Occupational Lead Exposure and Lead Poisoning

A Report Prepared by the Committee on Lead Poisoning

of the

INDUSTRIAL HYGIENE SECTION

of the

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Foreword

No attempt is made in the following report to present a comprehensive discussion of the nature of lead poisoning as thus far elucidated by experimental and clinical investigation and observation. Any such discussion, no matter how impartially presented, would have to deal indecisively with certain questionable and controversial matters, and thereby would not contribute to the purposes of this report, which are (1) to outline practical and effective measures for the recognition and prevention of hazardous lead exposure in industry, (2) to describe satisfactory methods for the differential diagnosis and treatment of lead intoxication, (3) to point out the factual requirements for medicolegal purposes and the means of satisfying such requirements, and (4) to refer the reader to selected sources of more detailed and comprehensive information.

For the purposes of this report, hazardous lead exposure has not been defined in terms of specific industries or specific occupations within industries, for the reason that no list of hazardous occupations would be complete or would have more than a tentative and temporary usefulness for the physician or hygienist. Modern manufacturing processes and materials are subject to frequent change. A plant which is free of lead exposure today may operate by a new process with a serious lead hazard tomorrow, and, conversely, a manufacturing process once notorious for its lead exposure may be freed of its hazards by a change in materials or procedure or by the institution of an adequate regimen of hygienic control. Fortunately, certain more specific and precise criteria available for the appraisal of the lead exposure of workmen than a history of employment in a supposedly hazardous trade. It has seemed best, therefore, to dispense with inaccurate generalizations as to the lead hazards of various occupations, and to recommend the application of these criteria.

The relative solubility of various lead compounds in body fluids, and their relative toxicity as studied experimentally, have not been employed herein as a basis for comparing the relative hazards of various lead trades. Industrial experience with lead compounds has demonstrated that practically all of them are toxic when dispersed in a finely divided form in sufficient concentration in the atmosphere breathed by workmen. The toxicity of the inorganic lead compounds in industry is dependent predominantly upon their absorption by or through the pulmonary epithelium. The extent of such absorption varies not only with the solubility and chemical reactivity of the compound, but also with the number of the particles distributed in the atmosphere, and the duration of the exposure. Generally therefore, there is little practical advantage, and some danger of arriving at false conclusions, in relating the hazards of lead trades to the chemical properties of the compounds involved. The extent of human lead absorption under a given set of occupational conditions can only rarely be determined by resort to such theoretical considerations, and certainly the safety of workmen warrants an examination of the actual facts in this regard.

In a report of this type it is not possible to discuss the experimental and

factual background of various phases of the subject, and therefore a certain dogmatic tone may seem to have been taken at times. Arbitrary and individual judgments have been avoided, so far as possible, and authority for certain statements of fact and more complete information on methods are given in a limited but carefully chosen list of references in the Appendix.

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Occupational Lead Exposure' and Lead Poisoning

The Recognition of Hazardous Industrial Lead Exposure

The Occurrence of Lead Poisoning in Industry

The available statistics indicate that there has been a progressive decline in the incidence of fatal lead poisoning in the United States of America over a period of more than twenty years. The records of state compensation agencies have also shown a fairly general trend toward reduction in the incidence of non-fatal lead poisoning over the period of years and in the areas for which information has been obtained. The decrease in the number of cases has not been so great or so consistent as has the decline in fatalities, and certain industries with a low or negligible incidence of fatal cases show relatively high rates of occurrence of non-fatal poisoning. These facts indicate that hygienic measures in many industries have eliminated the more obviously dangerous forms of lead exposure, without bringing the general level of exposure within the limits of safety.

Hazardous lead exposure has been eliminated in certain instances through technological developments whereby lead-bearing materials, once manufactured or employed under dangerous conditions, have fallen into disuse. In other instances, dangers have been recognized and eliminated or controlled. On the other hand, certain long established industries and processes involving lead hazards have not been subjected to adequate hygienic control. Illustrations could be given of the heedless or unwitting use of lead compounds in new industrial processes which may or may not require them, or in established processes in which such compounds have not been employed previously. Under the latter circumstances, inexperience in the handling of lead compounds, on the part of management and employee alike, may result in the creation of serious and uncontrolled lead exposure, and in the introduction of a high incidence of poisoning among the workmen. In any case, because of these and other factors, the frequency of occurrence of occupational lead poisoning in the United States of America is still such as to reveal serious shortcomings in the application of available hygienic knowledge and technic.

It is apparent, therefore, that the use of lead compounds and lead-bearing materials of all kinds, as employed in the production of commodities and in serving the needs of the modern community, should be subjected to careful scrutiny, from a hygienic point of view, to the end that the potential hazards associated with such use may be recognized and brought under adequate control.

The Recognition and Measurement of Occupational Lead Exposure

The existence of occupational exposure to lead compounds may be detected either by the study of the environmental conditions associated with a given type of work, or by the examination of men who have been working in that environment. Likewise, the extent of the exposure can be estimated with satisfac -

tory precision by applying quantitative measurements either to certain environmental factors, such as the lead content of the air of workrooms, or to certain physiological responses to exposure, as, for example, the urinary lead excretion of groups of workmen. The hygienic significance of the exposure (i.e., whether safe or dangerous, and the degree of danger), on the other hand, must be determined by correlating the data on the magnitude of the exposure with the results of observations on the general and specific effects of such exposure on the workmen. Experimental studies carried out under various conditions have provided some basis for predicting the effects of exposure to measured concentrations of lead compounds in the atmosphere of workrooms. In general, however, expert medical supervision of workmen, as well as careful and frequent study of their environment, is required for the purpose of determining the hygienic significance of industrial lead exposure.

