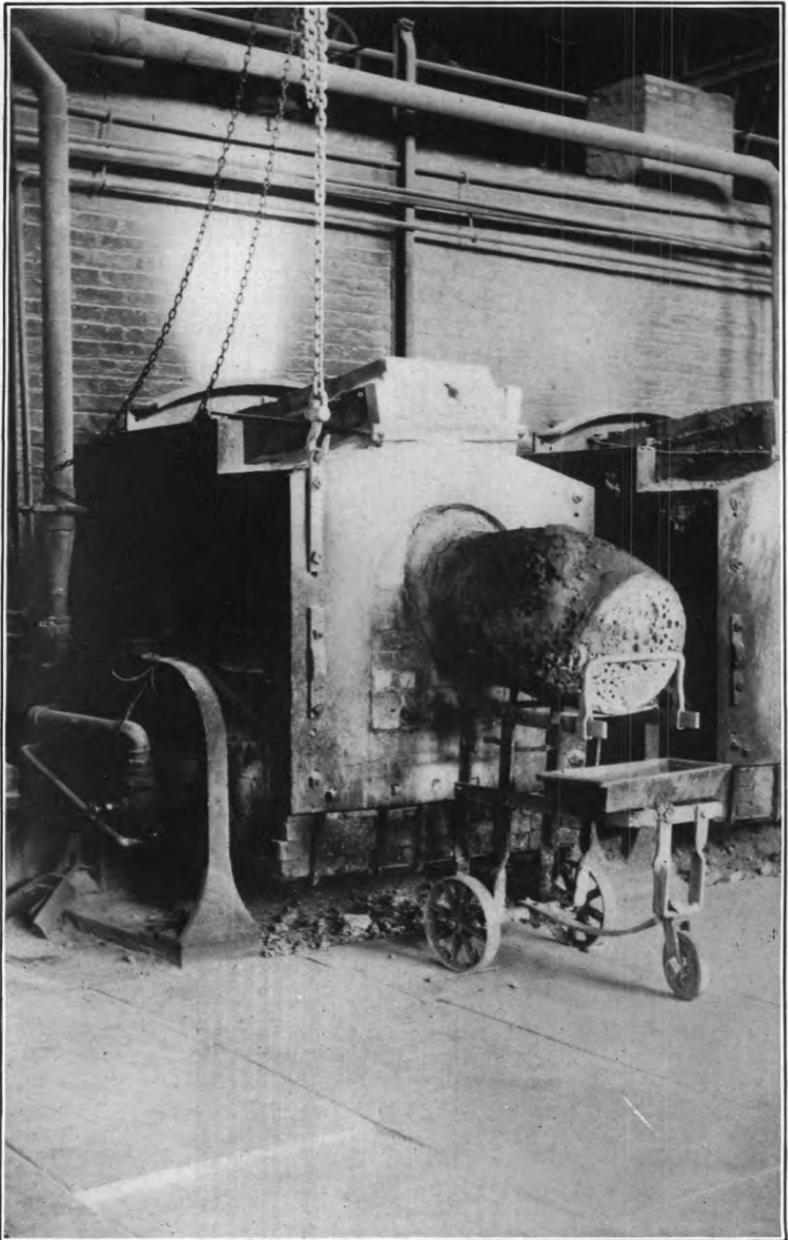


PLATE 13.—FABRE DU FAUR ZINC DISTILLATION FURNACE.

The retort is shown with the zinc condenser in place. When this is removed the rich lead or doré runs out. There is no hood to catch the fumes.

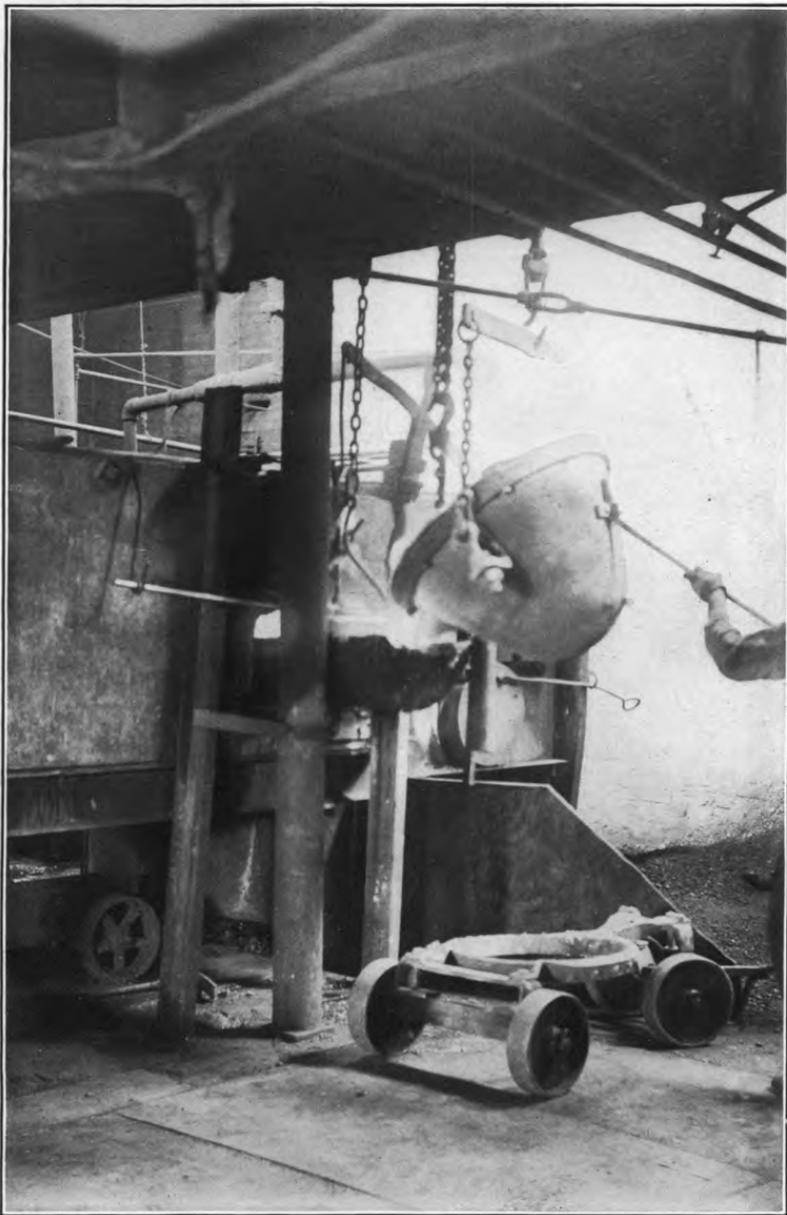


PLATE 14.—POURING THE RICH LEAD FROM A RETORT INTO A CUPELLING FURNACE.

This lead is red hot and there is no hood.

furnace, into which it is poured. From the cupels the doré, silver and gold, is recovered, the lead is oxidized to litharge, and the arsenic and antimony are lost in the fume.

The accompanying illustrations (plates 13 and 14) show where the dangers may arise in retort and cupel work. When the condenser is removed from the retorts, there usually is a copious discharge of fume.

In one large refinery in a room with nine retorts one large hood runs the whole length of the room over the doors of these furnaces. The draft inside this large hood is of course insufficient to carry off the fume, and the company is experimenting with individual hoods over two furnaces at the end of the row. These two, however, are connected with the same flue, and it is expected that the workmen will turn on the draft over one when it is tapped and at the same time turn off the other so as to concentrate the exhaust on one. When this room was visited, some Slavic workmen were engaged in tapping one retort and great clouds of white fume were pouring out and spreading through the room. The superintendent ran forward and threw open the draft with one motion of his hand, but the men could not understand his reproof, administered in vigorous English, and they evidently did not see what had been wrong or understand its importance.

In another refinery the "blue pot," which is a mixture of lead and zinc, was running out from one of the eight retorts, fuming, and the fumes continued to escape from the kettle which held it. There are no hoods here.

In all three of the largest cupelling plants the arrangements for catching and carrying off the lead fumes are far from adequate, and the litharge pot which catches the drip is allowed to fume also.

Müller believes that if precautions are not taken to prevent the escape of fumes work at the retorts and cupels may be as bad as that at the blast furnace. An additional danger is the dust caused by breaking up the cakes of litharge from the cupels, work which is always done by hand.

Collis<sup>1</sup> states that he examined seven men engaged in cupelling and all had the lead line and four a slight extensor tremor.

There is a process of driving out the last remaining zinc from the lead by means of a blast of dry superheated steam, which is considered distinctly dangerous. Lead oxide and zinc oxide are formed and at the same time atomized, and if the blast is too strong and the hooding insufficient they are driven out into the room in the form of a very fine dust. Probably there is always some lead oxide in the air around this kettle, even when steam is not pouring in, and the skin-

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<sup>1</sup>Lead smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead. By Edgar L. Collis, H. B., JI. M. medical inspector of factories, 1910, p. 13.

ming off of this mixture of oxides of lead and zinc is very productive of dust. It should only be done with every possible precaution.

There is but one refinery in which this method is used, and it has not yet been running long enough to show how much danger there is in the work

#### LIQUATING FURNACES.

These furnaces are few in number, small, and simply worked. The bars of lead are thrown in by hand or on a paddle, and the lead drips away from the sump into a kettle. The residue, which is small in amount, is scraped from the hearth by hand.

#### FLUE-DUST SYSTEM.

The dust and fume collection system in a modern American smelting or refining plant is very large and elaborate. Usually steel flues pass from the roasters and blast furnaces to end in great brick flues, and these in turn pass on to the bag house. The accompanying illustration (plate 15) shows how the flues may be arranged. The steel flues are usually furnished with some arrangement for allowing the heavier flue dust to be removed. This can be done through windows in the flues which permit the flue cleaner to insert a bent hoe or rake and to scrape out the dust, or, if the flue is very large, permit him to enter and shovel it out. Better than this is the arrangement found in many plants where hoppers are placed at intervals along the flue, and it is only necessary to open the sliding grate at the bottom of the hopper and let the dust fall into a car placed below. If a canvas chute is used from hopper to car, there need be very little dust in emptying the hopper, especially as the dust in steel flues is usually damp. The brick flues have doors, which are bricked up except during cleaning time. The lighter flue dust falls here, and the lightest passes on to the bag house.

The flue dust is a bluish black powder, light and fluffy, consisting chiefly of the oxides and sulphate of lead in varying proportions and also of arsenic, if the ore smelted contained arsenic. Western ore has often a large amount of arsenic, which complicates very much the difficulty of handling the flue dust.

Brick flues are always entered by the workmen and the dust shoveled out. Bag houses are handled in different ways. The dust clings to the sides of the bags and must be shaken out. This is done by hand in several otherwise well-managed plants, four in all, but fortunately the majority of modern plants are furnished with some sort of mechanical device for this dangerous piece of work. Reversing the current of air and thus causing a vacuum which makes the bag collapse is the best way of shaking them, and this is done in two plants. Others have a shaking mechanism controlled from the outside by a handle.



PLATE 15.—FLUE AND BAG HOUSE SYSTEM.

The long brick flues, connected over a gateway by a steel flue, run to the bag house in the left corner of the picture—the building without windows. This is one of the smelters in which there is no mechanical arrangement for shaking the bags.

A bag house should always be divided into separate compartments, not only because of the danger from fire, but also because if the bags are all in one room the whole house must be shut off once every day when they are shaken, and this means that the whole draft system is out of commission during that time. As for the emptying of the bag-house tunnels, in which this dust is caught, there are various methods used. The dust may be burned first in the tunnel, which makes it cake or sinter, or it may be shoveled out without burning. As a usual thing no sprinkling is used in this work.

It so happened that two plants were in process of bag house or flue cleaning at the time they were visited. A third has a continuous process of emptying. In the first (No. 9) the tunnel dust had been burned, and the two tunnels which were opened were still smoking. The men were at work in one of these and were shoveling out the hot dust which had been changed by the burning into masses like coral rock. No water was used, and the dust and fume were excessive. The manager said that it was not necessary for the men to go into the tunnel before it had quite cooled off, but they were working on contract and did it to save time. The men were well protected by a complete suit of overalls, a respirator, and an effective head covering. The cars full of flue dust were drawn away by the trainmen, the dust blowing all about. The bag house here has no mechanical shaker, and the bags must be shaken by hand. There is an excellent bathhouse here and an attractive lunch room.

No. 13 has only hand shaking, two men on each of three shifts being employed in shaking and repairing bags. The dust in the flues which comes from the blast furnace contains 40 per cent of arsenic. One of the great brick flues from the Dwight-Lloyd machines was being cleaned. It is a long, vaulted chamber piled with flue dust about 2 feet deep in the center and  $3\frac{1}{2}$  feet at the sides. This is very fine and light dust. It had not been burned or sprinkled, and the men were shoveling it out as it was. They had overalls and caps, and handkerchiefs tied over their mouths, but they were not really protected against the dust. A small wash room and lunch room is provided for the flue-dust men.

By far the best arrangement is seen in the United States smelter at Midvale. There is a very large bag house here with some unusual features. In the first place, the  $\text{SO}_3$  in the fumes is neutralized by mixture with volatilized zinc oxide, forming zinc sulphate. The process is patented by this company. Another scheme for neutralizing the  $\text{SO}_3$  is by introducing lime into the flues. This also is patented. The construction of the tunnels is different from that in any other plant. Instead of having simple openings in the roof of the tunnel through which the dust from the bags falls, each opening is connected with a hopper which catches the dust and discharges it

into a screw conveyer. The tunnels are all open, and carts could be seen standing at the discharge of the screw conveyers near the doors. The men are not obliged to go into the tunnel at all. Bags are shaken by reversing the current and causing a vacuum in one of the twelve compartments of the bag house at a time. Bag repairing must be done at least once a day, but never until the compartment has been shut off and the windows opened. The big flues are cleaned once in six months by flushing out. The workman opens a hole in the top of the flue and a vent at the bottom leading to a large pipe; then he directs the water from a hose into the flue, and the dust is washed out into a settling tank. The flue dust here contains a high percentage of arsenic, and the company has done much for the protection of the men against arsenical and lead poisoning by providing overalls, helmets, and gloves, a bathhouse with hot water, soap, and towels, separate lockers for street clothes and working clothes, and a well-heated lunch room.

There is the widest diversity of opinion among the managers of these plants as to the advisability of burning the flue dust and as to the feasibility of sprinkling it. All of them acknowledge that the work is very dangerous, and in those plants where the ore is rich in arsenic the men are quite efficiently protected against the dust. Fortunately the precautions taken against arsenic are equally effective against lead. Clean wash rooms, hot water, soap, and towels are always provided in these plants and some even furnish working clothes, masks, and gloves. In every plant where there is any provision at all for cleanliness it is evident that the needs of the flue men and the bag-house men have been first attended to and rightly so, for no other workers get as much lead dust on their bodies as the flue and bag-house men.

In smelting and refining plants the flue and bag-house work is regarded more or less as an emergency except for the men regularly employed at it, from about two to twelve in number. When the steel flues must be cleaned, once in two or four weeks, or the brick flues, once in three to six months, or the bag-house tunnels, once in four to twelve months, a special gang of men is collected for the work, usually from the yard gang, with perhaps some men from the briquetting house, unless a contractor from the outside brings in his own men. The work of cleaning must be rushed through as rapidly as possible, especially on the bigger flues and the bag house, because to shut off any considerable part of the flue system interferes with the working of the furnaces. Thirty or 40 men are often put on at once and when the work is not let out on contract the men are not required to work for long hours. Sometimes they work only five hours a day.

As to the sprinkling of the flue dust, one manager says that it is possible to sprinkle the bag-house dust, but not that in the flues, because the latter is hot and the steam would be excessive. Usually the opinion is that if the sulphate in flue dust is all combined, as it is in the dust from copper converters and from white lead, it can be dampened down without harm, but dust from reverberatory furnaces has free  $\text{SO}_3$  which with the water would form sulphuric acid and eat into men's clothing and cause painful burns on their skin. The success of the Midvale system comes from the neutralization of the  $\text{SO}_3$  practiced there. However, even in bag houses and flues which receive only lead sulphate dust, without free  $\text{SO}_3$ , the dust is sometimes handled dry, because sprinkling is said to stir up so much dust. Of course if the trouble from sulphuric acid could be eliminated there is no comparison between the danger of working with wet paste and with fluffy dust. As to the objection to sprinkling that it raises so much dust, this is true, as can be seen in any dusty street when the stream from a hose is turned on it with too much force, but no one would advocate cleaning the street by dry sweeping instead. The dust can be laid without much difficulty by a slower sprinkling. In those plants where the flue dust is made into briquettes there is a real advantage in having the stuff already damp and pasty.