Types of Industrial Lead Exposure

The mere presence or use of lead-bearing materials or lead compounds, in an industrial plant, does not necessarily result in exposure on the part of workmen. The lead must be in such form and so distributed as to gain entrance into the body or tissues of the workmen in measurable quantity, or no exposure can be said to exist. For practical purposes, there are two means for the entrance of inorganic lead compounds into the human body under industrial conditions, namely, (1) by way of the respiratory tract, through inhalation of vapors, fumes, dust, or mist, and (2) by way of the gastroenteric tract, through swallowing lead compounds trapped in the upper respiratory tract, or introduced into the mouth on food, tobacco, fingers, or other objects. Certain organic lead compounds, such as tetraethyl lead, penetrate the unbroken and normal skin with comparative rapidity and thus enter the body, but this route of absorption is of no practical importance in the case of the more common industrial lead compounds. Some of the mechanisms of lead absorption will be referred to in later paragraphs, but the portals of entry are mentioned at this time in order to stress the forms in which lead compounds must exist if they are to gain entrance into the body. The presence of vapors, or fumes, or fine dust of lead compounds in the air breathed by workmen is the most important factor in occupational lead exposure. However, lead compounds which contaminate the hands, food, tobacco, or other objects taken into the mouth, may not be ignored as means of exposure, even though the conditions be such that these compounds are not disseminated into the air breathed by men.

Metallic lead has a vapor pressure of about 0.1 mm. Hg at 800" C. (1,472" F.). The quantities of lead vapors that are given off from pots containing molten lead at temperatures under 1,000" C., are probably insufficient in themselves to create an important lead hazard, but alloys of high lead content prepared and handled at higher temperatures-often near and sometimes. above the boiling point of lead (1,629" C., 2,948" F.)-give rise to dangerous concentrations of lead vapors in the air. Even at the lower temperatures, however, a slight contribution made by lead vapors to the total lead exposure of workmen may have sufficient importance to warrant its elimination. Molten lead is easily oxidized at its surface and when it is skimmed, stirred, poured, or otherwise agitated in the presence of air, variable quantities of finely divided lead oxide may be thrown into the air. (Lead baths or melting pots which are covered with charcoal give rise to very little vapor, or fume, or dust so long as they are completely blanketed.) For these reasons the handling of lead or molten alloys of high le. tent, in foundries, molding ope soldering procedures, and in al plant processes in which the lea enclosed or adequately ventilate ways associated with some de lead exposure on the part of wo The degree of this exposure i instances should be determin hygienic purposes by metho precision.

Lead fumes may be distribut the atmosphere by the applica sufficient local or general heat tallic lead or to materials co lead and its compounds. Burnin ing, or melting operations ap surfaces heavily coated with lead-bearing materials (e.g., w red lead paint) result in the prc of variable quantities of fume: may be dangerous, especially in or poorly ventilated areas.

By far the most frequent in lead exposures are those whic from handling or processing le pounds in such a way as to ir dust into the surrounding air. lead and all of its compound present in finely divided form atmosphere breathed by workm be regarded as dangerous, un quantities present in the air within limits known to be safe the insoluble lead chromate, w haled in sufficient quantity, i ble of inducing lead intoxica absorption into the body.

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these reasons the handling of molten lead or molten alloys of high lead content, in foundries, molding operations, soldering procedures, and in all other plant processes in which the lead is not enclosed or adequately ventilated is always associated with some degree of lead exposure on the part of workmen. The degree of this exposure in most instances should be determined for hygienic purposes by methods of precision.

Lead fumes may be distributed into the atmosphere by the application of sufficient local or general heat to metallic lead or to materials containing lead and its compounds. Burning, welding, or melting operations applied to surfaces heavily coated with lead or lead-bearing materials (*e.g.*, white or red lead paint) result in the production of variable quantities of fumes which may be dangerous, especially in enclosed or poorly ventilated areas.

By far the most frequent industrial lead exposures are those which arise from handling or processing lead compounds in such a way as to introduce dust into the surrounding air. Metallic lead and all of its compounds when present in finely divided form in the atmosphere breathed by workmen must be regarded as dangerous, unless the quantities present in the air remain within limits known to be safe. Even the insoluble lead chromate, when inhaled in sufficient quantity, is capable of inducing lead intoxication by absorption into the body.

Lead compounds are also thrown into the atmosphere within droplets of mist in a number of operations in which paints, enamels, and glazes are applied as a spray. The inhalation of such mists constitutes a potential hazard which is not different in principle from that involved in the case of fumes and dust.

Certain organic lead compounds, of which only tetraethyl lead is manufactured and used in any considerable quantity at present, are' liquids which are sufficiently volatile at ordinary temperatures to give rise to dangerous concentrations of vapor. These liquid lead compounds when handled in undiluted form or in concentrated solutions also give rise to lead exposure by contact with the skin, through which they are absorbed. Any open receptacle which contains these liquids, and any container, article of clothing, floor or other object which has not been cleaned thoroughly after contact with them, may give rise to serious lead exposure on the part of persons who are nearby or whose skin may come in contact with them. The acute and frequently fatal character of lead intoxication from absorption of organic lead compounds of this type justifies special precautions for the avoidance of exposure to them.

METHODS FOR MEASURING LEAD EXPOSURE

The types of lead exposure mentioned above can usually be recognized by ordinary inspection of the processes and activities of an industrial plant. Critical examination of a plant on a background of some experience will often serve to classify the lead exposure as to type and severity, and may provide some basis for recommendations as to improvements and precautions. However, unless conditions are obviously hazardous, it is necessary to resort to more precise methods for the measurement of exposure as a means of locating all the hazards and defining their magnitude. Practical methods are discussed below under two headings. References to sources of detailed information will be found in a classified bibliography in the Appendix to this report.

Chemical Analysis of Suspended *and Settled Lead-containing Materials*

The determination of the lead content of the air of workrooms as a means of

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measuring the effective lead exposure of workmen employed therein is founded upon two general facts; (1) that the particles of lead compounds which are of such size as to remain suspended in the air for an appreciable period of time are subject to inhalation by human beings, to partial deposition in the air passages and upon the alveolar surfaces of the lungs, and to partial absorption into the tissues of the body; and (2) that the presence of lead compounds in the air is the preponderantly dangerous type of industrial lead exposure, not only because such exposure is difficult to avoid through individual precautions, but also because of the directness and effectiveness of the pulmonary lead absorption. Obviously, therefore, the collection of samples of air for analysis must be carried out by methods which will extract all of the lead which can be breathed, from accurately measured volumes of air which are fully representative of that which is actually breathed by workmen. If the air in a plant varies in its lead content from time to time or from area to area, the sampling must be correspondingly frequent and comprehensive. All such variables as changing plant operations, seasonal and other variations in ventilation, as well as shifting occupations and hours of employment, must be taken into account when collecting samples, if valid information is to be obtained in relation to the potential exposure of workmen.

The methods and the equipment for collecting lead compounds suspended in the air have been described in detail elsewhere and cannot be dealt with adequately here. Their successful use requires detailed knowledge of the principles upon which they are based, and considerable experience, not only in the handling of the equipment, but more especially in the selection of the sites for sampling and the collection of suitable volumes of air in relation to the conditions of exposure under study. Likewise, analytical methods devised and tested by experienced workers have been described fully in the texts, journal articles and bulletins referred to in the classified bibliography which is in the Appendix to the report. Good results in the use of these methods can best be accomplished by putting such work in the hands of well trained and competent chemists whose choice and application of analytical methods will be technically sound, and whose experience in the use of the methods has been such as to justify complete confidence in their results.

Information as to the contamination of the air of a plant over considerable periods of time can only be obtained with accuracy by frequent and comprehensive sampling and analyses. A single survey made by means of air analyses, regardless of its thoroughness, can only give knowledge of conditions prevailing at that particular time. On the other hand, the data of such a single survey may be supplemented by the collection and analysis of samples of dust deposited on carefully chosen surfaces which have been undisturbed for some time, thereby providing useful data for the interpretation of previous types, sources, and degrees of lead exposure. Microscopic examination of such dusts may reveal their character and, hence, their source. Quantitative chemical determination of their composition, likewise, may be of value in the interpretation of previously existing conditions. Such information is likely to find its chief usefulness in cases involving medicolegal questions.

Medical Procedures for the Detection and Appraisal of Lead Exposure

The general medical supervision of industrial employees will be dealt with in a later section of this report. For present purposes we are concerned only with the detection and the interpreta-

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tion of objective evidences of lead absorption in workmen, as a means of estimating the extent of their lead exposure. It has been clearly established by the investigations of recent years that human lead absorption is accompanied by the occurrence of certain signs which are not manifestations of lead intoxication, and which, up to a certain point in their development are not associated with lead intoxication. These signs are, (1) an increase in the number of certain young forms of erythrocytes in the peripheral circulation, and (2) an increase in the concentration of lead in the blood and other tissues of the body, and in the excretions.

A third sign of lead absorption, which is not necessarily associated with lead poisoning, is the deposition of lead sulfide in gum margins or in the mucous membrane of the large intestine and rectum. The gingival " lead line," while it is not a sign of lead intoxication, but only of absorption, is most frequently found under conditions of actually hazardous lead exposure. Its occurrence in a workman or a group of workmen justifies an immediate investigation of the working environment. However, since the deposition of a black sulfide in these tissues is not specific for lead, nor regular or predictable in its occurrence, nor capable of quantitative definition, it is not very useful as a practical measure of varying degrees of lead exposure. This phenomenon and its significance will be dealt with in some detail later.

1. Basophilic granulation (" stippling ") of the erythrocytes in lead absorption - Red blood corpuscles (erythrocytes) which yield basophilic granules of varying size when stained by various technics, are normally found in the circulating blood of human beings, and are subject to wide variation in number in response to a variety of environmental factors. Not all such factors have been defined, but it has long been known that lead absorption above certain levels results in an increase in these formed elements of the blood. It has been shown also that despite the considerable variation in individual reaction, groups of persons who are subjected to different types and degrees of lead exposure will show variations in the average or mean frequency of " stippling " of their erythrocytes, which are in accord with the relative severity of their lead exposure. The lack of specificity of this hematopoietic phenomenon, the wide range of individual variation, and the variability of the results obtained by different methods in different hands, give a somewhat inexact significance to quantitative expressions of normal and abnormal values, with respect to " stippling," and all such values must be expressed in relation to the methods of observation employed. On the other hand, the relative ease with which such observations may be carried out, their usefulness when properly controlled and interpreted, and their fallibility under the conditions of their present widespread use, justify careful discussion.

Several adequate procedures for determining the degree of basophilic granulation of the erythrocytes are in current use. The commonest and simplest of these consists in the preparation of blood films by a uniform technic which will give a single layer of erythrocytes and allow each one to be examined. The dried film may be stained by any one of the several methods which have been used successfully, but each method calls for careful standardization, experienced handling, and periodic checking as to reproducibility and uniformity of results. Sufficient time must be taken to examine each erythrocyte in each field and to count the " stippled " erythrocytes in not less than 50 fields, using an oil immersion lens and other microscopic equipment which will

give sharp definition at a magnification of not less than 900 diameters. The type of microscope which is commonly available for routine work in clinical laboratories does not give sharp enough definition to yield satisfactory results even in the hands of a skilled microscopist, and care must be given to the selection of a satisfactory microscope. The chief factors of accuracy, if satisfactory microscopic equipment is available, are skill in making uniform films (with frequent check upon the numbers of erythrocytes occurring in representative fields), and patience in examining the films and in counting the " stippled cells." Uneven films and thick-drop smears are entirely valueless in quantitative estimations of this type, and casual and hurried examination of the films will give useless and misleading results. Care and patience, on the other hand, will yield highly uniform and reproducible results. The method adopted should be applied to normal and unexposed persons in sufficient number to establish the normal range of variability of results by that method, after which it may be employed in examining the blood of exposed workmen. It is especially recommended that observations be made as frequently as possible on new employees of industrial plants to establish their normal level of " stippling " before they enter an occupation involving potential lead exposure. Failure to carry out such preliminary checks on the method and on the men has often resulted in misinterpretation of the results obtained on exposed workmen.

The " basophilic aggregation " test of McCord represents a useful modification of the simpler methods referred to above. In addition to " stippled " erythrocytes this method enumerates reticulocytes and other erythrocytes which contain basophilic material in finely divided form. Whether or not all of these cellular elements appear in the peripheral circulation in more or less uniform proportions in response to increased lead absorption is somewhat questionable, but the application of the method on the basis of established standards is justified.