Müller objects on practical grounds to wetting the dust in the flues, because if the water is squirted in it stirs up dust, and sprinkling takes too long. He also says that the sulphuric acid formed would be enough to destroy the bricks which line the flue. He advises burning the dust to cause sintering and then carefully protecting the workmen, giving them a short working period and choosing only strong men for the work.

Oliver <sup>1</sup> says that the British White Lead Commission visited certain smelters and as a result of what they saw advised that flue cleaners should never work longer than two hours at a stretch.

### HEAT AND EXERTION.

The exhausting effects of hard, physical work and of exposure to great heat are not so great in lead smelting as in the iron and steel industries. The work in a lead smelter is done by the day and is often intermittent, though hard and rapid work may have to be done at times on any job. When the contract system is followed, the men naturally work harder and the unloading and loading of cars, the molding of bullion, and the cleaning of flues is often contract work. On the ore hearths it is piecework. At the blast furnace front and at hand-rabbed reverberatories and on the ore hearths the work is hot and strenuous. On the whole, the most dangerous and exhausting labor is that of the ore-hearth men.

<sup>1</sup> Dangerous Trades, p. 286.

In considering the dangers of the smelting industry, it must not be forgotten that it is peculiarly liable to upsets, to accidents, and emergencies of all kinds. To quote again from a practical smelting expert:

In lead smelting there is a normal and ordinary course which the work is supposed to follow, but there are also periods of time, sometimes short, sometimes long, when accidents occur, adverse circumstances arise, and conditions alter. Such times are at the burnings out of furnaces and settlers, when hangs are heavy and the furnaces crowded, or when arsenical flue dust is being concentrated in furnaces, or when accidents happen to flues and fans and bag houses, or when bad materials impair the normal working of the furnaces. Sometimes the foremen and the superintendents do not know or do not care about these disturbances of the normal working of the plant. The management of most plants is often considerably out of touch with the actual working conditions, especially during the night shift, when much of the ugly work is done. At such times the men often suffer seriously, and instead of bettering conditions some plants put up with a continually shifting gang of men, new ones falling into the trap and all avoiding certain particular jobs as much as possible.

### RELATIVE DANGERS OF BREATHING LEAD DUST AND OF GETTING LEAD ON FOOD.

Experts in Great Britain, Germany, and Austria are agreed that in lead smelting and refining the danger comes, not from lead which adheres to the skin and is carried into the mouth with food or tobacco, not from lack of personal cleanliness, but from the presence of dust and fumes in the air. Personal cleanliness is not nearly so important in this industry as in industries which involve the handling of large quantities of soluble lead salts, such as the basic carbonate (white lead), or the oxides (red lead and litharge).<sup>1</sup> Collis, medical inspector of factories in Great Britain, says "Handling of lead may be practically disregarded as a source of trouble in these trades."<sup>2</sup> Laureck in Weyl's *Handbuch der Arbeiterkrankheiten* says "Unquestionably the greatest danger is the contamination of air by lead dust and lead fumes."<sup>3</sup> Yet, strangely enough, in the United States both physicians and laymen connected with lead-smelting plants almost invariably lay far greater stress on the danger of uncleanness on the part of the workman than on anything in his surroundings. Chargemen on feed floors with leaking stacks, workmen tapping matte and lead from the blast furnace, men working in clouds of dust at the pots or the roast and sinter machines, all are supposed to get leaded from

<sup>1</sup> In the United States the roasting of oxides to form red lead and litharge is a separate industry, while in England, Germany, and Austria it is carried on together with lead smelting. Among the 20 plants studied in the United States only 1 makes oxides on a large scale. In the others litharge is produced in the dezincing processes in refineries, but nowhere else. From foreign statistics it is evident that the making of oxides is more productive of lead poisoning than most of the processes of lead smelting. Thus, in Austria, in 1901 to 1903, there was 1 case of lead poisoning to every 15.1 men engaged in smelting, but 1 to every 2.9 men engaged in making white lead and oxides. (Grotjahn and Kaup *Handwörterbuch der sozialen Hygiene*, vol. 2, p. 275.)

<sup>2</sup> Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead. By Edgar L. Collis, M. B., H. M. medical inspector of factories, 1910, p. 6.

<sup>3</sup> *Krankheiten der Arbeiter in Blei-, Silber-, Zink- und Quecksilberhütten*, by P. Laureck. In Weyl's *Handbuch der Arbeiterkrankheiten*, pp. 33-67.

eating their lunch without washing their hands and faces. One argument against this view seems to have escaped those who hold it. The product handled in a smelter or refinery gets richer in lead as it goes through successive processes, and therefore the dust that adheres to the skin has more lead toward the end than at the beginning. By the time it reaches the refiners and desilverers it is practically pure lead, and so there should be much more lead poisoning in this department than in the mill, or in charging, or in breaking up the roasted ore, or in blast-furnace work, where the dust has only a relatively small proportion of lead, yet every practical smelting expert knows that refining and desilvering are about the safest kinds of work in the whole plant.

These figures that were prepared by E. Toth and quoted in Leymann's *Bekämpfung der Bleigefahr in der Industrie* (p. 242) show the amount of lead found in the water in which men employed in different kinds of work in a smelter had washed their hands at the end of the day's work. Toth had them use not only soap but dilute acetic acid, so the amount of lead in the water is greater than that which would be found after ordinary washing.

AMOUNT OF LEAD FOUND IN WATER IN WHICH MEN EMPLOYED IN A SMELTER HAD WASHED THEIR HANDS AT THE END OF THE DAY'S WORK, BY CHARACTER OF WORK

Character of work.	First man.	Second man.
	<i>Grams.</i>	<i>Grams.</i>
Furnace men .....	0.1286	0.1591
Mixing charges .....	.1648	.2288
Shoveling charges .....	.1776	.1995
Refining .....	.2589	.3238
Cupelling .....	.2924	.3563

Müller goes thoroughly into the question of the comparative danger of lead carried into the mouth from dirty fingers and of lead contained in the dust and fume in the air. He found the lead content of 1 cubic meter of air in the flue over the slag tap at the level of the workman's mouth to be 1.184 g. Estimating that this would be diluted about five times at the tapping platform he calculates that there would be 0.2368 g. in each cubic meter breathed by the tapper. As a man breathes about 0.45 cubic meters in an hour or 4.5 in 10 hours, the tapper would breathe in 1.0625 g. in the course of a 10-hour day. On the other hand, Müller collected from the hands of one man working on the tap floor only 0.0876 g. and from another 0.032 g. at the end of 10 hours' work.<sup>1</sup>

Now, assuming that all this quantity would be on a man's hands, not only at the end of the day, but before each of two meals, and

<sup>1</sup> The difference between his figures and those of Toth is explained by the fact that Toth's subjects used dilute acetic acid and Müller's only soap and water.

that every bit of it should get into his food (obviously an impossibility unless the man should literally wash his hands in his soup or coffee) he would still get only 0.1752 g. or 0.064 g. of lead in this way.

How significant these quantities are it is difficult to say, inasmuch as some men are very susceptible to lead and succumb to a comparatively small amount while others are resistant even to large quantities. Teleky stated in 1912 at the meeting of the Council of the Institute of Industrial Hygiene that a daily dose of rather more than 0.001 g. for several months may lead to symptoms of lead poisoning, while a daily dose of 0.1 g. may lead to severe symptoms in a few weeks.<sup>1</sup>

Other analyses of air and dust taken from different parts of a smelter are given in the Austrian report already frequently quoted.<sup>2</sup> Flue dust is, of course, richer in lead than any other.

Charging floor, blast furnace 0.4 mg. in 28 liters of air. The dust on a ledge here contained 19.7 per cent lead (estimated as oxide).

Tapping floor, blast furnace, 0.3 mg. in 28 liters of air, 14 per cent in dust.

Cupels and retorts, 0.4 mg. in 28 liters of air, 9.3 per cent in dust.

Grinding and crushing roasted ore, 29.3 per cent lead in the air.

Dust chamber, 42 per cent lead in the air, 68 per cent in the dust.

Collis<sup>3</sup> quotes Hofman's analyses of dust and fumes in lead smelting, omitting from the list constituents that are of no hygienic importance.

#### ANALYSIS OF DUST AND FUMES.

PERCENTAGE OF POISONOUS CHEMICALS IN DUST AND FUMES FROM VARIOUS SOURCES.

Material analyzed.	Arsenic.	Arsenious oxide.	Lead.	Lead monoxide.	Lead sulphate.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
All dust collected in 10 years, average.....			25.6		
Dust from—					
Down comers of 11 blast furnaces.....			47.5		
Roof of blast-furnace building.....			27.1		
Hood above slag tap.....		0.6		28.5	27.1
Fumes from—					
Slag pot while boiling.....		4.8		41.0	26.2
Reverberatory settling furnace.....	2.3			31.0	
Flue dust from—					
Friedrichshütte, Silesia.....				62.8	
Příbram, Bohemia.....		1.0		45.5	
Freiberg, Saxony.....	A 7.5 B 37.5 C 46.4		26.2 21.3 16.2		
Flue dust from—					
Omaha and Grant Works, Denver.....		15.8			57.3
Globe Works, Denver.....	A .3 B .3 C D		18.7 12.6 5.1 19.4		

<sup>1</sup> Teleky Protokoll der Sitzung des grossen Rates des Institutes für Gewerbehygiene, 1912, p. 15.

<sup>2</sup> K. k. Arbeitsstatistisches Amt im Handelsministerium: Bleivergiftungen in Hüttenmenschenn und gewerbliche Betrieben. Wien, 1905.

<sup>3</sup> Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead. By Edgar L. Collis, H. B., H. M. medical inspector of factories, 1910, p. 9.

In spite of the fact that almost every manager and physician of a smelting or refining plant lays the responsibility for what lead poisoning there is among his men to their own carelessness, because they will not wash before they eat, it is the exception to find any proper provision made for this washing which is regarded as so essential. The men are not supposed to go home during their working time; if they eat any lunch, it must be in or near their place of work, so that in the majority of cases they must choose between fasting or eating with unwashed hands and face, for there is no place where they can wash properly. The men in the blast furnace department can almost always use the hot water which runs out from the water jackets of the furnaces, and if they provide themselves with soap and towels these men can get clean. In the smelter at Salida the hot water from the furnaces has been made to flow through big wooden troughs, which are very convenient places for the men to wash. But in one large smelter the hot water is conducted away in pipes and the men can not get at it at all. All they have to wash with is cold water from the tap.

A few plants have ample washing and bathing facilities and good lunch rooms. Much the best one so far is that of the National Lead Co. at their Collinsville plant. The American Smelting & Refining Co. is constructing large "comfort houses" with bathing, washing, and lunching facilities in their plants at Federal and South Chicago which will compare favorably with the one in Collinsville. Other plants which have a good or fairly good equipment are the one at East Helena where there are small wash rooms and lunch rooms conveniently scattered through the plant, the refineries at Omaha and Perth Amboy, the Picher plant at Joplin, and the St. Joseph plant at Herculaneum. Others have either a less adequate equipment, or one which is designed for flue dustmen only, or none at all.

A safe and abundant supply of drinking water is also a necessity which has sometimes been neglected. Work in a lead smelter is hard and hot and the men need drinking water; if it is not supplied they will bring it in open pails and leave it exposed to the dust. In East Helena the superintendent of the safety department has had galvanized iron boxes with easily sliding doors placed at a convenient level on the wall and the pail of water stands inside.

### **POISONS OTHER THAN LEAD ENCOUNTERED IN LEAD SMELTING.**

Arsenic is an important feature in the smelting plants at Denver and Midvale and in the refineries at South Chicago and Grasselli, but it is also present, though in smaller amounts, in the bag-house dust at Murray, Tooele, East Helena, East Chicago, and Perth Amboy. It is rarely that one hears of any arsenical poisoning except in the

form of ulceration of the skin, and when this occurs the men are promptly changed to other work. Where the flue dust has large quantities of arsenic, special precautions are always taken, the men are protected by proper clothing and caps or helmets or hoods, and either respirators or cloths; they are required to bathe after work and to eat their lunch in a special room. One case only of severe arsenical poisoning with systemic symptoms was reported. This was a Montenegrin employed in the bag house of a western smelter. He had a severe case of arsenical neuritis which nearly proved fatal.

Although so few cases of arsenical poisoning have been noted, several physicians say that they sometimes suspect arsenic as a complication of lead, but it is impossible to be certain of it.

Concerning the part played by antimony in causing disease in this industry, nothing positive can be said, for the arsenic, which is present at the same time, masks the effect of antimony.

### **LEAD POISONING IN THE SMELTING INDUSTRY IN GREAT BRITAIN, GERMANY, AND AUSTRIA.**

The record of lead poisoning in Great Britain is to be found in the report of the chief medical inspector of factories and workshops for the year 1912. Among 2,404 men engaged in the smelting of metals there were 56 cases of plumbism or about 2 per 100 employed.<sup>1</sup> The zinc-smelting industry, however, was responsible for an undue proportion of these cases. Dr. T. M. Legge, chief medical inspector, informs us that 395 of the 2,404 men were engaged in the smelting of zinc and that 19 of the 56 cases occurred among them. This would give 37 cases for 2,009 men engaged in lead smelting, which means a rate of only 1.8 per 100. This is decidedly lower than the rates in most German and Austrian smelters. According to Collis there was an increase in the number of reported cases of plumbism in the smelting of metals during 1908 and 1909. The average for the eight years previous to 1908 was 34.4 cases per year, then in 1908 there were 70 cases and in 1909, 66.<sup>2</sup> The 56 cases of 1911 show that the number is falling again.

Lead smelting has long been regarded as a very dangerous trade in both Germany and Austria, and the early records show that lead poisoning used to be appallingly frequent 20 years ago. Since then both the German and the Austrian Governments have brought the industry under regulation and there has been a marked lessening of lead poisoning of late years, although certain plants in those countries still have a high rate. In no European country is the smelting of lead as important an industry as it is with us. According to the

<sup>1</sup> Annual Report of the Chief Inspector of Factories and Workshops for the year 1912, pp. 198, 205.

<sup>2</sup> Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead. By Edgar L. Collis, H. B., H. M. medical inspector of factories, 1910, p. 1.

figures given by the Metallurgische Gesellschaft of Frankfort-on-the-Main<sup>1</sup> the world production of lead in 1904 was 926,000 English tons, of which 284,700 tons came from North America, 190,000 tons from Spain, and 137,500 tons from Germany. Less than this was produced in Austria and in Great Britain.

It does not seem possible to find a full report of lead poisoning in this industry in Germany during recent years. The last volume of the factory inspection report (*Jahresberichte der Gewerbeaufsichtsbeamten u. Bergbehörden*) is for the year 1911 and gives information with regard to only a few plants. The Royal Friedrichshütte in Tarnowitz, employing 581 men, had not one case of lead colic during the year, while the Walter Croneck plant, employing 217 men, had 23 cases, a rate of 10.6 per 100. The report goes on to state that among the 798 men employed in both plants together there were 80 cases of gastritis and 62 of rheumatism; these are affections which in many reports would be classed as forms of plumbism. In another plant, in the district of Wiesbaden, there were 65 cases of lead colic in a force of 387 men, and in a fourth plant in the same district 13 cases among 115 men, this last having about the same rate as the Walter Croneck plant, 11 per 100. In the last two plants there was an increase over the record of the year before which was attributed to the introduction of converter roasting in which the breaking up of the caked ore causes much dangerous dust.