With due regard for the variability of results obtained by different methods of staining and enumeration, " stippled " erythrocytes are found in the blood of normal persons with no industrial lead exposure in numbers ranging from a scattered few to more than 1,500 per million erythrocytes. Occasional unexplained numbers as high as 6,000 per million have been found. In general, however, only a small percentage of normal blood films will show more than 1,000 per million, and the large proportion of the counts will be considerably below this figure. Average or mean normal numbers are approximately 300 to 350 per million erythrocytes, if the method of staining is sensitive and the technic of examination is carefully carried out. The range of occurrence of " stippled " erythrocytes in groups of men exposed to lead in their work, will overlap normal findings but will extend above them. The mean results on exposed groups will exceed the normal values from two to eight times, and in individual cases as many as 19,000 " stippled " erythrocytes per million have been found in exposed but apparently healthy persons. More than twice that number have been seen in the blood of lead-sick persons.

Roughly comparable variations in the " basophilic aggregation " count are seen in groups of normal unexposed persons and in groups of variably exposed workmen. Reference should be made to the published articles cited in the Appendix.

In practice, it is not always feasible to appraise the comparative lead exposure of different functional groups of workmen in a plant on the basis of the microscopic examination of their blood. The groups may be too small or too variable, or they may not be sufficiently isolated to represent definite types of work or areas in the plant. cases, and, in fact, usually, th scopic examination of the bloo ful, not so much for the pu comparing different types of e as in determining whether the lead exposure is within essenti. limits. Usually some conserva more or less arbitrary limit i representing the upper permissi of increase in the occurrence philic elements. The occurrence ings above this limit, which in of " stippling " is commonly se to 1,000 " stippled cells " per erythrocytes, is the signal for t fer of individuals to less expo: and for a reëxamination of the of exposure to determine wheth some new factor has developed. and progressive changes in " st in an individual should be reg significant, while such chang group must be accepted as evi definitely increased lead absorp

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work or areas in the plant. In such cases, and, in fact, usually, the microscopic examination of the blood is useful, not so much for the purpose of comparing different types of exposure, as in determining whether the general lead exposure is within essentially safe limits. Usually some conservative and more or less arbitrary limit is set as representing the upper permissible limit of increase in the occurrence of basophilic elements. The occurrence of findings above this limit, which in the case of " stippling " is commonly set at 800 to 1,000 " stippled cells " per million erythrocytes, is the signal for the transfer of individuals to less exposed jobs, and for a reexamination of the sources of exposure to determine whether or not some new factor has developed. Abrupt and progressive changes in " stippling " in an individual should be regarded as significant, while such changes in a group must be accepted as evidence of definitely increased lead absorption.

2. Lead in *the excreta and blood in lead absorption-*

Accurate analytical data on properly collected samples of the excreta or the blood of representative persons employed under conditions of lead exposure, constitute the most precise measure of the magnitude of the actual lead exposure associated with the work. Such data portray not only the general level of the unavoidable lead exposure, but also the variations in exposure associated with certain unpredictable factors such as temporary lapses in precautionary measures and lack of adequate personal hygiene. For example, it is not necessary for workmen to swallow lead compounds because of uncleanly habits of working or eating, but sometimes they do so. Or, their use of respirators may be believed erroneously to be satisfactory merely because good equipment is available. Such lead exposure as may develop out of these and other factors can be measured by repeated analyses of excreta and blood as long as circumstances require or permit, or the conditions prevailing at any one time can be ascertained by one adequately planned analytical study of the workmen. These methods of measuring lead exposure may be too laborious, too time consuming, and too costly for practical general application in many industries, and in some instances they may be superfluous, but they are of the greatest possible value in promoting the safety of workmen in industries or occupations in which the lead exposure is variable or difficult to control. However, there are many pitfalls in their use, and unless they are carried out with precision, they are not only useless but grossly misleading. Therefore, it is necessary in this report to deal with them at some length.

a. Lead in the feces as a measure of occupational lead exposure-Lead compounds introduced into the mouth from any source appear in only slightly diminished quantity in the feces within a period of one to three days, dependent upon the individual emptying time of the alimentary tract. For this reason, the analysis of properly obtained samples of the feces of groups of workmen will reveal the order of magnitude of any current lead exposure associated with the ingestion or inhalation of lead compounds. (A considerable proportion of particulate material breathed in is deposited in the respiratory passages and finds its way thence into the pharynx. The proportion so deposited is greatly reduced if the inhaled lead occurs in the form of fume or vapor, and the analysis of feces is much less useful when the exposure is predominantly of these types.) If the workmen are selected carefully to represent the various occupations in a plant, the general and relative magnitude of the exposure associated with these occupations can

be demonstrated in most instances.

The lead content of single fecal evacuations,* in the case of normal individuals with no occupational lead exposure, ranges from about 0.10 mg. to more than 2.00 mg., with a mean value of about 0.33 mg. Approximately 85 per cent of all such fecal samples contain quantities of lead not in excess of 0.40 mg. Average or mean results above 0.50 mg. per fecal evacuation on groups of persons, are definitely indicative of abnormal lead exposure, and the higher the results go above this level, the greater is the exposure. It is possible by adequate sampling of the feces of workmen, to locate sources from which particles of lead-containing materials are distributed into the air, to determine the relative importance of such sources, and to establish the cross-sectional picture of the daily exposure of the plant population.

The greatest source of error in the use of this procedure is in the collection of samples. Gross contamination of the fecal samples occurs almost without exception unless adequate precautions are observed. Satisfactory samples may be collected by the distribution to workmen of chemically clean pint or quart size fruit jars with glass tops, sealed in a paper bag, and accompanied by proper instructions for the avoidance of errors. The samples must not be collected at a plant, but at the homes of the workmen. Preferably, on the day following a customary work day (i.e., not on the day after a holiday or week-end), a single average stool is evacuated directly into the jar, which then is covered, making use of a lead-free rubber ring as gasket, labeled with name and date, and resealed in the paper bag, for return to the plant or the laboratory. The workman is advised not to eat any game animal which has been shot, until after the sample has been obtained, and against catharsis as a means of obtaining a sample, particularly the use of epsom salt, which may be high in its lead content, and which, thereby, will distort the result. He is also warned against the inclusion of any dust or foreign material in the sample. Little difficulty is experienced if care is taken to explain what is desired and why.

Procedures suitable for the analysis of the samples are referred to in the Appendix to this report. It must be emphasized that only the most precise methods of analysis, in the hands of analysts who are competent and experienced in carrying out such analyses, can be expected to yield useful results.

b. Lead in the urine as a measure of occupational lead exposure-In contrast with the analytical results on the feces, which portray only the relative magnitude of the immediate lead exposure of workmen, the analysis of representative samples of urine will reveal the general level of the lead absorption associated with months or years of exposure to the conditions in an industrial plant. Therefore, if analytical facilities are limited and only one material from exposed workmen is selected for analytical study, properly collected urine samples will yield the most useful information.

The concentration and the daily output of lead in the urine have been found to vary with a number of factors, of which the most significant, in decreasing order of importance, are (1) the quantity of lead available for excretion in the body, (2) the daily stream of lead absorption into the tissues, and (3) the rate of water loss through the urinary system. Obviously, the first two of these factors depend primarily upon the mag-

* Obviously, the attempt should be made to collect samples of feces which will represent 24 hour evacuations. However, in view of the variability and incompleteness of the emptying of the alimentary tract on the part of entirely healthy, normal individuals, this is not possible. Experience has shown that satisfactory results can be obtained by collecting single fecal evacuations, which, in the judgment of the subjects, are representative of average normal alimentary function.

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Samples of urine should be
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Samples of urine should be obtained from carefully selected groups of workmen who represent the various occupations and locations in a plant. A chemically clean gallon jug, sealed in a paper bag, is given to each selected employee, or is delivered to his home. He is instructed to void his urine directly into the jug while at home, until not less than a liter or more than three liters have been obtained. Detailed instructions are given for the avoidance of contamination of the sample, and to maintain the customary daily intake and output of water. Despite instructions, occasional badly contaminated samples will be obtained, but care in the instruction of workmen will result in generally satisfactory samples, the accurate analysis of which will portray faithfully the conditions under investigation.

Smaller samples than those indicated above can be employed successfully and, if necessary, spot samples can be collected under the supervision of the examiner. These will require more careful interpretations, in view of their greater intrinsic variability, and their usefulness will depend upon the most meticulous precautions in their collection, since any factor of contamination will be greatly magnified by the smallness of the volume. Such samples cannot be collected at the plant unless there is available a clean room, which is rendered dust-free by adequate filtration of the air, and into which workmen enter only after removal of work clothes and bathing. Every item of precaution against the contamination of the container, its stopper, and its contents, must be exercised in detail, not for the purpose of theoretical precision, but for the avoidance of grossly misleading results.

Normal individual values for the urinary lead concentration range from 0.01 to 0.08 mg. per liter in the case of samples of a liter or more, and from 0.005 to 0.12 mg. per liter or even slightly more, occasionally, in spot samples of 50 ml. or more. The mean value of a sufficiently large number of normal samples, regardless of volume, is approximately 0.03 mg. per liter. Under conditions of occupational lead exposure the upper limit of individual urinary lead concentration rarely exceeds 0.50 mg. per liter, while statistically stable mean values for even the most heavily exposed groups in present-day industry are seldom over 0.25 mg. per liter.

c. Lead in the blood as a measure of occupational lead **exposure** -The analysis of samples of blood taken from representative groups of workmen will also show the magnitude of their lead exposure. The concentration of lead in the blood is subject to less variation during the day than is that in the urine, and might, therefore, be regarded as a more satisfactory criterion of lead exposure. On the other hand, the change in the lead concentration in the blood is not so great, proportionately, as that in the urine, in response to lead absorption, and, therefore, lead exposure is not

so readily or dramatically revealed by blood analyses. In view of the additional disadvantages associated with the difficulty of avoiding contamination of blood samples collected in industrial plants, and the necessity of venapuncture, this method of study is less likely to be practicable than analyses of excretory lead output. However, sampling of the blood in conjunction with the collection of spot samples of urine is an exceedingly useful procedure in determining the order of magnitude of the lead exposure of small groups of individuals, in that it can be done quickly in the course of a series of physical examinations.

The concentration of lead in the blood of normal North Americans with no occupational lead exposure ranges from 0.01 to 0.06 mg. per 100 gm. of whole blood. Values in excess of 0.05 mg. per 100 gm. of whole blood are rare in normal individuals and most of the results are between 0.01 and 0.04 mg., with a mean value slightly under 0.03 mg. per 100 gm. of whole blood. Occupational lead exposure results in increased lead concentration in the blood. Values between 0.10 and 0.20 mg. per 100 gm. are met with frequently, between 0.20 and 0.30 occasionally, and above 0.30 very rarely.

3. *Nonspecific clinical evidence of incipient lead intoxication* -

Within certain limits of lead absorption, toxic effects are not to be expected, and within such limits no clinical methods are available for the purpose of determining the relative magnitude of lead exposure and absorption except those already mentioned and briefly discussed. On the other hand, the detection of the earliest and least injurious effects of lead absorption, if followed by prompt and effective measures for the reduction and control of lead exposure in an industrial plant, may serve as a practical and adequate measure of the lead exposure in terms of its hygienic significance. Indeed, a well planned and competently executed regimen of medical supervision of the workmen in an industrial plant may be, of itself, an entirely satisfactory source of information as to the lead exposure, if *the basic* or unavoidable *lead exposure* of *the workmen is within generally safe limits.* In a plant of this type, the medical supervision, in so far as the *measurement* of lead exposure is concerned, is designed for the purpose of recognizing any type or degree of injurious effect as an indication that the lead exposure is greater than it should be. Such medical supervision involves the careful collection and recording of information as to the general health and well-being of the workmen.

Preexposure examinations of all employees must be used to collect basic data for comparison with those obtained in subsequent examinations, and the systematic elicitation and recording of subjective and objective findings periodically will give invaluable information as to the hygienic status of the workmen. Subjective complaints, as well as certain general signs of ill health, may give a wholly unsound basis for judgment in individual cases, but when symptoms and signs develop spontaneously among groups of stable and reliable employees as well as in those who are apprehensive or less trustworthy, the physician must satisfy himself as to their origin and meaning. Experience has shown that mild or incipient lead intoxication often manifests itself in varying degrees of ill health, in loss of appetite and in vague digestive complaints, in neuro-muscular disturbances of indefinite character, and in malaise, fatigue, and loss of weight. These clinical findings taken singly or in combination are not indicative or even necessarily suggestive of lead intoxication, but when they occur with noteworthy frequency in groups of workmen whose lead exposure approaches hazardous levels they had best be regarded as incipi
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had best be regarded as incipient toxic effects of lead absorption until evidence to the contrary has been obtained.