The Austro-Hungarian Government in 1903 ordered an investigation of lead poisoning in the smelting industry and the results of the labors of the commission appointed for this purpose were published in 1905. Very full descriptions are given of several smelters together with analyses of dust and fumes, and the records of physicians concerning lead colic and other forms of plumbism in these plants. In the Příbram works the records for the 10 years from 1894 to 1903, inclusive, show an average of only 39 cases of lead colic and of chronic gastric catarrh and chronic constipation, diseases which are probably plumbic in origin. This would be a rate of only 9 per 100 employed.<sup>2</sup> In Gailitz where the dangerous ore hearth method is used there is a rate so low that it can be explained only by the short working day on the hearths and the fact that the physician in charge suspends from furnace work all men who have lost appetite and puts them on outdoor work. In 1899 there were 14 cases of lead colic among 61 employees in this plant and no less than 94 cases of possible lead poisoning (gastric catarrh or intestinal catarrh or anemia), but in 1903 there was not one case of colic among 49 men and the suspected cases were reduced to 18.<sup>3</sup>

<sup>1</sup> *Krankheiten der Arbeiter in Blei-, Silber-, Zink und Quicksilberhütten*, by P. Laureek. In Weyl's *Handbuch der Arbeiter Krankheiten*, p. 33.

<sup>2</sup> K. k. Arbeitsstatistisches Amt im Handelsministerium. *Bleivergiftungen in hüttenmännischen u. gewerblichen Betrieben*. Teil I, p. 14.

<sup>3</sup> *Idem*, p. 27.

The Scheriau smelter has a very different record. Here there were 39 cases of lead colic among the 153 men employed in 1903, or 25 per 100. The report states that this plant suffers from the disadvantage of a poor and shifting class of labor, but it is evident also that extensive alterations in old buildings and a tardy installation of washing facilities played some part in the trouble.<sup>1</sup>

In German smelters the work is divided for the most part into two shifts of 12 hours each with 24 hours of work every second week when the shift changes. The report of the factory inspector for the Aix-la-Chapelle district makes mention of an 8-hour shift, but on the blast furnaces only. Thus in one plant, 128 men are said to have worked 12 hours and 25 men 8 hours. Austrian smelters work in 3 shifts of 8 hours, except the men who form what we would call the yard gang, who have a 10-hour day as with us. The 6-hour shifts of the Austrian ore-hearth men have already been described.

Certain of the foreign plants can show a very brilliant improvement in the health of their men at present when compared with former years. For instance in Pöfbram the average number of cases of lead poisoning for the years between 1879 and 1888 was 38.2. From 1894 to 1903 it was 12.9.<sup>2</sup> Even better are Toth's statistics<sup>3</sup> of lead smelting in Schemnitz, Hungary:

CASES OF LEAD POISONING AMONG EMPLOYEES OF LEAD SMELTERS IN SCHEMNITZ, HUNGARY, AND RATE PER 100 EMPLOYEES FOR SPECIFIED YEARS, 1895 TO 1905.

Year.	Employees.	Cases of lead poisoning.	
		Number.	Rate per 100 employees.
1895.....	328	241	73.5
1897.....	363	147	40.5
1899.....	386	166	43.0
1901.....	382	113	29.6
1902.....	359	47	13.0
1903.....	296	40	13.5
1904.....	290	25	8.6
1905.....	271	6	2.2

E. J. Neisser<sup>4</sup> gives a table showing the incidence of lead colic in two large German smelters, the royal Friedrichshütte and the Walter Croneck, the one showing a low and decreasing rate, the other a high and increasing rate.

<sup>1</sup> K. k. Arbeits statistisches Amt in Handelsministerium. Bleivergiftungen in hüttenmännischen u. gewerblichen Betrieben. Teil I, p. 34.

<sup>2</sup> Krankheiten der Arbeiter in Blei-, Silber-, Zink und Quicksilberhütten, by P. Laueck. In Weyl's Handbuch der Arbeiterkrankheiten, p. 38.

<sup>3</sup> Quoted in Leymann loc. cit., p. 245.

<sup>4</sup> Internat. Übersicht über Gewerhygiene, p. 7. Berlin, 1907.

## CASES OF LEAD COLIC AMONG EMPLOYEES OF TWO LARGE GERMAN SMELTERS, AND RATE PER 100 EMPLOYEES, BY YEARS, 1903 TO 1905.

	Year.	Employees.	Cases of lead colic.		
			Number.	Rate per 100 employees.	
K. Friedrichshütte:	Roasting and sintering—Huntington-Heberlein pots.....	1903	86	12	13.9
		1904	87	8	9.2
		1905	83	11	13.3
	Blast furnace.....	1903	267	59	22.1
		1904	232	24	10.3
	Desilvering.....	1905	247	27	10.9
		1903	56	12	21.4
	Retorts and cupels.....	1904	73	4	5.5
		1905	75	4	5.3
		1903	16	4	25.0
	Other work.....	1904	15	1	6.7
		1905	14	1	7.1
		1903	330	5	1.5
	Walter Croneckhütte.....	1904	309	4	1.3
		1905	347	7	2.0
1903		118	20	16.9	
1904		143	69	48.2	
	1905	144	99	68.7	

This is as great a contrast as can be found in the literature between two contemporaneous plants in the same country. Neisser attributes the trouble in the Walter Croneck plant to the fact that it is an old, overcrowded smelter which has not been enlarged as its output has increased, and which employs large numbers of migratory foreigners.

A German smelter which has shown marked improvement of late years is that at Ocker in Brunswick. The change after 1900 is to be attributed chiefly to efficient exhausts which were placed on the tapping floor.<sup>1</sup>

## CASES OF LEAD COLIC AMONG EMPLOYEES OF SMELTERS AT OKKER IN BRUNSWICK, AND RATE PER 100 EMPLOYEES, BY YEARS, 1897 TO 1905.

Year.	Employees.	Cases of lead colic.	
		Number.	Rate per 100 employees.
1897.....	179	20	11.2
1898.....	179	18	10.1
1899.....	177	46	25.6
1900.....	184	7	3.7
1901.....	186	5	2.5
1902.....	189	5	2.5
1903.....	189	6	3.2
1904.....	189	4	2.6
1905.....	189	1	.5

<sup>1</sup>Internat. Übersicht über Gewerbehygiene, p. 24.

## LEAD POISONING IN THE SMELTING INDUSTRY IN THE UNITED STATES.

### HISTORICAL.

Everyone who has followed the development of the lead industry in the United States for many years back asserts that lead poisoning is far less common in this industry and far less severe than it used to be. This must be true for many reasons. In the early days, even if some efforts were made to prevent accidents, practically no attention was paid to the protection of the men against disease. The industry was in a very crude condition, and the one thing of importance was to get furnaces installed and smelt the lead. Naturally the equipment of these plants was not elaborate. Hoods over furnaces, and flues and bag houses to catch and recover the fumes are comparatively recent innovations. There must have been much more sickness in the eighties than there is now; physicians, smelting experts, and old workmen all testify to this, but it is not easy to prove it.

Physicians who have practiced for many years in these centers have seldom kept records; and those who have done so have probably altered their standards as the years went on, and they now record as plumbism cases which formerly seemed too mild to notice. At least this seems the only way to account for the fact that, though their records give as high figures now as in former years, they still insist that there is not nearly so much lead poisoning as there used to be. For instance, one western physician could furnish records for 1898 and 1899 and for 1912, which made it possible to compare two dates 14 years apart. His records contain relatively few cases of plumbism, but many cases of indigestion and several of myalgia and lumbago. It seemed best to follow the German and Austrian system and regard these as probably less typical forms of chronic plumbism.

EMPLOYEES ON PAY ROLL AND CASES OF PLUMBISM, MYALGIA, AND INDIGESTION,  
AS REPORTED BY A PHYSICIAN OF A WESTERN PLANT IN THE UNITED STATES,  
1898, 1899, AND 1912.

Year.	Employees.	Cases of—			
		Plumbism.	Myalgia.	Indigestion.	Total.
1898.....	800-850	74	48	174	296
1899.....	800-850	74	47	242	363
1912.....	500-550	52	93	197	342

In spite of this showing he insisted that lead poisoning is not so common nor so severe as it was in 1898.

In another western plant the records, which go back only to 1906, show no improvement at all.

## CASES OF LEAD POISONING IN A WESTERN PLANT IN THE UNITED STATES, AND RATE PER 100 EMPLOYEES, BY YEARS, 1906 TO 1912.

Year.	Employees.	Cases of lead poisoning.	
		Number.	Rate per 100 employees.
1906.....	550	65	11.8
1907.....	550	95	17.8
1908.....	350-400	67	16.8
1909.....	350-400	38	9.5
1910.....	350-400	56	14.0
1911.....	450-500	84	16.8
1912.....	450-500	81	16.2

A record which covers 21 years is the, following, which was kept throughout by the same physician:

## CASES OF LEAD POISONING, ACCORDING TO SEVERITY, IN A WESTERN PLANT OF THE UNITED STATES, AND RATE PER 100 EMPLOYEES, FOR SPECIFIED YEARS, 1891 TO 1912.

Year.	Employees.	Cases of lead poisoning.				Rate per 100 employees.
		Severe.	Moderate.	Mild.	Total.	
1891.....	500	8	55	58	121	24.2
1892.....	500	4	49	80	133	26.6
1895.....	500	1	17	78	97	19.4
1900.....	500	1	19	77	96	19.2
1905.....	500	1	21	55	77	15.4
1906.....	500-550	1	20	90	110	20.0
1912.....	630	1	41	134	175	27.7

At first sight this report does not show any improvement; rather it shows that the lowest number of cases was reached in 1905, before the introduction of copper converters, and that since then there has been a decided increase, but though the number of cases has risen there has been a great falling off in the number of severe cases. While in 1891 the severe and moderate numbered more than the mild, in 1906 the mild were more than four times and in 1912 more than three times as numerous as the moderate and no severe cases at all were reported, so that this record really shows an improvement.

It does seem to be true that the severe nervous forms of plumbism, convulsions and insanity, occur very seldom now, at least in those plants where there are no open hearths. Thus in Denver, Pueblo, Leadville, Salt Lake City, Omaha, South Chicago, and East Chicago it was not possible to hear of a single case of convulsions or insanity that had occurred in 1912, although the physicians had known of many such cases in former years. Records were found, however, showing that lead convulsions or insanity still occur in Perth Amboy,

Newark, Collinsville, Federal, Herculeaneum, Joplin, Salida, Tooele, and East Helena.

Early hospital statistics in the lead-smelting districts are largely worthless and the only records obtainable which seemed trustworthy and significant were those of St. Vincent's Hospital in Leadville. Lead smelting began at Leadville in 1877 with one small smelter and increased rapidly till at the end of 1879 there were 10 to 12 different plants operating, most of them comparatively small and not employing over 100 men.<sup>1</sup> After 1882 the improvement in smelting practice was rapid and plants of inferior design, construction, and management were eliminated, while the remaining plants enlarged their operations so that the total number of men employed did not alter materially. In 1885 there were only 6 plants in operation, in 1892 only 4, and the following year, during the panic, all closed down. After that up to the time of this investigation only 1 plant, the Arkansas Valley, has been operated regularly.

According to Ingalls, by 1885, the smelting works at Leadville (except the Cummings & Finn smelter) exemplified about as good practice as there was anywhere at that time. The Arkansas Valley was always the best and in subsequent years was greatly improved. During the first few years of lead smelting in Leadville no attention whatever was paid to hygienic conditions in the plants, but after a few years the disastrous effects of excessive sickness among the men began to be felt and efforts were made to improve conditions. It is only during the last five years, however, that anything really systematic has been done to eliminate lead poisoning.

The statistics of St. Vincent's Hospital illustrate this short sketch of Leadville's history. They begin in 1879 toward the end of the year, and in 1880 there were 54 recorded cases of lead poisoning in men from the smelters and no less than 67 among miners, showing the nature of the ore mined in the early days. In 1881 the number of cases from smelters had risen to 109 and in 1882 it reached the highest point in the hospital records, 424, to which must be added 54 cases among miners. There were no less than 26 cases in one week in June of that year and 27 in one week in April. The total number of cases treated in the hospital in 1882 was only 818, so that lead poisoning was responsible for more than half of the patients, in spite of the large number of accidental injuries in those days. The year 1883 had a lower record, 259 out of a total of 459 patients, and 1884 had only 143. Probably the enormous morbidity of 1882 represents the culmination of two or three years' work under wretchedly unhygienic conditions, while the lessened number in the following years shows the effect of efforts at improvement in the plants.

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<sup>1</sup> The author is indebted for these facts to W. R. Ingalls, editor of the *Engineering and Mining Journal*, and to L. G. Eakins, of the Colorado Department of the American Smelting & Refining Co.

The records of individual plants during this year, 1882, show the high rate of plumbism which obtained in those days in certain plants. The La Plata smelter, which is said to have had an average pay roll of 250 men, had 198 cases in that year. Cummings & Finn, employing over 300 men, had 156 cases. These are only the hospital cases, they do not represent the whole number poisoned.

The figures keep up to between 120 and 240 for several years and there is no regular or decided diminution till the year after the panic of 1893. During this year no plants were operated in Leadville, and the 42 cases treated in the hospital must have been left over from previous years. After 1894 there was a great depression in both mining and smelting in Leadville and operations were not resumed on a large scale for several years, yet we find a steady increase of cases of lead poisoning, reaching 139 in 1900. Then comes a gradual descent to 4 cases in 1905 and from then on the figures fluctuate between 8 and 35, the last being the number of cases for 1912. From 1901 only one plant of consequence has operated in Leadville, and in 1912 this plant had an average pay roll of a little less than 300 men.

No one can show from this record that there has been a steady and consistent improvement in the lead-smelting industry in Leadville as far as the hygiene of the industry is concerned. All that can be said is that in 1882 a plant employing 250 men had a rate of lead poisoning of 79 per 100 employed while in 1913 a plant employing less than 300 men had a rate of about 12 per 100 employed.

It must not be forgotten that these are all hospital cases. We have no way of knowing the full truth about lead poisoning in this city either in former years or at present.

#### NUMBER AND KIND OF CASES FOUND.

In the present investigation records were secured of 1,769 cases of lead poisoning which occurred during the year 1912 in 19 of the lead smelting and refining plants visited. The twentieth, a newly erected refinery, had not been in operation long enough for cases of poisoning to develop among the men. These 19 factories employ about 7,400 men; that is, 7,400 represents the sum of their average pay rolls. It does not represent the actual number of men who have entered and left, or still remain in the employ of these 19 plants.

The cases of lead poisoning were secured from the following sources: Hospitals, 347 cases; physicians' records, 1,320 cases; and 102 cases reported by laymen.

It is not possible with the scanty information which has been obtained to classify these 1,769 cases according to the severity of the symptoms, but it can be done with a limited number because the records of a few plants are fairly full. For instance, in one plant, among 175 cases occurring in 1912, there were no severe ones, 41 were moderate, and 134 mild. In another, among 81 cases, there were 5 severe, 17 moderate, and 59 mild.

In a third plant the physician presented a record which had few cases of lead colic but many cases of diseases which German and Austrian authorities almost always include in their lists as milder and less typical forms of plumbism. His 342 cases were divided into: Lead colic 52, myalgia and lumbago 93, indigestion 197.

A fourth physician had kept account for two months not only of the severity of the symptoms, but also of the department in which the man had worked, so that his records show which kinds of work give rise to the more serious forms of poisoning. Forty-four of his 66 cases were mild, 22 were moderately severe. They were distributed as follows:

CASES OF LEAD POISONING RECORDED BY THE PHYSICIAN OF A CERTAIN PLANT IN THE UNITED STATES, ACCORDING TO SEVERITY AND DEPARTMENT IN WHICH EMPLOYED.

CASES RECORDED FOR TWO MONTHS.

Employed in—	Moderately severe.	Mild.	Total cases.
Handling ore.....		6	6
Mills.....	2	4	6
Sintering.....	2	4	6
Blast furnace:			
Feeding.....	2	5	7
Tapping.....	11	10	21
Settling furnace and slag dump.....	3	3	6
Converters.....		3	3
Bag house.....	1	2	3
Motor men.....		2	2
Mechanics, repairers, furnace wreckers.....	1	5	6
	22	44	66

It is easier to get information covering the cases of encephalopathy (convulsions, delirium, insanity) because they are unusual enough to arrest the attention of the physician and remain in his memory; the same is true of the more pronounced and lasting forms of palsy. It was possible to gather information concerning 41 cases of convulsions or delirium, some of them followed by temporary insanity, 12 of them ending fatally. These all occurred in 1912. It was also possible to obtain records of 35 cases of severe and more or less persistent palsy of the extensors of the arms. Thirty-two of the cases of encephalopathy were reported by physicians, 9 by laymen; 29 of the cases of palsy by physicians and 6 by laymen. The 61 cases of severe nervous derangement reported by doctors would represent 3.7 per cent of the 1,667 cases which came from professional sources.