The frequency of occurrence of non-specific illness, and the extent of time losses and employment turnover among workmen, in relation to the apparent seriousness of their lead exposure, may also be of considerable significance, and should be subjected to careful clinical study. In this connection, it is perhaps not irrelevant to suggest that the detailed medical study of plant populations in relation to general and specific environmental factors has not been developed to the extent justified by its hygienic significance and its practical value. It should be more widely recognized that the careful and systematic collection and interpretation of such information are necessary adjuncts to any other method of studying lead exposure, and that in the final analysis, the solution of a number of perplexing questions as to the effects of human lead absorption can only be solved by observations made on large numbers of persons carrying on their daily normal activities.

Safe Limits of Occupational Lead Exposure

Safe human lead exposure whether met with in industry or elsewhere may be defined as a degree of exposure which, while resulting in lead absorption, does not produce any injurious effects upon the human organism. For present purposes, however, it is necessary to define safe industrial lead exposure in much more specific and practical terms. Any such definition at present is empirical, somewhat tentative, and limited in its application. Nevertheless, practical experience and systematic investigation have demonstrated that certain levels of occupational lead exposure and absorption are compatible with normal healthy existence and activity, and that any ill effects resulting from such lead exposure and absorption are so tenuous and vague as to be purely speculative in character. There are good reasons for the belief that present standards will be acceptable in practice for a long time to come.

Safe Limits as Defined by Air Analyses

As pointed out previously, industrial lead exposure is not necessarily limited to the inhalation of lead. It has been found, however, that when the air of workrooms regularly contains not more than **1.5** mg. of lead per 10 cu.m. of air as measured by standard methods, cases of disabling lead intoxication do not occur among the men who work regularly in such workrooms, and cases of questionable or mild intoxication are rare. In practice the attempt is made to maintain the lead content of the air within such limits as will yield an average of not more than 1.5 mg. of lead per 10 cu.m. throughout the working day, while preventing the occurrence of materially higher concentrations (5 mg. per 10 cu.m. or more).

Safe Limits as Defined by Analytical Results on the Excreta and Blood of Workmen

The upper limit of safety for concentrations of lead in the tissues and excreta of human beings is capable of most precise definition in the case of the urine. Lead intoxication occurs rarely, if at all, and only in its mildest manifestations, among regularly employed industrial workers, if the mean urinary lead concentration of representative groups of such workmen is kept below 0.10 mg. per liter and if the exposure is controlled so uniformly that individual results are generally below 0.15 mg. per liter and very rarely in

excess of 0.20 mg. per liter. (These figures are based upon the use of highly sensitive and accurate analytical methods applied to large samples of urine collected under carefully controlled conditions.)

With some variation due to differences in the origin and size of the particles suspended in the atmosphere and breathed in by workmen, the mean lead content of single fecal evacuations of men whose urinary lead concentrations fall in the ranges given in the preceding paragraphs, lies between 0.60 and 1.00 mg. Mean values consistently above 1.1 mg. in the fecal evacuations of groups of workmen who are subject to inhalation of particulate lead compounds, are associated with the occurrence of lead intoxication among them.

The upper limit of safe lead concentration in the blood of regularly exposed industrial workmen has not been defined with the necessary degree of precision. In lieu of a definite threshold value, it may be said that mean blood lead concentrations as high as 0.07 mg. per 100 gm. of whole blood are compatible with complete health and well-being, but it has not been established up to the present that lead intoxication in adults does not occur occasionally when the lead concentration is at this level. In frank lead intoxication the blood levels are usually considerably higher (0.09 to 0.30 mg. per 100 gm. of whole blood), although poisoning which at its onset was associated with concentrations within this range, may continue, somewhat abated, when the blood lead concentration has fallen to 0.07 mg. per 100 gm. Mean results of 0.05 mg. per 100 gm., with individual results rarely above 0.065 mg. per 100 gm., are representative of safe conditions of exposure and are associated with a mean urinary concentration of 0.08 mg. per liter, with the upper limit of variability in the urinary concentration at 0.15 mg. per liter. It appears, therefore, that the upper limit of safety for the concentration of lead in the blood lies somewhere between 0.05 and 0.07 mg. per 100 gm., and it is probably not far from the latter figure.

Safe Limits as Defined by Clinical Evidences of Impending Lead Intoxication

As indicated in the previous discussion of signs of lead absorption, no satisfactory clinical methods have yet been developed for the adequate measurement of the magnitude of human lead exposure in advance of prodromal symptoms of intoxication, with the exception of those based on chemical analyses of the blood or excreta of exposed persons. The nearest approach to a satisfactory method is to be found in the determination of microscopic changes in the erythrocytes in the peripheral circulation. By the use of these methods the occurrence of serious and disabling lead intoxication can be prevented in most instances,* if a sufficiently low value for the occurrence of basophilic erythrocytes is taken as an arbitrary basis for the transfer of workmen to jobs involving little or no lead exposure, and if the level of the customary lead exposure of the workmen is kept within or very near safe limits as defined in terms of air analyses or excretory rate. In the case of "stippled" erythrocytes, as determined by standard methods, this value has been set most commonly at 800 to 1,000 per million erythrocytes, or, as often expressed, at 10 to 12 "stippled" erythrocytes per 50 microscopic fields. The application of this standard will result in changing the work of men who are not absorbing significant quantities of lead, but it will usually serve to call attention to persons whose lead absorption has approached toxic levels. It must be emphasized, however, that the strict-

* Exceptions to this arise out of severe accidental exposures which induce acute illness within short periods of time.