The only plants in which there are records of more than a rare case of encephalopathy are the three which have open hearths. Twenty-one of the 32 cases of this form of plumbism reported by physicians came from these three plants and 8 of the 9 reported by the men, leaving only 12 for all the other plants. The cases of palsy also came chiefly from these same plants, 15 of the 29 from medical sources and 4 of the 6 from lay sources.

In a study of lead poisoning in the white and red lead industry<sup>1</sup> it was noted that Negroes appeared to be more susceptible to the nervous forms of plumbism than white men. This seems to be borne out by the records of encephalopathy in lead smelting. Only one of the plants reporting encephalopathy employs Negroes to any extent. This is one of the Scotch hearth plants and it would be expected that a larger number of such cases would be found here than in those plants in which this very dangerous kind of smelting is not used. Still, comparing the record of this smelter with those of the other two smelters in which there are Scotch hearths, the number of cases of encephalopathy is found to be large. The number of employees and the number of reported cases of encephalopathy in three Scotch hearth plants is shown by the following table:

CASES OF ENCEPHALOPATHY REPORTED AMONG WHITE AND NEGRO EMPLOYEES IN 3 SCOTCH HEARTH PLANTS IN 2 YEARS.

Race.	Employees.	Cases of encephalopathy.	
		Number.	Rate per 100 employees per year.
White.....	875	22	1.3
Negro.....	110	15	6.8

The Negroes were all employed in one smelter which has Scotch hearths, a sublimed white lead plant, and an extensive bag-house system. Seventy-five of the Scotch hearth men were Negroes, and 35 were white. The 45 sublimed lead men were white, and the flue and bag-house work was done by white men, this requiring 4 men all the time, and a much larger number at intervals. Thus 75 Negroes and at least 84 white men were employed in the three most dangerous divisions of the plant. The following shows the relative incidence of encephalopathy among the Negroes and whites:

CASES OF ENCEPHALOPATHY REPORTED AMONG WHITE AND NEGRO EMPLOYEES IN THE MOST DANGEROUS DIVISIONS OF A SCOTCH HEARTH PLANT IN 2 YEARS.

Race.	Employees.	Cases of encephalopathy.	
		Number.	Rate per 100 employees per year.
White.....	84	4	2.4
Negro.....	75	15	10.0

Doctors in this town and the foremen and workmen in the plant all agreed in saying that the Negroes were more liable to this form of lead

<sup>1</sup> Journal of the American Medical Association, 1912, vol. 59, p. 777.

poisoning than the whites, and this is the only town in which "lead fits" is a term in common use. That the Negroes are given to alcoholism is, of course, true in many instances, but they are said to be not as heavy drinkers on the whole as are some of the whites employed in this smelter, especially the American born, so that their susceptibility to lead poisoning of the central nervous system can not be explained on this ground.

It would be a mistake to draw any conclusions as to the cases of palsy on our list because the only ones reported were the striking and pronounced cases.

As has been found in other lead trades which employ a shifting class of workmen, unskilled or semiskilled, poorly paid, and therefore not bound to their trade, fatalities from lead poisoning are not numerous. A severe attack of colic is usually enough to make a man employed in lead smelting quit the work, and chronic plumbism is not nearly so frequent as it is in a skilled trade, such as painting or the glazing of pottery. Only 16 fatal cases were gathered during this inquiry, 8 from hospitals' or doctors' records, and 8 from the men, all having occurred during 1912. The 8 deaths reported by laymen are, of course, not free from doubt as are those obtained from physicians, yet they can not be absolutely rejected, for all but one came from the employees of two plants in which it was impossible to obtain any information from the physicians in charge. The reports were given by priests, by fellow workmen, and by relatives, and were apparently accurate. The eighth death was reported by the man's sister. He had been employed on an open hearth, had fallen in convulsions in the street one day as he was returning from work, had then gone to the country to recover, and died shortly after in a second convulsion.

The 16 fatalities were scattered through 8 plants, the 3 open-hearth smelters being responsible for 9.

#### PERIOD OF EXPOSURE AND ATTACK RATE.

Whenever it was possible to obtain interviews with men who had had lead poisoning, they were questioned as to the length of time they had worked before they first began to suffer from symptoms of poisoning. The following statement shows the period of exposure of 167 cases of lead poisoning in this industry:

Less than 1 month.....	18
1 and less than 2 months.....	19
2 and less than 3 months.....	22
3 and less than 4 months.....	33
4 and less than 5 months.....	17
5 and less than 6 months.....	12
6 and less than 12 months.....	11
Total, less than 1 year.....	132

1 year and less than 2 years.....	16
2 and less than 3 years.....	8
3 and less than 4 years.....	4
4 and less than 5 years.....	1
5 and less than 6 years.....	2
6 and less than 7 years.....	.....
7 and less than 8 years.....	3
8 and less than 9 years.....	.....
9 and less than 10 years.....	.....
Over 10 (30) years.....	1
<hr/>	
Total, over 1 year.....	35

There were two plants, one a small refinery and the other a smelter with ore hearths, in which information was available as to the length of employment of the men who showed evidence of plumbism and of those who did not. This is given in the following table:

LENGTH OF EMPLOYMENT OF MEN WHO SHOWED AND WHO DID NOT SHOW EVIDENCE OF PLUMBISM, IN A SMALL REFINERY AND IN A SMELTER WITH ORE HEARTHES.

Men with signs of plumbism.				Normal men.			
Employed—	Smelting.	Refining.	Total.	Employed—	Smelting.	Refining.	Total.
Less than 1 month.....	1	.....	1	Less than 1 month.....	34	2	36
1 to 6 months.....	4	.....	4	1 to 6 months.....	21	3	24
6 to 12 months.....	3	.....	3	6 to 12 months.....	2	2	4
1 to 2 years.....	5	1	6	1 to 2 years.....	8	4	12
2 to 5 years.....	13	4	17	2 to 5 years.....	21	7	28
5 to 10 years.....	15	4	19	5 to 10 years.....	14	1	15
10 to 15 years.....	12	7	19	10 to 15 years.....	2	.....	2
15 to 20 years.....	5	1	6	15 to 20 years.....	3	1	4
Over 20 years.....	4	.....	4	Over 20 years.....	3	.....	3
Total.....	62	17	79	Total.....	108	20	128

Only 8 out of 79 positive cases, or 10.1 per cent, had worked less than 1 year, and 64 of the 128 negative cases, or 50 per cent. For the period of 10 years and over, the rates are 36.7 per cent for the positive cases and only 7 per cent for the negative. Still, 3 men who had worked for more than 20 years did not even show the lead line.

When these figures are compared with the figures which show the period of exposure of 167 cases of lead poisoning, a wide divergence is seen, but in that case the information came from 167 men who were suffering from acute lead poisoning, most of whom had already quit work when they came under notice, while in this case we have to do with a working force actually employed at the time, the majority of those affected showing evidence of chronic, not acute, plumbism.

The attack rate of 143 men was as follows:

1 attack only.....	73
2 attacks.....	14
3 attacks.....	16
4 attacks.....	4
5 attacks.....	1
6 attacks.....	1
7 attacks.....	2
8 attacks.....	1
More than 10 attacks.....	5
"Many attacks," "several attacks," etc.....	26
Total.....	143

### RELATIVE DANGER OF DIFFERENT KINDS OF WORK.

There is just one plant where records have been made of the physical condition of the men in the different departments showing which kind of work has the greatest attendant risk of lead poisoning. The figures given do not represent attacks of acute poisoning; they represent the number of men who, on medical examination, were found to show signs of chronic plumbism.

At the time the plant was visited, 232 men had been recently examined, but 42 of them had worked only one month or less than a month, and in the case of 16 the employment was not distinctly stated, leaving 174 men, distributed as follows:

CASES OF PLUMBISM AND RATE PER 100 EMPLOYEES IN A CERTAIN PLANT VISITED ACCORDING TO CHARACTER OF WORK PERFORMED.

Occupation.	Number examined.	Cases of plumbism.	
		Number.	Rate per 100 employees.
Yard gang, unloading, wheeling charges, etc.....	26	5	19.2
Furnaces.....	119	37	31.1
Bag house and flues.....	8	5	62.5
Miscellaneous refining, repairing, masons, etc.....	21	3	14.3

This was only about one-half the force, and the number of men under the different headings do not represent the actual proportion of men employed in the different departments, for they were not examined in any particular order. The blast furnaces here are poorly hooded and dangerous, but the flue and bag-house men are the worst sufferers in the plant.

Out of 174 men examined in this plant, 66 had the lead line, 63 had pronounced anemia, 50 a history of recent colic, and 11 a history of colic more than a year ago. Five had palsy and one a history of palsy.

Another record which throws light on the danger of different kinds of work was kept during two months of 1913 in a plant employing regularly 622 men. Sixty-five cases of plumbism occurred in those two months. The men were employed as follows:

CASES OF PLUMBISM AND RATE PER 100 EMPLOYEES DURING TWO MONTHS OF 1913, BY DEPARTMENTS.

Department.	Number employed.	Cases of plumbism.	
		Number.	Rate per 100 employees.
Mills, crushing and sampling .....	42	6	14.3
Ore bins .....	45	6	13.3
Sintering .....	60	6	10.0
Blast furnace feeding .....	35	7	20.0
Blast furnace tapping .....	90	21	23.3
Settling furnace and slag dump .....	18	6	33.3
Converters .....	45	3	6.7
Miscellaneous .....	280	7	2.5
Bag house .....	7	3	42.9

These would be high rates for a whole year, and this record covers only two months.

The following shows the record for 1905 in the different departments of the German smelter at Tarnowitz, the Friedrichshütte.<sup>1</sup>

CASES OF PLUMBISM AND RATE PER 100 EMPLOYEES IN THE GERMAN SMELTER AT TARNOWITZ, BY DEPARTMENTS, 1905.

Department.	Number employed.	Cases of plumbism.	
		Number.	Rate per 100 employees.
Sintering, H. H. pots .....	83	11	13.3
Blast furnace .....	247	27	10.9
Desilvering, refining, cupeling, etc .....	75	4	5.3
Retorts .....	14	1	7.1
Miscellaneous .....	347	7	2.0
Total .....	766	50	6.5

In Collis's report of an examination of men engaged in different processes in smelting it is shown that the men at the furnaces had a shorter average duration of employment and a larger percentage of them had the lead line than was true of the general laborers or the men at the melting pot. The general laborers suffered more than the others from impaired extensor strength in the forearms, the furnace men coming next. Men at the melting pot had the longest average duration of employment.<sup>2</sup>

<sup>1</sup> Krankheiten der Arbeiter in Blei-, Silber-, Zinn und Quecksilberhütten, by P. Laueck. In Weyl's Handbuch der Arbeiterkrankheiten, p. 37.

<sup>2</sup> Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials containing Lead. By Edgar L. Collis, H. B., H. M. medical inspector of factories, 1910, p. 6.

### INFLUENCE OF THE SEASONS.

There is a decided seasonal variation in the incidence of lead poisoning in this industry. If we plot a curve based on the three heaviest months in each of 33 hospital years, or if we make the curve represent the months in which 2,847 hospital cases occurred we arrive at the same result. The highest points are reached in January and June. It is not easy to discover the reason for this curve. Physicians and superintendents explain the rise during the fall months as due to the onset of cold weather, causing the men to close windows and doors, to stay near the furnaces for warmth, and to eat their lunch indoors instead of outdoors. As for the summer rise, they are usually ready enough to explain it on the ground of greater skin absorption during hot weather, but if that were the case then July and August should show even higher numbers than June. The most probable explanation seems to be that these June cases are the acute cases of poisoning which occur among newly hired employees. During the spring there is a great exodus of the regular force from these smelters, the men going off to work on the farms or railroads, and there is a corresponding entrance of new men, some of them very susceptible to lead poisoning, most of them inexperienced and careless. By June they have worked for 8 to 12 weeks, and have become poisoned, for, as has already been shown, the majority of cases of acute plumbism among lead smelters occur after less than 4 months' exposure.

One smelting expert suggested that the two crests of the curve were coincident with the dates of flue-cleaning operations, but a careful inquiry has failed to show that there is any such regular periodicity in flue cleaning in the western smelters from which most of these statistics come.

### METHOD OF COLLECTING CASES.

The 1,769 cases given in these lists do not represent all the cases of lead poisoning which occurred in a year's time in these 19 plants because the methods followed in collecting them could not possibly yield full and accurate results. Hospital records can be looked on as above criticism, and the 347 cases on our lists are probably all the cases of plumbism treated by these hospitals during 1912, for lead poisoning is an old story to the physicians in smelting towns and it is very improbable that any case escaped diagnosis in the hospital. But there are only 9 of the 19 plants whose men were sent to hospitals, except as an unusual emergency, and even these 9 do not send all their cases to the hospital. The less serious ones are especially likely to be treated outside.

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<sup>1</sup> Collis, *op. cit.*, p. 6.

The next source of information, the records of doctors, is open to many criticisms. The company doctor who is well trained in diagnosis, who examines all the men once a month and writes down the results, is the only one who can give full information. There are two refineries in Illinois which are served by doctors of this type and for these two plants we have entered the number of cases as given by their records, further search having revealed no additional cases. One physician outside Illinois had made a thorough examination of more than one-half of the men employed in the plant and his records for these men were entirely above criticism. It must be said, however, that it is difficult to discover all of the cases of lead poisoning, even with a regular examination, for the very proper procedure followed by some company doctors of suspending from work a man who is suspected of plumbism has sometimes the unfortunate effect of making the men conceal their symptoms. This is especially true of those who hold the better paid places, such as the ore-hearth men, who sometimes are found to have been under the care of an outside physician for weeks while they were insisting to the company doctor that they were in perfect health. It is, of course, very difficult to make a diagnosis of lead poisoning upon observation alone if the man refuses to admit that he has any symptoms.

In the case of the other 16 plants the physicians do not see all of the cases of lead poisoning that develop, for they treat only the men who come to them for advice, and there are some workmen who distrust the company doctor simply because he is the company doctor. Also there are foreigners who prefer men of their own nationality and who will sometimes go off to the nearest city to find one, thus escaping entirely the notice of the physician employed by the company. Besides this, the doctor who sees only the men who come to him with the complaint of illness will fail to include in his records the incipient cases not yet developed to the point of alarming the patient and also the chronic cases with minor symptoms. Therefore no physician, no matter how careful and accurate he is, can report every case occurring in the plant unless he sees all of the men at regular intervals.

But not all physicians are entirely careful and accurate, and not all are sufficiently accessible to the men. Some of them do make frequent, even daily, visits to the plant and may be approached by the men without any formality. On the other hand, others come only when they are sent for and the men are supposed to get an order from their foreman and go to the doctor's office if they wish to see him.

It was of course necessary to make a further search for lead poisoning in places where the information obtained from the doctor was very unsatisfactory. Other physicians were visited, and also apothecaries, priests, and men who were known to have a wide

acquaintance among certain of the nationalities employed. These outside physicians could sometimes swell the number of cases very decidedly, especially in two towns where the company doctors are disliked and distrusted by the men. For instance, in one of these towns two doctors gave records of 144 cases which had occurred in 15 months' time in the plant. Though the wage scale in this refinery is low, as in all refineries, and the men have been obliged to pay for the services of the company doctor, they are willing to pay again in order to have a doctor who can speak their language and whom they can trust.

However, few doctors in general practice keep records, and as a usual thing these outside physicians could not do more than confirm the investigator's belief as to the existence of lead poisoning in a certain plant, for it was considered best not to give the same weight to general statements as to records of individual cases. Such statements as "12 cases a month last year," or "about 40 in the course of a year," were noted, but the figures were not included in the statistics of lead poisoning given in this report. Had that been done the list would have been increased by some 700 cases, but we could not have been sure that we were not counting the same case more than once.