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Individual Susceptibility in Relation to the Safe Limits of Occupational Lead Exposure

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est application of such a rule cannot be expected to prevent the occurrence of acute episodes of lead intoxication among workmen, if the lead exposure of the plant is well above safe limits, either commonly or frequently. Moreover, under inadequately controlled conditions of exposure compliance with this rule is likely to result in disorganization of plant activities through frequent shifting of employees.

Other nonspecific clinical methods for the detection of prodromal or incipient lead intoxication have been referred to in an earlier section of this report. Suffice it here to say of them, that the most skillful and conscientious efforts cannot make of them more than means for the recognition of unsafe lead exposure. As such, they are and will continue to be the last word in judging the adequacy or inadequacy of all standards of safety in occupational lead exposure, but they cannot in themselves serve as such standards in other than the negative sense. It may be possible to prevent the occurrence of the most serious consequences of dangerous lead exposure among industrial workmen, by their prompt removal from further exposure upon the appearance of the earliest evidences of lead intoxication. However, the performance of this role in medical supervision has iittle relation to safe occupational conditions.

INDIVIDUAL SUSCEPTIBILITY IN RELATION TO THE SAFE LIMITS OF OCCUPATIONAL LEAD EXPOSURE

The traditional and commonly held belief in the extreme susceptibility of some persons to lead poisoning has been the bugbear of all efforts made to set up safe limits for any type of lead exposure. There can be no doubt that a considerable variability exists among human beings with respect to the effects of lead absorption. Variability is such a regular characteristic of biological phenomena that it would be strange indeed if it were lacking in this instance. However, the results of clinical and experimental investigation do not support the idea that the variability in the response of human beings to the absorption of lead compounds is of unusual and wholly unpredictable proportions. The careful study of entire plant populations, kept essentially intact over periods of years and exposed to fairly uniform and barely safe basic conditions, has shown that remarkable degrees of susceptibility to lead intoxication are not an important source of difficulty. On the contrary, frequent determinations of the lead content of the air and regular study of the lead excretion of workmen have demonstrated that the important factor in the unexpected occurrence of lead intoxication among the workmen is the periodic occurrence of accidental or unforeseen lead exposure, locally or generally. Likewise, the study of individual cases of lead poisoning at or shortly after their onset has completely failed to prove that episodes of lead intoxication can develop without definite and characteristic increase in the lead concentration in body fluids or excretions.

Generally speaking, it is fair to say that the occurrence of lead poisoning in a plant or operation in which such cases have not occurred for a long time, is associated with some change in the procedure of the plant or in the technic of individuals whereby the previously insignificant lead exposure has come to be hazardous. Unusual and unforeseen cases of lead poisoning in industry, therefore, should not be credited to the " unusual susceptibility " of individuals, as they might well have been before the development of adequate methods for detecting lead exposure, but should be regarded as evidence of the existence of dangerous lead exposure and should be investigated thoroughly to establish the source of such exposure.

A further fact concerning individual susceptibility must be emphasized in

connection with the limits of safe lead exposure defined herein. These limits are not set up on any theoretical basis, but are derived from the fact that certain well defined conditions of lead exposure in normally operating industrial plants did not cause illness or disability among the workmen. Admittedly the population of an industrial plant is often subject to selective factors, among which are certain medical standards of physical fitness. However, the standards for safe lead exposure, as given above, are applicable to representative groups of industrial workmen, and they make automatic allowance for the factor of individual susceptibility as it occurs commonly among such groups.

Dietary and Therapeutic Prophylaxis in Relation to Safe Limits of Occupational Lead Exposure

From time to time various prophylactic measures have been recommended for the prevention of lead intoxication among industrial workers. The systematic administration of citrus fruit drinks fortified with acids or basic salts, of saline and other cathartics, or of ascorbic acid as more recently suggested, may conceivably have advantageous therapeutic effects. It has not been demonstrated that they are specifically beneficial in connection with lead absorption for even short periods of use, and there is no valid information as to such effects over long periods of time. Certainly, in the present state of our knowledge, their use does not justify the slightest relaxation of the requirements for the control of lead exposure. Indeed to the extent that such use may promote laxity in this respect, they are likely to be more dangerous than useful.

In principle, the administration of ascorbic acid in connection with occupational lead exposure may be regarded in the same light as the common practice of promoting the consumption of milk by lead workers. To the extent that industrial workers suffer from general or specific nutritional deficiencies, any procedure which promotes the correction of these deficiencies is good hygienic practice, but despite the existence of certain intriguing working hypotheses, there is no adequate evidence that any dietary regimen, other than one based on general nutritional principles, is beneficial under conditions of prolonged occupational lead exposure. Obviously, generous quantities of milk are likely to be advantageous in the diet of industrial workers, especially if, as often happens, their diet is deficient. It is not sensible, however, to count upon the drinking of milk to offset the effects of dangerous lead absorption. In the final analysis, there is no known substitute for adequate control of lead exposure, if lead poisoning among industrial workers is to be prevented.

The Control of Occupational Lead Exposure

Certain General Considerations

The maintenance of lead exposure within safe limits in an industrial establishment may be accomplished in some instances by the application of simple hygienic measures that involve little training and discipline on the part of workmen, average technical knowledge on the part of management, and only slight increase in the cost of plant operations. More frequently, however, the character and the potential severity of the lead exposure are such as to impose a heavy burden of responsibility upon the management of a plant, necessitating the use of trained personnel and the skillful application of safeguards for the health of the employees. Obviously, any method of procedure which

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clinical background in a plant

ffects over long periods of time. ıly, in the present state of our d their use does not justify relaxation of the require- for the control of lead exposure. to the extent that such use may e laxity in this respect, they are o be more dangerous than useful. principle, the administration of c acid in connection with occu- ıl lead exposure may be regarded same light as the common practice noting the consumption of milk d workers. To the extent that ial workers suffer from general or nutritional deficiencies, any pro- which promotes the correction of leficiencies is good hygienic prac- ıt despite the existence of certain ing working hypotheses, there is quate evidence that any dietary n, other than one based on gen- ıtritional principles, is beneficial conditions of prolonged occupa- lead exposure. Obviously, gen- luantities of milk are likely to be ageous in the diet of industrial s, especially if, as often happens, iet is deficient. It is not sensible, r, to count upon the drinking of o t the effects of dangerous bsorption. In the final analysis, is no known substitute for ade- control of lead exposure, if lead ing among industrial workers is revented.