The cases gathered from nonprofessional sources which were described with enough particularity to seem trustworthy, but which lack medical confirmation, have been listed separately. They form, however, less than one-seventeenth of the total number of cases. Among them are cases reported by priests, who have visited the men in their sickness and in some instances attended them at death. These priests could often give inside information as to the character of the plant, the increase or decrease of accidents and sickness among the men, and above all as to the relations between doctor and men. Another good source of information is the apothecary, especially the Slavic or Hungarian, for he often sees cases which never reach a physician and he grows fairly skillful in diagnosis. The remaining cases in this class were reported by the men themselves or by relatives or by fellow workmen.

Therefore as regards the figures of lead poisoning, given above, we believe we are justified in claiming that the degree of lead poisoning among the workmen in these plants is decidedly higher than our figures show, since the sources of information which were drawn upon for them were almost always insufficient and since the standard applied was strict and no doubtful cases were included.

It may be well to give a summary of the records of some of the physicians attached to smelting plants to show that it is not an overestimate when we say that the rate of lead poisoning in the lead-smelting industry is at least 22 in 100.

## CASES OF LEAD POISONING AND RATE PER 100 EMPLOYEES REPORTED BY PHYSICIANS OF 6 SMELTING PLANTS IN 1912.

Plant.	Average monthly pay roll.	Cases of lead poisoning.	
		Number.	Rate per 100 employees.
No. 13.....	450	81	18.0
No. 17.....	660	120	18.2
No. 12.....	630	175	27.5
No. 11.....	300	85	28.3
No. 18.....	660	204	34.0
No. 20.....	350	183	52.3

There was a seventh plant which, in a force of 623 men, had 65 cases of lead poisoning in two months' time. If this rate were kept up during the year, it would mean 390 cases or about 62.6 per 100, but we do not know whether this record did persist throughout the year.

The results of three house-to-house canvasses, which were made in smelting villages, are pertinent here. Two of the villages were near smelters with ore hearths, the third near the usual type of smelter without ore hearths. The houses were visited haphazard and the men or their wives interviewed in the effort to ascertain whether or not the man had ever suffered from lead colic or palsy. In the first village 42 were questioned, of whom 26 gave a history of lead colic and 3 of palsy as well, while 16 had never been poisoned. In the second village 21 were interviewed; 12 had had lead colic, 9 had not. In the third village 17 out of 30 had had colic, 2 of them palsy also, while 13 had not.

**MEDICAL SUPERVISION.**

Lead smelting is an industry attended with a certain amount of risk of accident, and in consequence it has long been the custom of the employers to engage physicians whose duty at first had to do chiefly with cases of accidental injury. This system was advantageous to the company in view of possible suits for damages and probably also to the men since it insured the prompt attention of a surgeon who was likely to be one of the best in the town. It was natural that many of these physicians should gradually come to take charge of cases of lead poisoning also, and finally of all forms of sickness. At present every one of the plants which form the subject of this study has at least one physician who gives more or less regular attendance to the employees. In a well-managed smelter the physician comes out at regular intervals to the plant, where he is usually assigned a room for his use, and he is at the service of any man who wishes to consult him. No formality is needed beyond the foreman's permission for the man to quit work. Often the company has an

arrangement with some hospital and sends there the serious cases and those who could not be properly cared for at home, the expenses being paid out of the sickness insurance fund. Where there is no hospital, the company doctor attends cases of disabling sickness in the men's homes.

The arrangement is not always so good as this. Some physicians go to the plant only when they are summoned for an accident or for an acute attack of lead poisoning occurring at the plant. If the men wish attention, they must get an order from the foreman and go to a doctor's office, which may be miles away. No plant was found in which there was absolutely no provision for medical care, though the amount and character of the service given varies greatly. There are some physicians who act only as medical attendants and know nothing at all about conditions in the plant, who lecture the men about washing their hands without ever asking if it is possible for them to do so, and who do not know enough about the work to be able to say from which department most of the lead poisoning comes. On the other hand, there are physicians who act as consulting sanitary experts, who go over the plant frequently, keep track of the men, and notify the superintendent when any department is sending in an unusual number of cases.

In their relation to their patients, too, we can find all types of physicians in these plants, from the doctor who is feared and suspected by the men to the one whom they gladly seek out when they are ill and call on to take care of their wives and children.

Ignorance and neglect on the part of the company doctor can not be controlled by legal machinery; it must be in the hands of the manager, and it is a pity that company officials do not always realize how important a matter this is, how much the doctor influences the attitude of the workmen, making them hostile toward their employers or winning their confidence and loyalty. In talking with workmen in the privacy of their homes where they can speak freely, one is always impressed by the large part the doctor plays and the influence he has on their attitude toward the company.

Of course the employer really wants first-class medical and surgical service, for he knows that the efficiency of his workmen depends largely on this, but unfortunately, such service is not an easy thing to gauge. The results of good sanitation and medical care show themselves slowly and seldom with indubitable clearness. They can not be calculated as can the results of new machinery, and therefore the neglect or incompetence of the doctor may escape detection by his employers. It does not occur, for instance, to the manager of a certain large refinery that there is any connection between the almost impossible shifting character of his force of Slavic workmen and the brutal manners of the company doctor, who despises his patients,

can not speak their language, and gives them the impression that he cares only to shield the company against possible damage suits.

For thorough medical supervision, there should certainly be regular inspection of all of the men at stated intervals, as there is in Germany and in Great Britain.<sup>1</sup> But whatever system is adopted, its success depends on the skill and character of the doctor, and on his character, perhaps, more than on his skill. There are plants in Illinois which with the regular inspection required by the law do not give as good medical care to the men as do several plants outside Illinois where such inspection is not practiced. A physician who is not naturally overthorough, whose sympathies are not easily aroused, and who knows that his tenure of office depends on superintendent or manager, may easily fall into careless superficial habits with his patients and make up for it by scrupulous attention to the company's interest in accident suits.

At present the medical service given in these 20 plants may be classed as excellent in 9, fair in 5, and poor in 6.

#### SICKNESS AND ACCIDENT INSURANCE.

There is some form of accident and sickness insurance in all these smelters and refineries, usually the following:

A sum which runs from 60 cents to \$1.50 is deducted from the monthly wage of each man and goes to the insurance fund. Out of this is paid the salary of the physician and his assistant, if he has one, the hospital expenses in case the company sends its employees to a hospital, and half pay for the men who are disabled by accidental injuries. Men who have industrial lead poisoning do not receive half pay.

The sum of \$1 a month, which is what the men contribute in the greater number of plants, is often sufficient to cover all expenses, and the company need not contribute anything. In three plants it was stated that \$1 was ample, while in another the manager stated that 75 cents a month would be sufficient for all demands and that \$1 would mean a surplus. In other plants, however, \$1 or even \$1.50 is not enough to cover expenses and the company must make a contribution almost every month.

It is not surprising that the expenses of medical care and insurance are often fully covered by the men's contribution when one considers that it is the custom in the majority of these plants (outside Illinois) to collect the sickness insurance for the whole month during the first week of a man's employment. If then he leaves at the end of the week and another takes his place, the dollar is collected from the

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<sup>1</sup> For foreign regulations concerning medical care of workers employed in industries involving risk of lead poisoning, see Appendix V.

latter also, so that it is conceivable that \$3 or even \$4 may be collected from the successive holders of one job in one month's time. As a matter of fact, \$1,100 was collected during August, 1913, from the employees of a lead and copper smelter whose average daily pay roll is only 835 men.

This system of accident and sickness insurance is singularly generous to the company, which thus throws back upon the men the larger part, if not all, of the expense of occupational accident and disease. The company also selects the doctor, has control of him, and commands his loyalty, yet is not obliged to pay him anything, or at the most only a small part of his salary. Nor have the men any possible redress if the doctor neglects his duty.

There are, however, other methods of managing sickness and accident insurance. The Illinois occupational disease law, which was passed in 1911, makes it incumbent on employers to provide for a monthly medical examination of all the men in their employ who come in contact with lead or its salts. The physician retained for this service naturally gives treatment as well. He is, of course, paid entirely by his employers. The Picher Lead Co. has a system more like ordinary industrial insurance. The men pay 15 cents weekly apiece and the company puts in an equal amount for each man. In this plant not only is medical care given, but a systematic examination made as in the Illinois plants.

In the International Smelter at Tooele the \$1 collected from the men goes for medical services only, the company paying full wages to men incapacitated by injury. The doctors hold their positions only as long as they give satisfaction to the men.

The St. Joseph Lead Co. in Herculaneum employs two physicians to care for their accident cases. The company has built a dispensary for them and pays the expenses of all accident cases and of all cases of sickness which are sent by the doctors to the hospital at Bonne Terre or to some St. Louis hospital. It is optional with the men whether or not they will employ these doctors for sickness. If a man decides to do so, the company deducts \$1 monthly from his pay and gives it to the doctor, and for this sum the man is entitled to medical care for himself and his family. Practically all the men, except some of the "floaters," avail themselves of this arrangement, but the mere fact that it is optional, that the men may save that \$1 if they choose and go to a doctor in a nearby town, gives them the normal attitude of patients toward their physician and is certainly not without its effect on the physician's attitude toward them. It would seem fairer, however, for the company to bear at least a share of the expense of medical treatment, especially in cases of disease distinctly traceable to the men's work.

## CHARACTER OF EMPLOYEES.

The men employed in lead smelting and refining are for the most part foreign born of different nationalities, often newly arrived immigrants unable to speak English and unacquainted with the dangers of the work they undertake. This does not mean that they do not know the work is dangerous, for usually they have been warned by their fellow-countrymen, who have already worked in the plant, but they have no idea how to protect themselves against the dangers. On the Atlantic seaboard the men are chiefly Austrian Slavs, and the same nationalities are found in and around Chicago, with Magyars in addition. As we go farther west the mixture of nationalities increases. In the Federal plant near Alton there were in the spring of 1913 about 200 American-born whites and 25 Negroes, the rest being Germans, Italians, Slavs, and Greeks. The Italians were employed at the heaviest work, loading and unloading cars, the Greeks and Austrians in the yard and on blast furnaces, the negroes in the refinery, and the American whites on the ore hearths and in the powerhouse. In Collinsville the employees are Negroes, American-born whites, Lithuanians, Italians, Syrians, Mexicans, and Germans. The Hoyt Metal Co., in Granite City, employs Turks, Armenians, and Macedonians in addition to other nationalities. At Herculaneum the force consists of a much larger proportion of American-born whites, some of whom are regular smelters by trade, while some are farmers working at smelting only in winter. Some of these are descendants of Washington County French. There are also Slavs, who form the more shifting part of the force. In Joplin alone the men are all Americans, many of whom come from Arkansas farms, work through the cold season, and return home in the spring. This alternation of employment is excellent for the men's health, and it is fairly general in the smelting industry. In Colorado the beet fields draw the men for the summer months, while the Slavs and Greeks of Chicago and southern Illinois go off on railroad-extension work.

Leadville, Salida, and Denver have chiefly Austro-Hungarians and Greeks, with a few Italians and Russians. Pueblo has more Italians and has also Mexicans. Montenegrins are found in the Utah smelters, in addition to other southeastern Europeans. In 1911 a census of the Omaha Smelting & Refining Co. gave the following nationalities: Italians, 134; Austrians, 82; Hungarians, 85; Americans, 59; Bohemians, 53; Irish, 20; Poles, 18; Swedes, 12; Germans, 11. In 1913 the East Helena plant had 92 Austrians and 44 Americans, the remaining 56 men being scattered among no less than 17 different nationalities. In all these smelters there is always at least a small proportion of skilled American-born or northern European workmen holding the better-paid places.

The force is roughly divided into the yard gang, employed at day wages for a 9 or 10 hour day (8 hours in Colorado) and the inside men who work for 8 hours, three shifts, in the western plants and in Perth Amboy, or for 12 hours, two shifts, in Graselli, East Chicago, South Chicago, and Newark. In one typical smelting plant the yard gang numbers 175 to 200, the inside men 90 to 100. In one large refinery the yard gang, including repairing men, has 300; the converters and blast furnaces, 250; the refinery, 90.

Wages in the largest eastern plant were given as 20 cents an hour for men in the yard gang, who work 9 hours, and 25 cents an hour for the inside men, who work 8 hours. In East Chicago the day wage is \$1.75; piecework averages \$3 a day. In Collinsville and Federal the day wage is \$1.65 to \$1.80; the work on the ore hearths, in dust collecting system, and in unloading cars is piecework, and for this the men are paid from \$2.25 to \$3.00 a day. Farther west the wage for day labor rises, but that for more skilled work hardly changes at all. Thus, in Herculaneum and in Omaha day laborers are paid \$1.65 a day, in Denver \$1.75, in Leadville and in Salt Lake City \$2, in Tooele and in East Helena \$2.25 or \$2.35, while in all these plants \$2.35 to \$3 was given as the wage for skilled work. Mechanics, repairers, plumbers, blacksmiths, etc., are not included here.

Many vague charges of alcoholic excess are brought against the men employed in lead smelting, but not often by the people who know them best—their own foremen and employers. That Slavic, Magyar, Italian, and German workmen drink beer, wine, and even whisky is readily admitted, but they are not regarded as an intemperate class of men on the whole, nor are the Negroes. It is really in the plants where many American workmen are employed that one hears most complaint of alcoholism, perhaps because American workmen can not stand alcohol so well as Europeans.

The workers are a very shifting lot of men and even the cash bonus offered by one large company to men who remain as long as a year in its employ is not inducement enough to make them stay. This refinery had succeeded in keeping less than 30 per cent of the force as long as one year at the time it was visited. Naturally such a state of things results in far more lead poisoning among the men than is found in a plant where the workmen remain for years, acquire a fair amount of skill, and learn the risks to which they are exposed.

The Austrian commission's report lays especial stress on the danger of a continually changing personnel, and ascribes the high rate of lead poisoning in the Scheriau smelter largely to the fact that the labor employed there is ignorant and shifting. In 1903, 560 men were taken on in this plant to keep up a monthly pay roll of only 91, and among the 153 men reported on by the physician there were 39 cases of lead colic and 31 of gastro-intestinal catarrh.

The German factory inspectors also speak of the trouble arising from casual workers. In the Walter Croneck smelter, in Silesia, a certain proportion of the employees come from Ruthenia and, like the foreign employees in American smelters, they do not understand the language of the country; they enter the industry only as a temporary expedient and during the short period that they work they live in crowded, unsanitary quarters and do not have sufficient food. In 1911, 233 Ruthenians were employed in the Walter Croneck plant and of these 192 left work and 71 remained at the end of the year. The native German workmen, numbering 160, had only 9 cases of lead poisoning, while 60 Ruthenians had 16 cases. This plant increased its force in 1902 and the increase in lead poisoning was at once perceptible. In 1901 there were 13 cases among 73 men (17.8 per cent); in 1902, 35 cases among 129 men (27.1 per cent), showing that there were susceptible men among the newly employed.<sup>1</sup>

Although almost all of the managers of American plants complain of the shifting character of their labor, the condition is worse on the Atlantic seaboard and in the neighborhood of Chicago and St. Louis than in western Missouri, Colorado, and Omaha. The following are some of the statements made by superintendents as to the shifting character of the men employed by them:

"From 25 per cent to 30 per cent new men must be employed every month."

"We can not get steady workmen; we are always losing our men, though we pay more than the usual rate of wages."

"Not 30 per cent have been here as long as one year, and those who do stay average only 20 days' work a month."

"In one month 25 out of 92 men quit work."

"Not many of the men stay more than two months. We always prepare for the semimonthly pay day by sending to the employment agencies in St. Louis and Chicago."

"Six hundred and thirty are employed all the time, but there were 800 on the books last month."

"The monthly pay roll is 350, but 100 new men were employed during August, 25 on the blast furnace alone."

In only two plants could accurate information be obtained as to the length of employment of the men then at work. In one, out of 238 men, 52 had been there less than 1 month, 91 less than 6 months, 106 less than 1 year, while exactly one-half the force, 119 men, had been employed less than 2 years. On the other hand, 75 had been employed over 5 years and 13 over 20 years.

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<sup>1</sup> Gewerbliche Vergiftungen deren Vorkommen, Erscheinungen, Behandlung und Verhütung. J. Rambousek, Leipzig, 1911, p. 156.

The second plant gave a more detailed report, as follows:

Employed less than 1 year.....	298
1 to 2 years.....	75
2 to 3 years.....	43
3 to 4 years.....	35
4 to 6 years.....	39
6 to 8 years.....	22
8 to 10 years.....	14
10 to 15 years.....	15
15 to 20 years.....	16
Over 20 and under 30 years.....	53
Over 30 years.....	15

In spite of the large number of casual workers, this is an unusually good showing, with 68 men employed over 20 years.

It is evident from the records that while none of the managers can boast of anything like a steady force of workmen, yet some of them suffer far more than others from the continual shifting. The plants which are near the big centers of industry naturally have more difficulty in holding their men than do those which are situated where there is not so much demand for labor. It is also true, however, that some of these plants enjoy fair reputations, while others are so notoriously dangerous that the newly arrived Greek or Slav or Italian is warned by his fellow countrymen that two months is the longest time he may safely work there, after which he must look for work in the open air to get rid of the poison.

In talking with the men employed in two neighboring plants it was learned that while one plant was receiving many applications for work from old employees returning from a summer on the farms the other was actually crippled for lack of men. It was easy to see why there should be this difference between the two plants, for one was unusually clean and under the management of an intelligent and careful man, while the other was one of the two most dangerous plants to be found in the country.

#### HOUSING.

In almost every lead smelter there is a large number of foreign-born workmen, who have no families with them, who have taken up the employment as a temporary thing, and who are eager to save as much as possible from their wages so that they may send home for their families or return to them. This part of the force usually lives close around the smelter, and groups of men of the same nationality rent a few rooms which they use to the utmost limit permitted by the three-shift system. These rooms are sometimes surprisingly clean and well kept; more often they are as neglected and dirty as would be expected. Most smelting villages are very unattractive, dreary, and squalid, and the dreary effect is added to by the sulphurous fumes which escape from the smokestacks of the

works, sometimes only at intervals, sometimes almost continuously. Yet there are some pleasant, prosperous looking smelting villages of permanent homes, such as the one at Herculaneum, the one at East Helena, and the Slavic village at Pueblo. It is partly a question of permanence as against excessive shifting, for a migratory population will take little interest in a place of temporary sojourn only, but it is partly also a question of nationality, as can be seen in the contrast between the Italian-Mexican village in Pueblo, with its utter neglect of ordinary cleanliness in the surroundings of the houses, and the clean attractive Slavic village across the river. As a rule the smelting companies do not rent houses to their workmen, but in the three instances where this is done these houses compare very favorably with workmen's houses in the neighboring towns, and the rent is moderate.

#### COMPULSORY REGISTRATION OF OCCUPATIONAL PLUMBISM.

The effort to collect trustworthy data as to lead poisoning in the smelting industry showed that no one could expect very much help from the physicians attached to some of the plants. In the first place there is absolutely no uniformity of standard among these physicians as to what constitutes lead poisoning. For instance, one man reports as a mild case of plumbism a workman with anæmia and a lead line. This is entirely in accordance with British and continental usage. Another, however, designates as mild plumbism a severe attack of colic, constipation, nausea, and vomiting, requiring medical care for two weeks. Such a case would be classed as moderately severe in British reports, but the American physician in question does not consider anything milder than this a reportable case of lead poisoning.

The relation between physician and employer sometimes interferes with the effort to obtain full reports of lead poisoning from a plant. Fleck complains that in Germany there is a tendency on the part of physicians attached to lead works to spare their employer's feelings by keeping the list of cases of lead poisoning low and recording such diagnoses as "gastric catarrh" or "chronic constipation," or "anæmia" instead.

In view of the fact that several States have passed laws requiring physicians to report to some central office all cases of industrial plumbism which come to their notice, it may be well to note how the Illinois law has worked. Illinois requires employers in establishments where lead salts are handled to provide for a monthly medical examination of all employees exposed to the danger of lead poisoning and to report all cases of lead poisoning. Missouri has recently made the same requirement. Similar laws in other States require all

physicians to report such cases, but do not call for regular medical inspection.

Physicians and sanitarians have always said that the only way in which we can hope to gather accurate statistics concerning any occupational disease incident to the lead industry, such as are available in Great Britain and continental countries, is to have all the men who are exposed to lead examined more or less frequently and a report of the findings sent to some central bureau. It was largely for this reason that the Illinois law was framed as it was, but the requirement to report cases unfortunately applies only to the physicians attached to the factories which come under the law. The experience of Illinois after two years' operation of this law seems to show that if we are ever to have trustworthy statistics comparable with those of other countries it must be with the help of all of the physicians in the State, and, in addition to this, there must be some way of checking up reports sent in by the company doctors.

The records of five smelting and refining plants in Illinois concerning which information is available in the chief factory inspector's office, were examined in the search for reports of lead poisoning. For No. 1, the company doctor sent in every month during the last half of 1912 and the first three months of 1913 reports of the physical examination of 300 to 400 men with only two cases of plumbism. Yet this is a plant with ore hearths and a bag house in addition to all the other dangerous parts of a smelter. Meantime, during 1912, hospitals in near-by cities had treated 46 cases from this plant, and physicians had treated 68 cases, making 114 among which were 8 encephalopathics, but none of these reached the factory inspector's office. To anyone who knows the smelting industry, whether or not he has studied medicine, it is incomprehensible how any physician could examine 165 to 175 ore-hearth men, month after month, without finding any evidence of lead poisoning.

No. 2 is a contrast to this, yet curiously enough the two plants belong to the same company. In No. 2 the doctor reported every case of profound anæmia, or obstinate constipation, with a lead line, as plumbism, a carefulness of diagnosis rare even among private physicians. This plant employs 100 to 125 men.

In No. 3 the policy is very like that followed in No. 1, and the physician in charge of 350 to 450 men sent to the chief factory inspector's office reports of monthly inspections of all the men, showing only five cases of lead poisoning during 1912.<sup>1</sup> This also is a plant with ore hearths. Hospital records during 1912 yielded 66 cases from this plant, and physicians reported 33 more, making

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<sup>1</sup> It is only fair to state that vigorous remonstrances on the part of the chief factory inspector resulted in a sudden change in January, 1913, and during the next three months 29 cases were reported.

99, while 47 additional cases came to the knowledge of the investigators but lacked medical confirmation. Among the 99 cases were 7 encephalopathies, 5 palsies, and 2 deaths.

No. 4 is a contrast to No. 3. It is a small refinery employing only about 30 men in work which exposes them to lead. The physician in charge sends monthly records of his examinations giving a list of negative cases, of all those who show a lead line, and of those with symptoms of chronic plumbism.

Of No. 5 little need be said. It is a refinery employing 150 men in the smelting and refining of dross and scrap lead. There is both dust and fume to an unusual extent in this factory, yet the physician in charge stated that he had had no case of lead poisoning since he was employed more than a year ago. Such an assertion needs no comment.

The working of the Illinois law therefore has not produced the result that was hoped for. It does not provide the chief factory inspector's office with accurate records concerning lead poisoning in the smelting industry, whatever may be true of other lead industries. The requirement to report cases of lead poisoning should apply to all physicians, not alone to those employed by the companies; and it would be a very good thing if the law should provide also that physicians connected with the State factory inspector's office should at certain intervals go through the plants, examine the men, and check up the company doctor's reports. Unless something of this sort is done we shall never be able to claim that the statistics of occupational lead poisoning in this industry are trustworthy.

## APPENDIXES.

### APPENDIX I.—THE SOLUBILITY OF LEAD SULPHIDE ORES AND OF LEAD SULPHIDE IN HUMAN GASTRIC JUICE.

By A. WOELFEL and A. J. CARLSON, Department of Physiology, University of Chicago.

The following tests of the solubility of lead sulphide ore dust in human gastric juice were made at the request of Dr. Alice Hamilton, special investigator of occupational lead poisoning for the United States Bureau of Labor Statistics, who reported to us that she had found some 25 cases of lead poisoning among men employed in mines and concentrating mills in southeastern Missouri. The mines in this region are supposed to yield practically pure galena.

The literature on industrial plumbism usually takes for granted the nonpoisonousness of lead sulphide in the animal body, though the experimental data on which this belief is founded are both meager and conflicting. Blum,<sup>1</sup> who is the most widely quoted authority on the subject, found that he could feed animals large quantities of lead sulphide without apparently producing any injurious effects. Leymann<sup>2</sup> says that the sulphide is the compound found in most of the ore smelted in Germany, and experience shows that it does not give rise to lead poisoning in workmen—experience which is confirmed by tests on animals. If there is any danger at all in the handling of these ores it is so slight as to be practically negligible.

Rambousek,<sup>3</sup> at the International Congress of Industrial Hygiene which was held at Milan in 1906, quoted the work of Leymann and of Blum and confirmed their opinion as to the nonpoisonous nature of lead sulphide, which he had fed to animals in large doses without producing any ill effects. He found also that artificial gastric juice (0.1 per cent HCl with or without about 1 per cent of peptone) had no effect whatever on lead sulphide. Biondi<sup>4</sup> opposed this assertion and claimed to have seen among the galena miners of Sardinia many men who showed the usual signs of lead absorption. While severe colic or neuritis is extremely rare among these men, that is explained by improved hygienic regulations in the mines, since in former years such phenomena were common enough. On the other hand, Rambousek cited the statistics of the galena mines of Píbram in Bohemia, where among 10,000 miners there was not 1 case of lead poisoning, while among the 4,000 smelters there were 150 cases.

Experimental evidence of the solubility of lead sulphide in the animal body seems to have been furnished first by Murgia,<sup>5</sup> who, after feeding dogs and rabbits with blende (zinc sulphide) which contained lead sulphide in the proportion of 0.2 per cent, found traces of lead in both liver and intestines. Recently Brezina and Eugling<sup>6</sup> undertook to study chronic plumbism in animals, basing their conclusions as to lead absorption on the appearance of basophilic granules in the red blood corpuscles of the animals in question. The lead compounds were introduced into subcutaneous

<sup>1</sup> Wiener Medizinische Wochenschrift, 1904, vol. 54, pp. 538-543: Über das Schicksal des Blei im Organismus, F. Blum.

<sup>2</sup> Leymann, Bekämpfung der Bleigefahr in der Industrie, Jena, 1908, p. 4.

<sup>3</sup> Rambousek, Transactions 1st International Congress for Industrial Diseases, Milan, 1906, pp. 609-617; also Il Ramazzini, 1907, pp. 472, 473.

<sup>4</sup> Biondi, Transactions 1st International Congress for Industrial Diseases, Milan, 1906, pp. 293-308; Il Ramazzini, 474-479.

<sup>5</sup> Murgia, Clinica Moderna, 1906, No. 27, p. 3.6.

<sup>6</sup> Wiener Arbeiten aus dem Gebiete der Sozialen Medizin, II Heft, 1912, vol. 5, pp. 29-34. Untersuchungen über experimentelle chronische Bleivergiftung. E. Brezina und M. Eugling.

pockets, were rubbed into the shaved skin with lanoline ointment, and finally were mixed with the food. The animals selected were guinea pigs. The characteristic stippling of the cells appeared in the animals treated with lead sulphide more quickly and in larger numbers than in those which were treated with lead sulphate.

The general plan of the present series of tests is the same as that followed in our previous tests with white lead (Carlson and Woelfel, Bulletin of the United States Bureau of Labor Statistics, No. 120, p. 22 et seq.) with the exception of feeding experiments on animals. The gastric juice was obtained from Mr. V., our man with the permanent gastric fistula. The juice was collected while Mr. V. was chewing palatable food when hungry. It was therefore the so-called appetite gastric juice, ranging in free acidity from 0.43 to 0.48 per cent. The collection of the gastric juice was extended over several days, the different lots being mixed, so that all the tests on the various ores were made with the same stock of human gastric juice.

Samples of lead sulphide ores were kindly sent us by the Federal Lead Co., of Federal, Ill., and by the St. Joseph Lead Co., of Herculaneum, Mo. The Federal Lead Co. sent one sample from the Federal concentrator at Flat River and one sample from the Desloge concentrator; both samples were pulverized. The ore sample from the St. Joseph Lead Co., which has its concentrator at Bonne Terre, was not pulverized when received. According to the statements kindly furnished us by the two companies these ore samples assayed the following percentages of lead:

Federal Lead Co.:	Per cent of lead.
Sample from the Federal concentrator.....	73.4
Sample from the Desloge concentrator.....	70.1
St. Joseph Lead Co.: Sample of ore from Bonne Terre.....	72.0

Parallel tests were run with lead sulphide such as is furnished to chemical laboratories. This turned out not to be absolutely pure lead sulphide, however, as the human gastric juice brought into solution a trace of iron besides the lead. All the ore samples contained a good deal of iron, some of which was dissolved by the gastric juice together with the lead. The iron was, of course, not included in figuring the percentage of the lead sulphide dissolved by the gastric juice.

In order to render the tests directly comparable with the previous tests on white lead we used the following quantities: Lead sulphide ore, 0.5 g.; human gastric juice, 25 cc.; distilled water, 25 cc. (38° C. (100° F.) for 10 hours).

The results are given in the following table:

TESTS AS TO SOLUBILITY IN HUMAN GASTRIC JUICE OF LEAD SULPHIDE ORE FURNISHED BY VARIOUS ESTABLISHMENTS.

[Solvent used, 25 cc. human gastric juice and 25 cc. distilled water at 38° C. (100° F.) for 10 hours.]

	Amount of lead sulphide ore used for digestion.	Lead contained in ore.	Lead sulphate derived from digestion.	Lead contained in lead sulphate.	Average percentage of lead dissolved.	
	Gram.	Gram.	Gram.	Gram.		
Federal concentrator.....	1..	0.5	0.367	0.0164	0.0111	} 2.94
	2..	.5	.367	.0156	.0106	
	3..	.5	.367	.0158	.0107	
Desloge concentrator.....	1..	.5	.350	.0072	.0049	} 1.38
	2..	.5	.350	.0076	.0051	
	3..	.5	.350	.0066	.0045	
St. Joseph Lead Co.....	1..	.5	.360	.0172	.0117	} 3.32
	2..	.5	.360	.0178	.0121	
	3..	.5	.360	.0176	.0120	
Laboratory lead sulphide.....	1..	.5	1.433	.027	.0185	} 4.60
	2..	.5	.433	.029	.0197	
	3..	.5	.433	.032	.0218	

<sup>1</sup> Calculated on the basis of the material being pure lead sulphide, containing 86.5 per cent lead.

Pure lead sulphide and the dust of lead sulphide ores are soluble in human gastric juice at body temperature. Lead sulphide ore dust is therefore soluble in the human stomach, somewhat less so than basic lead sulphate, very much less so than basic lead carbonate. In our tests with the sulphate and the carbonate, using the same quantity of gastric juice, the solubility of the lead sulphate amounted to 9.5 per cent; that of the carbonate to 46 per cent. The table shows that the solubility of lead sulphide ore averages about 2.5 per cent, while the solubility of laboratory lead sulphide is higher. We can not account for the distinctly lower solubility of the ore dust from the Desloge concentrator.

SUMMARY.

1. Lead sulphide is soluble in human gastric juice.
2. The solubility of lead sulphide is less than that of basic lead sulphate or basic lead carbonate, but the sulphide is sufficiently soluble to be dangerous to the health of persons engaged in mining and milling lead sulphide ore, if the mining and milling processes involve the production of dust.
3. The persons engaged in mining and milling lead sulphide ore should therefore be protected in the same way as workers in other dangerous lead industries.

## APPENDIX II.

Since this investigation was undertaken the following regulations have been adopted in New Jersey. Practically all the precautions adopted abroad are recommended, but there is no attempt to forbid the employment of workers in the more dangerous processes for more than a strictly limited number of hours per day.

### REGULATIONS FOR THE LEAD AND COPPER INDUSTRIES.

Drafted by LILLIAN ERSKINE, special investigator for the New Jersey Department of Labor, approved by ERNST F. EURICH, consulting metallurgical expert for the State, and issued in the form of a circular letter to these trades by LEWIS T. BRYANT, commissioner of labor.

The lead and copper industries of the State having been reported upon by our consulting metallurgical expert and special investigator, I desire to call the attention of your company to the sanitary regulations governing these trades which are approved by the department of labor.

I. In view of the dust generated in the handling, sampling, and transportation of ores, the department requires that care be exercised to protect the workers by means of a thorough sprinkling of such ores when practicable; that automatic machine sampling shall be the standard method; that the air of the sampling mill or mills shall be kept free from dust, either by means of sprinkling or efficient mechanical exhaust ventilation; that if no means can be devised to control the dust generated in emptying sacks containing lead ores, the workers engaged in such operation shall be furnished and required to wear an approved type of respirator; that no sacks in which lead or other ores have been shipped shall be cleaned by hand, but that all such sacks shall be cleaned by sanitary mechanical methods; and that all ores containing lead stored in bins shall be dampened before transportation.

II. As the roasting of lead ores, whether in furnaces or in sintering machines, or by any other method, may expose the workers to injurious fumes or gases, the department requires that when such danger exists, the points at which such fumes or gases enter the workrooms shall be properly hooded, and the hoods connected with efficient mechanical exhaust ventilation.

III. The making up of charges for the lead-blasting furnaces being recognized as offering special risk to the health of workers engaged therein, the department requires the thorough sprinkling of all materials handled in such charges, to the end that they may be damp when dumped upon the feed floor.

IV. In view of the fact that in the event of the breakdown or repair of any mechanical exhaust system for the control of fumes generated in the various tapping operations of the blast furnaces treating lead ores or leady copper ores the workers on the feed floor will be exposed to risk if the floor is not tight the department requires that such feed floors shall be impervious to fume.

V. As dangerous fumes are generated in the tapping operations of lead-blast furnaces, the department requires the installation of hoods with efficient mechanical exhaust ventilation at all points where, in the tapping operations, fumes are liberated.

VI. To prevent fumes and gases issuing from the charging openings of lead and copper blast furnaces, the department requires flues of a sufficient size, with an efficient natural or mechanical draft, and suitable provision for any accidental blocking which may occur, e. g., providing each furnace with a separate stack communicating directly with the air and closed with a damper.

VII. (a) In view of the unsanitary features of hand shaking of bags in the bag house or houses designed for collecting flue dust in lead and copper processes, the

department requires the installation of such mechanical method for shaking as shall prevent the exposure of the workers to dusts generated in shaking the bags.

(b) The department further requires the protection of such workers as are exposed to dust in cleaning flues, bag houses, and bag-house cellars by means of the use of special clothing and approved respirators to be furnished them by the employer for such purpose; and urges the enforcement by the employer of rules calling for special sanitary precautions on the part of the workers employed.

(c) As the cleaning of flues, bag house, and bag-house cellars is universally recognized as an employment hazardous to health, the department calls the attention of employers to the foreign practice of shortening the hours of such workers as are directly exposed to flue dust in cleaning processes.

VIII. If in any of the various operations connected with lead refining, lead fumes habitually, or from time to time, pass into the air of the workrooms, they shall be removed by means of efficient mechanical exhaust ventilation.

This applies especially to retort furnaces, cupelling furnaces, antimony slag furnaces and lead reverberatory furnaces.

IX. In view of the fact that some copper matte contains lead, arsenic, and antimony, and that in converting copper matte there is always a copious evolution of sulphurous acid gas, the department requires the efficient hooding of all converters, and that such hoods shall effectively remove the fumes and gases generated, whatever may be the position of the converter.

X. (a) To protect the health of the workers, the department requires that the electrolytic tanks be placed in spacious, well-ventilated buildings, and, where necessary, that fresh air shall be continually supplied by means of fans.

(b) The department requires that all liberating tanks shall be so protected that the gas bubbles rising to the surface shall not spray the acid solution into the air of the tank rooms.

(c) The department requires that the purifying of the foul electrolytic solutions, and the precipitation of copper from the solutions by means of iron, shall either be carried on in tanks placed under a hood or hoods connected with effective mechanical exhaust ventilation, or that such tanks shall be placed in the open air in such position that the gases given off will be quickly diffused and not be a source of harm.

XI. The department suggests the adoption of air rabbling of the copper refining furnaces, as hand rabbling exposes the worker to excessive heat and glare.

XII. The department urges the elimination of hand charging of the anode and cathode furnaces, to the end that the prevailing mechanical injuries to the workers may be lessened.

XIII. In order that the air of the workrooms in which furnace processes are carried on may be kept free from dust, the department requires that skimmings, drosses, matte, and slag from furnaces shall not be allowed to accumulate on the floors of the workrooms; that all such by-products as produce dust shall be thoroughly sprinkled before transportation; and that no dry sweepings but only wet cleaning shall be permitted in the departments where lead is treated.

XIV. Because of the production of lead oxides, and the possible evolution of lead fumes in the melting of pig lead for trade purposes, or in the manufacture of lead alloys not containing arsenic, the department requires the protection of all such lead melting and alloy kettles by means of hoods connected with an efficient method of ventilation.

XV. In view of the dangerous character of the fumes liberated in the making of alloys of lead and arsenic, and of the lead oxides and fumes produced in the melting of scrap lead, the department requires the protection of all such lead and arsenic alloy kettles and scrap lead melting kettles by means of hoods connected with efficient mechanical exhaust ventilation.

XVI. In view of the established fact that cleanliness on the part of the workers is an important factor in lessening lead poisoning in all processes in which that metal is handled, and that copper sulphate, to a greater or less degree, gets on the clothes and on the persons of workers in the electrolytic refining of copper, and that all employees in furnace processes and the handling of molten metals are exposed to excessive heat at certain times, the department requires the furnishing of sanitary lockers, dressing room or rooms, and convenient and adequate washing facilities, with shower baths for all lead and copper employees, and urges upon the management the necessity for a strict enforcement of the use of these washing facilities by the workers.

XVII. Since it is recognized that eating in workrooms contaminated by lead dust or fumes is a menace to the health of the worker, and that the general eating in rooms where metallurgical processes are carried on may, in many cases, be very questionable from a sanitary point of view, the department requires the installation of a sanitary and convenient lunch room, or rooms for the use of all lead and copper employees, and urges upon the management the necessity for a strict enforcement of their use.

The efficient mechanical exhaust ventilation required is fixed by the State's standard of 1912.

Sufficient suction head shall be maintained in each branch pipe within 15 inches of the hoods to raise 2 inches of water column in a U-shaped tube. Pressure to be taken by pressing tube attachment over small opening through pipe, commonly called static method. Tests to be made with all branches open and unobstructed.

## APPENDIX III.—GERMAN REGULATIONS FOR LEAD-SMELTING WORKS (JUNE 16, 1905).<sup>1</sup>

### GENERAL REGULATIONS.

1. Workrooms in which lead ores are roasted, sintered, or smelted, pig lead produced and submitted to further treatment, distillation of rich lead (bullion cupellation) litharge, red lead, or other oxides of lead prepared, ground, or sieved, stored, or packed, or zinc skimmings distilled shall be roomy, high, and so arranged that a sufficient constant exchange of air takes place. They shall be provided with a level and solid floor to allow of easy removal of dust by a moist method.

The walls shall be smooth, so as to prevent collection of dust; they shall be either washed down or limewashed at least once a year.

*Provided*, That this shall not apply in the case of calcining sheds with wooden walls.

2. An abundant supply of good drinking water, protected against contamination from dust, shall be provided for the workers on the furnaces and smelting pots, and in such close proximity to them that they can obtain it at any time without having to go into the open air.

Arrangements for sprinkling the floors shall be provided near the furnaces. The floors of the rooms mentioned in paragraph 1 shall be wet cleansed at least once daily.

3. Prepared (i. e., concentrated) lead ores and leady smelting products, unless moist, shall not be crushed except in an apparatus so arranged as to prevent as far as possible penetration of dust into workrooms.

*Provided*, That this shall not apply to calcined material from converters.

Sacks in which lead ores and materials containing lead have been packed shall not be freed from dust and cleaned except in a dust-proof apparatus or by washing.

4. Materials containing lead for charging the blast furnaces, if they are oxides and form dust, shall be damped before they are mixed with other materials, stocked on the feeding floor, or charged into the blast furnaces.

*Provided*, That this shall not apply in the case of calcined material from converters.

5. Dust, gases, and lead fumes escaping from furnaces and converters, tapping spouts, tapping pots, drain sump, slag pots, slag cars, or slag channels and from glowing residues taken from the furnaces shall be caught as near as possible to the point of origin and removed harmlessly.

Dust-collecting chambers, flues, as well as furnaces which have been "blown down" shall not be entered by workmen unless sufficiently cooled and ventilated.

### SPECIAL REGULATIONS FOR SUCH PARTS OF A FACTORY WHERE LEAD COLORS ARE PREPARED.

6. In grinding, sieving, and packing dry leady materials, in charging, and emptying litharge and red-lead furnaces, in collecting the red lead and similar operations in which leady dust is developed, exhaust arrangements shall be provided for preventing the entrance of dust into the workrooms.

7. Apparatus producing leady dust, if their construction and manner of use does not effectually prevent evolution of dust, shall have all cracks protected by thick layers of felt or woolen material, or by similar means, so as to prevent the entrance of dust into the workrooms.

Apparatus of this character shall be provided with arrangements for preventing compression of air in them. They shall only be opened when the dust in them shall have completely settled and they are absolutely cool.

<sup>1</sup> From Great Britain, Home Department. Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead and in the Manufacture of Red and Orange Lead and Flaked Litharge. By Edgar L. Collis, M. B., H. M. medical inspector of factories. London, 1910. pp. 24-27.

**SPECIAL ARRANGEMENTS IN FORCE FOR THE DISTILLATION OF ZINC SKIMMINGS.**

8. Proposed new furnaces for the distillation of zinc skimmings (for which, according to paragraphs 16 and 25 of the industrial code, a special permission is required) shall be so arranged that (1) there shall be at least a clear space of 10 feet in front of the charging opening; (2) any passages under the distillation rooms shall be roomy, at least 11½ feet high in the center, light, and airy.

9. Dust, gases, and fumes arising from the zinc skimmings distillation furnaces shall be collected as near as possible to the point of origin and carried outside the smelting room.

The entrance of gases from the fires into the smelting room shall be prevented as far as possible by suitable arrangements for drawing them off.

10. Sieving and packing of by-products obtained in the distillation of zinc skimmings (poussière, flue dust) shall not be done except in a special room separated from the other workrooms and complying with the requirements of regulation 1.

Sieving shall only be done in an apparatus so constructed that dust shall not escape.

**EMPLOYMENT OF WORKERS.**

11. Women and young persons shall not be employed or permitted in rooms mentioned in regulation 1, in flue-dust chambers, or dust flues, or in the removal of flue dust.

12. No person shall be newly employed in rooms mentioned in regulation 1, in flue-dust chambers, or dust flues, or in the transport of flue dust, without a certificate of fitness from the surgeon appointed by the higher authorities.

These certificates shall be collected and shown to the factory inspector and appointed surgeon on request.

13. No person shall be employed in charging blast furnaces, apart from mere laboring work on the floors, for more than eight hours daily. The same shall apply in the case of workmen employed in the inside of furnaces when cool, or in emptying flue-dust chambers, or dust flues which contain wet flue dust.

No person shall be employed in cleaning out, from inside, flue-dust chambers, or dust flues containing dry flue dust for more than four hours daily; and including emptying and work of transport of this kind altogether no longer than eight hours daily.

Other workers in rooms specified in regulation 1 shall not work more than 10 hours in 24, exclusive of mealtimes.

Exception to this is allowed in the case of those workers who are employed for the purpose of a weekly change of shift, and for whom exception as to Sunday employment is permitted by imperial decree.

**CLOTHING, OVERALLS, LAVATORY ACCOMMODATIONS, ETC.**

14. The occupier shall provide for all persons employed in cleaning out flue-dust chambers, dust flues, repairing of cooled furnaces, grinding, sieving, and packing of litharge, red lead, or other lead colors, complete suits of working clothes, including caps and respirators.

15. Work with lead salts in solution shall not be done except by workers who either grease their hands or are provided with impermeable gloves.

16. The suits of clothes, or overalls, provided in regulations 14 and 15, respirators and gloves, shall be provided in sufficient amount and in proper condition. The occupier shall see that they are always suitable for their purpose, and are not worn except by those workers for whom they are intended; and that they, at stated intervals (the overalls at least once a week, the respirators and gloves prior to use), are cleaned, and during the time that they are not in use are kept in a place specially reserved for each article.

17. A lavatory and cloakroom shall be provided for the use of the workmen in a part of the building free from dust. Separate from it there shall be a dining room. These rooms must be kept free from dust and be warmed during the winter.

In a suitable place provision shall be made for warming the workers' food.

Water, soap, and towels, and arrangements for keeping separate the overalls from other clothing taken off before the commencement of work shall be provided in sufficient amount in the lavatory and cloakroom.

The occupier shall afford opportunity for persons engaged in cleaning out flue-dust chambers, dust flues, and the cooled furnaces, to take a bath daily after the end of the work, and for those handling oxides of lead, at least once a week, during working hours, inside the works. The bathroom shall be warmed during the winter.

18. The occupier shall place the supervision of the health of the workers in the hands of a surgeon, appointed by the higher authorities for this purpose, whose name shall be sent to the inspector of factories. The surgeon shall examine the workers at least once a month in the factory, with a view to the detection of symptoms of lead poisoning.

The occupier shall not employ persons suspected by the surgeon of having contracted lead poisoning in the processes mentioned in regulation 1 or in cleaning out flue-dust chambers, dust flues, or furnaces when cold, or transport of the flue dust, until they are quite well. Those who appear peculiarly susceptible shall be permanently suspended from working in these processes.

19. The health register shall be shown to the factory inspector and appointed surgeon on demand. (Similar to regulation 15 of spelter regulations (Appendix I) with an addition.)

20. The occupier shall require the workers to subscribe to the following conditions:

(1) Food must not be taken into the workrooms. Meals may only be taken outside the workrooms.

(2) Workmen must only enter the meal room to take their meals or leave the factory, after they have taken off their overalls and carefully washed their faces and hands.

(3) Workmen must use the overalls, respirators, and gloves in those workrooms and for the particular processes for which they are given them.

(4) Cigar and cigarette smoking during work is forbidden.

(5) A bath in the factory must be taken every day at the close of their work by those engaged in the emptying and cleaning of flue dust chambers, flues, and furnaces when cold, and by those employed on oxides of lead once a week: *Provided*, That this shall not apply in the case of workmen exempted by the appointed surgeon.

Workers contravening these orders will be liable to dismissal without further notice.

21. In every workroom, as well as in the cloakroom and meal room, there shall be posted up by the occupier, in a conspicuous place and in clear characters, a notice of these regulations.

The occupier is responsible for seeing that the requirement of regulation 20 (1) is obeyed. He shall make a manager or foreman responsible for the precise carrying out of regulation 20 (1), (2), and (5). The person thus made responsible shall see to the carrying out of the regulations and for the exercise of necessary care as prescribed in paragraph 151 of the factory act.

22. No work in a lead-smelting works shall be commenced until notice of its erection has been sent to the factory inspector. After receipt of the notice he shall personally visit to see whether the arrangements are in accordance with the regulations.

23. These regulations came into force on January 1, 1906.

Where structural alterations are necessary for the carrying out of regulations 1, 5 (1), 6, 9, 10, and 17 the higher authorities may allow an extension of time to a date not later than January 1, 1908.

If it seems necessary on strong grounds of public interest, the council (Bundesrath) may extend the time in particular works until January 1, 1913, and until then allow exceptions from the regulations as regards regulation 13 (1) and (2).

## APPENDIX IV.—FRENCH REGULATIONS RELATING TO PRECAUTIONS AGAINST INDUSTRIAL LEAD POISONING.

### DECREE OF THE PRESIDENT OF THE FRENCH REPUBLIC (APRIL 23, 1908) RELATING TO CERTAIN INDUSTRIES IN WHICH LEAD IS USED.

[Translated from Journal Officiel de la Republique Francaise, 29 Avril, 1908.]

1. In the lead industries hereinafter mentioned, viz, smelting, cupellation of argenterous lead, manufacture of accumulators, glass making, manufacture and use of lead enamels, manufacture of pottery, decoration of porcelain or faience, ceramic chromolithography, manufacture of lead alloys, oxides, salts, and colors, employers, directors, or managers are required, apart from the general measures prescribed by the decree of November 29, 1904, to take special measures for protection and health as set forth in the following sections:

2. Lead melting pots shall be erected in an airy place separated from the other workrooms. Hoods or other means for the effectual removal of fumes shall be provided—

(a) Over the openings for the run of lead and slag in lead smelting;

(b) Before the furnace doors in the manufacture of lead oxides; and

(c) Above the pots for melting lead and its alloys in the other industries enumerated in section 1.

3. All work with oxides and other compounds of lead capable of producing dust shall be done as far as possible when in a damp condition.

When this work can not be done in the presence of water or other liquid, it shall be carried out by mechanical means in covered air-tight apparatus.

If it is impossible to conform to the requirements of either of the first two paragraphs of this section, the work shall be done under a strong draft so arranged that the harmful products may be intercepted by apparatus suitably placed.

Finally, if none of these systems is possible the workmen shall be supplied with respirators.

4. Oxides and other compounds of lead, whether dry or damp, in suspension or solution, shall not be handled with the bare hand. The employer shall at his own expense provide the workers in these operations with either gloves made of impervious material, such as india rubber, or suitable appliances, and shall cause them to be kept in good repair and frequently cleaned.

5. Tables on which these products are handled shall be covered with some impervious material, kept in a perfectly water-tight condition.

The same requirement applies to the floors of the workrooms, which shall also be kept damp.

The floor shall be slightly sloped toward a water-tight receptacle for collecting the lead substances which are washed down.

The work shall be so arranged that there shall be no splashing. The tables, floors, and walls shall be washed at least once a week.

6. Without prejudice to the requirements of section 3, the grinding and mixing of lead products, and the use of them in dusting shall be effected in special places with active ventilation.

If the materials can not be damped, the workers shall be provided with respirators.

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<sup>1</sup> From Great Britain Home Department. *Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead and in the Manufacture of Red and Orange Lead and Flaked Litharge.* By Edgar L. Collis, M. B., H. M. medical inspector of factories. London, 1910, pp. 27-29.

7. Pottery shall not be dipped with bare hands in solutions containing litharge, red lead, galena, or white lead in suspension.

8. No food or drink shall be brought into the works.

9. Employers shall, at their own expense, provide and maintain for the use of the workers, overalls or clothing for use during work only, in addition to gloves and respirators.

10. In a part of the building separated from the workrooms, there shall be provided for the use of the workers exposed to lead dust or fumes, a cloakroom and lavatory kept in good order, provided with basins or taps in sufficient number, a plentiful supply of water, soap, and a towel for each worker replaced at least once a week.

The cloakrooms shall be provided with cupboards or drawers with locks or padlocks, the ordinary clothing being kept apart from the working clothes.

11. A warm bath or shower bath shall be provided each week for the workers exposed to lead dust or fumes.

A warm bath or shower bath shall be provided every day after work for each worker employed, either in emptying or cleaning the condensing chambers and flues, or in repairing furnaces in lead works, or in carrying lead corrosions from the beds in white-lead factories, or in packing red lead, or in grinding lead enamels and in dry dusting.

12. Employers are required to exhibit, in a conspicuous position in the works, regulations imposing on the workers the following obligations:

To use the appliances, gloves, respirators, and working clothes placed at their disposal.

Not to bring into the works either food or drink.

To pay great care, before each meal, to the cleanliness of the mouth, nose, and hands.

To take the baths weekly or daily as provided in section 11.

13. The minister of labor may, by order made with the advice of the consultative committee for arts and manufactures, exempt an establishment for a specified period, from all or part of the requirements of regulations 2 (a), 2 (b), 2 (c), 5 (2), and 6 (1) in any case where it is found that observance of these requirements is practically impossible, and that the health and safety of the workers are assured by conditions at least equivalent to those prescribed in the present order.

14. Subject to additional postponements which may be granted by the minister in pursuance of section 6 of the act of June 12, 1893 (as amended by that of July 11, 1903), the delay required for the carrying out of the alterations necessitated by the present decree is limited to one year from the date of its publication.

15. The ministry of labor is charged with the administration of this decree.

**RECOMMENDATIONS FOR SMELTING MATERIALS CONTAINING LEAD, BY M. BOULIN,  
INSPECTEUR DIVISIONNAIRE DU TRAVAIL, LILLE.**

1. Ore moved from the store heap to the furnaces shall be moistened to prevent the formation of dust while it is being moved and when the furnaces are being charged.

2. If it is proved that at any time the draft of the furnace is not adequate, or if air taken from close to one of the working doors shows the presence of lead in form of vapor, or of dust, a competent authority shall have the right to call for erection of hoods or for some other form of efficient ventilation.

3. Calcining furnaces shall be discharged in such manner that no dust or vapor can gain access to the workroom.

4. Breaking up of ore, whether slagged or not, shall be preceded by damping, or be carried on in a closed apparatus, or under conditions which do not expose the men to inhalation of dust.

5. The charges for the furnaces shall be prepared in a separate large airy place. The mixing of the materials composing these charges shall be carried out so that the

<sup>1</sup> Bulletin de l'Inspection du Travail, Paris, 1906.

atmosphere breathed by the workmen shall not contain dust. The workmen shall, moreover, have at their disposal respirators which shall be kept scrupulously clean.

6. The charges shall be brought ready prepared to the mouth of the blast furnaces, and the charging of the furnaces shall be done as automatically as possible.

7. The receptacles for the slag from the blast furnaces shall be so arranged that the fumes which are given off during the run shall be immediately carried outside the workroom.

8. In works where they still use the furnace known as "bas-foyer Americain," the American low hearth, the draft caused by the outside hood shall be so active that no fume can escape into the workroom. The competent authority shall have the right to compel this draft to be produced by means of a mechanical fan.

9. When the lead is run, whether this running takes place at the reverberatory furnace or elsewhere, and during the whole time that the metal remains liquid, there shall be over the vessel containing the lead a hood with a good draft.

10. During cupelling, fumes shall not escape by the furnace door. If they do escape they shall be completely caught up and drawn away by a ventilating fan.

11. Repairs in the nature of pulling down or rebuilding furnaces shall only take place after complete cooling, and after damping to prevent the formation of dust.

12. The removal of dross, of litharge, and of the different oxides drawn out of the furnaces, crucibles, or melting pots shall be so carried out as to prevent the formation of dust.

13. The floors of the rooms in lead-smelting works shall be of paving stone, of metal, or of concrete, etc., and shall be made so that it can be washed or at any rate damped out of the usual work hours.

14. The walls and ceilings, as well as the woodwork supporting the roof, if there is no ceiling, shall have a surface which can be efficiently washed, or they shall be lime-washed at least once a year.

15. Workrooms not situated in the open air shall always be well lighted and ventilated.

16. The walls shall be as smooth as possible, and every precaution taken to prevent dust from accumulating.

17. The tools and implements used to work the ore, the oxides, etc., shall be cleaned as often as possible, and always before being sent to the repair shops.

18. No food or drink shall be kept or consumed in the workrooms.

19. Employers shall provide for the use of their workpeople a suitable dining room. This room shall contain a table, benches, and apparatus for warming food, and a set of numbered pigeonholes with locks, where each man can place his food. The room shall be warmed, lighted, and properly kept up by the employer.

20. No alcohol, or drink containing more than 10 per cent alcohol, shall be brought into the works.

No smoking, snuff taking, or chewing tobacco shall be allowed in the workshops.

21. In every works there shall be lavatories of sufficient number, and conveniently placed, so that the men may have no difficulty, and the least possible loss of time, in using them. These lavatories shall be provided with the necessaries for washing the body, hands, and nails.

22. The employers shall provide for the use of the workmen a room with shower baths, where there shall be warm water, soap, and towels. They shall make arrangements for every man to have a shower bath at least once a week. The constituted authority may order, for the whole of the workpeople, or for the men in certain workshops, more frequent shower baths.

23. In every works there shall be a room provided with one or more baths according to the size of the staff, and with everything necessary for the men to take a complete bath if they wish to or on the surgeon's order.

24. The employers shall provide for the use of the workmen working clothes, and shall see that they are used. These clothes shall be cleaned at least once a week and not be shaken.

25. No women or children shall be employed in workshops where lead is smelted or manipulated.

26. The employers shall provide for the use of their workmen a cloakroom, so arranged that each man can place his clothes under lock and key. No part of their ordinary costume shall be laid down in the workshops, nor elsewhere than in the cloakroom.

27. Every man wishing to be employed in a lead-smelting works shall produce a medical certificate stating that he has no physical defect rendering him specially liable to suffer from the influence of lead.

28. In every works a surgeon shall be appointed to examine, at least once a month, every man on the premises. The results of his visit shall be noted down in a register, which may be examined at the office of the works by the authority appointed to inspect the factory.

29. Any man who does not conform to the regulations which concern him, and who becomes the victim of plumbism, may be discharged, moved from his workshop, or suspended according to the regulations or custom, without having a right to any compensation other than that which is provided (or may be provided) by the law or assurance in case of illness.

30. Every case of plumbism, causing suspension from work for at least 48 hours, shall be notified to the mayoralty, without delay, by the employer or his representative. Receipt for this notification shall be given by the mayor and kept in the register appointed by regulation 28.

31. A notice drawn up in a simple form, and within the understanding of any one, pointing out the causes of plumbism, the means of preventing it, or of curing it, shall be put up in the dining room of the works. The wording shall be the same as the present order.

32. A man employed in lead-smelting workshops shall not be employed continuously more than 8 hours in 24 hours or more than 12 hours in 36 hours. He shall be given from the former an interval of at least half an hour; from the latter of one hour to eat food brought to the works.

33. Gases and fumes returned to the atmosphere shall only contain traces of lead.

34. The cleaning of the flues and the condensation chambers shall be done by porters in special light costume and in respirators. These men shall take a warm shower bath after every spell of work. No spell may be longer than four hours.

## APPENDIX V.—PROVISIONS FOR MEDICAL INSPECTION AND CARE IN ENGLISH, GERMAN, AND FRENCH SMELTERS.

### A. GREAT BRITAIN.

Regulations, dated August 12, 1911, made by the secretary of state for the home department, for the smelting of materials containing lead, the manufacture of red or orange lead, and the manufacture of flaked litharge.

13. (a) Every person employed in a lead process shall be examined by the surgeon once in every calendar month (or at such shorter or longer intervals as may be prescribed in writing by the chief inspector of factories) on a date of which due notice shall be given.

(b) A health register containing the names of all persons employed in any lead process shall be kept in a form approved by the chief inspector of factories.

(c) No person after suspension shall be employed in any lead process without written sanction from the surgeon, entered in the health register.

17. Every person employed in any lead process shall present himself at the appointed time for examination by the surgeon in pursuance of regulation 13 (a).

18. No person employed shall, after suspension under these regulations or under any other regulations or special rules applying to factories or workshops where any process involving the use of lead is carried on, work in any lead process without written sanction from the surgeon, entered in the health register.

### B. GERMANY.

German regulations for spelter works <sup>1</sup> (16th February, 1901).<sup>2</sup>

14. The occupier shall place the supervision of the health of the workers under the care of an approved surgeon, whose name shall be given to the factory inspector. The surgeon shall examine workers at least once a month and pay special attention to signs of plumbism.

On the report of the surgeon, workers who show signs of injury to health from employment, i. e., signs of plumbism, shall be suspended until complete recovery, and such as show special susceptibility shall be suspended permanently from employment in the distillation rooms, in operations mentioned in regulation 8 and on work connected with removal of residues.

15. The employer shall keep a book, or have it kept by one of the works officials, to register the changes and number of his workmen, as well as their condition of health. He is responsible for the completeness and accuracy of the entries, in so far as they are not made by the surgeon. This register shall contain:

(1) The name of the man by whom the register is kept.

(2) The name of the doctor responsible for the supervision of the workmen's state of health.

(3) Christian and surname, age, domicile, and the date of entering and leaving of each workman, as well as the nature of his employment.

<sup>1</sup> These regulations were adopted for lead smelters also; see p. 88.

<sup>2</sup> From Great Britain Home Department. *Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead and in the Manufacture of Red and Orange Lead and Flaked Litharge.* By Edgar L. Collis, M. B., II. M. medical inspector of factories. London, 1910. Pp. 23, 24.

- (4) The date and the nature of the sickness of a workman.
- (5) Date of recovery.
- (6) Date and results of the general medical examination as specified in regulation 14.

16. The occupier shall require the workers to subscribe to the following conditions:

(1) Food must not be taken into the workrooms. Meals may only be taken outside the workrooms.

(2) Workmen must only enter the meal room to take their meals or leave the factory, after having carefully washed face and hands.

17. In every workroom, as well as in the cloakroom and meal room, a notice of the preceding regulations shall be posted up by the occupier in a conspicuous place.

The occupier is responsible for seeing that the requirement of regulation 16 (1) is obeyed. He shall make a manager or foreman responsible for the precise carrying out of regulation 16 (1), (2), and (5).<sup>1</sup> The person thus made responsible shall see to the carrying out of the regulations and to the exercise of necessary care, as prescribed in paragraph 151 of the factory act.

### C. FRANCE.

French regulations (*mesures d'ordre general*), drawn up by the commission of industrial hygiene, for industries in which there is danger of lead poisoning.<sup>2</sup>

8. Medical supervision of the staff employed in the factories specified in regulation 1 shall be made by a surgeon paid by the employer and chosen by him from a list prepared every year. The name of this surgeon shall be notified every year to the inspector of factories by the employer during the month of January.

The minister of commerce, after consulting with the commission of the factory department and the commission of industrial hygiene, when he has heard the interested parties, need not ratify this choice.

A periodical inspection of the staff shall take place every month; further, every workman who feels ill shall be seen or visited by the appointed surgeon. This surgeon shall inform the employer and the workman whenever he recognizes a case of plumbism.

The employer shall immediately send to the inspector of factories an extract of the register, indorsed according to the next regulation, relative to the case which has been notified to him.

Workpeople who present symptoms of plumbism shall be removed from work places named in regulation 1. They may only be readmitted on producing a medical certificate stating their fitness for the work; but they may meanwhile be employed in other parts of the factory.

9. The employer shall be responsible for a register containing the following details:

(1) Name, Christian name, age, address, date of commencement and of leaving of each worker, as well as the nature of his work;

(2) The nature, the date of onset, and termination of every attack of plumbism which causes incapacity from work or necessitates a change of employment (by application of the twelfth line of the preceding regulation);

(3) The date and general conclusions of each of the regular medical inspections and instructions with regard to sections 2 and 3 shall be written in the register by the surgeon himself.

<sup>1</sup> See No. 20, p. 90.

<sup>2</sup> From Great Britain Home Department. Lead Smelting. Special Report on Dangerous or Injurious Processes in the Smelting of Materials Containing Lead and in the Manufacture of Red and Orange Lead and Flaked Litharge. By Edgar L. Collis, M. B., H. M. medical inspector of factories. London, 1910, p. 27.

10. The employers, etc., shall exhibit this decree so that it can be easily seen from the place where the men are engaged and paid. They shall also fix in the same place a workshop regulation imposing the following obligations upon the hands:

- (1) To use the tools and the means of protection placed at their disposal to prevent contact of the bare hands with lead compounds;
- (2) Not to walk with bare feet in the shops;
- (3) To use the overalls placed at their disposal for work and to return them to their proper place;
- (4) To be clean, and specially to rinse out the mouth after every spell of work;
- (5) To take regularly every month a sulphur bath;
- (6) Not to smoke, take snuff, or chew tobacco; not to bring or consume any food or any beverage within the work places specified;
- (7) To present themselves at the regular monthly visits.

The workshop regulations must state the name and address of the surgeon appointed to undertake the medical supervision of the staff, and also state the places, days, and hours that he will examine sick workmen apart from the regular visits.

10A. Every man employed in the specified places shall receive a copy of instructions stating the dangers of lead poisoning and the means necessary to avoid it.

The text of these instructions is fixed by ministerial order under the advice of the commission of industrial hygiene of the minister of commerce.

11. The minister of commerce may, by decree issued on the report of the factory inspectors and after consulting the committee of arts and manufactures and the committee of industrial hygiene, exempt a factory permanently or provisionally from observing regulation 3 (1) and regulation 5 (1) when it is recognized that the practical observance of these regulations is impossible in the factories under consideration and that the health of the workmen is assured by conditions at least equivalent to those fixed by the present decree.