I Lead Exposure

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More frequently, however, the ter and the potential severity of ıd exposure are such as to impose y burden of responsibility upon anagement of a plant, necessi- the use of trained personnel and illful application of safeguards e health of the employees. Ob- . any method of procedure which will protect workmen against the more serious types of exposure to lead will also control lesser exposure, and therefore the following discussion will be directed toward the more difficult problem.

In general, in large plants and industries, it is necessary to develop an organization that will be engaged continually in promoting the health of the personnel and in maintaining safety in all operations. Such an organization will usually be made up of full-time or consulting physicians, engineers, and executives or supervisors of production, each person or group having special responsibilities but sharing the knowledge of the problems that are to be met. In addition, nurses may be assigned to special duties as well as to their usual tasks. Regardless of the precise plan of organization, the test of the adequacy of measures taken to control lead exposure lies in the maintenance of freedom from the injurious effects of lead absorption. The responsibility for determining whether or not this is being accomplished must fall upon the physician, who therefore must have the facilities necessary for adequate study of the workmen, and the authority required to obtain action on his recommendations concerning them. He must be empowered to arrange for or carry out studies of environmental conditions, and to initiate hygienic improvements. *The physician should* inform *himself on the industrial processes* of *the plant by* making regular and *thorough inspections.* All information relating to the environment and health of workers should pass through his hands, and he should be kept informed of all proposed changes in plant equipment and processes. In short, he should be the health officer of the plant, with broad powers and direct access to executives. Engineers and supervising personnel assigned to hygienic activities may work under the general direction of the physician or not, as circumstances may require, but they must have some direct means of close collaboration with him.

Experience has shown that adequate control of potentially dangerous types of lead exposure depends more upon the proper design of a plant and its equipment than upon any other factor. Therefore, it should be axiomatic that when a new plant is to be built or an old one is to be remodeled or reequipped for the production of lead-containing commodities or materials, details of construction should be worked out carefully so as not to create new hazards or neglect old ones, and to provide adequate sanitary, engineering, and medical facilities. Mistakes are likely to be costly, and therefore engineers or physicians who are familiar with the problems to be met should be consulted *before* plans are adopted, not after they have been carried out. Likewise, the introduction of new processes, new personnel, and new working hours may greatly influence the safety of workmen, and are of immediate concern to all persons who have any responsibility for hygienic conditions. It is apparent, therefore, that executives should put responsibility into the hands of their medical and hygienic advisers, require from them a high degree of competence, and make full use of their capacities.

Some of the usual medical and engineering activities concerned with the problem of industrial lead exposure are worthy of detailed discussion.

Medical Supervision in the Lead Trades

In order to obtain the necessary clinical background in a plant population tion, it is necessary to carry out careful and effective pre-employment and

periodic examinations and *to* record systematically the results of such observations as are required to determine the status of individual workmen. The primary purpose of such examinations is the maintenance of good health among the employees.

The objectives of the particular examination, whether preemployment or periodic, should always be kept in mind by the examining physician. The doctor's specific duties in this respect depend on the type of examination. The main objectives of the preemployment examination in the lead industries are the selection of safe workmen, rejection of the obviously unfit, including those with communicable disease, and the proper placement of the physically substandard worker. On the other hand, the primary objective of the periodic examination in these industries is to detect evidences of potentially dangerous lead absorption so as to recognize and localize hazardous lead exposure, to bring about corrective measures, and to prevent acute or chronic illness. It is not enough, however, to give attention only to such medical data as are believed to be of specific importance in relation to lead absorption. Other types of illness occur among lead workers, the differential diagnosis of which may often depend upon satisfactory records of previous physical examinations.

The physician must be familiar with the legal aspects of industrial medical practice in his state. In certain states medical examinations of employees in lead industries are required by law, and reports may be required from time to time by state authorities. Children up to the ages of 16 and 18 are legally excluded from employment in most lead-using trades, and in some of the states the employment of women is prohibited. Cases of lead poisoning are required to be reported to state health departments, and in some states to state labor departments. The responsibility of the physician in certain of these instances is direct and personal, and cannot be delegated to the management of the plant.

PREEMPLOYMENT EXAMINATIONS

The initial examination should be comprehensive and complete. It should include a record of the applicant's occupational or employment history, past medical history, symptoms of illness and physical findings. These examinations, if conducted according to accepted methods, will require at least 30 minutes and often more per man to complete. In lead-using industries, experience has shown that the general physical examination should be supplemented by hematologic tests and a routine analysis of the urine that includes at least tests for albumin and sugar, and a microscopic study of the sediment. The blood picture should be determined by the enumeration and examination of ervthrocytes and leucocytes, determination of hemoglobin (preferably by an acid-hematin method), and by counting the erythrocytes that show basophilic material, whether reticulocytes, stippled erythocytes, or the combination of these forms as in the basophilic aggregation test. Determination of the rate of erythrocytic sedimentation is also a useful procedure. In relation to the general health of the population of a plant, and for the control of communicable disease, the practice of carrying out routine serologic tests for syphilis is recommended. Radiologic chest examination is also advantageous and is necessary if occasional cases of incipient tuberculosis are not to go unrecognized. When employed primarily for this purpose such examinations can be reduced in number by carrying out intracutaneous screening tests with Old Tuberculin.

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This grading has been given
American College of Surgec
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Class Z-Those physically underdev
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Class J-Those fit only for certai
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Class 4-Those unfit for any emp

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that there is a safe job for almost every workman, the examiner should use some system of grading. The most common industrial practice appears to be that of rating the physical fitness -of workmen in four grades: 1, 2, 3, and 4, or A, B, C, and D. All men with impairments or diseases that put them *in* class 4 (or D) and some in class 3 (or C) must be rejected. Men in classes 1 and 2 (or A and B) may be employed in any job, and those in class 3 (or C) require special placement. This grading has been given by the American College of Surgeons, the National Industrial Conference Board, and other organizations. The classification formulated by the Conference Board of Physicians in Industry is as follows:

Class 1-Those physically fit for any work
Class 2-Those physically underdeveloped, or with some slight anatomical defect; otherwise fit for work
Class 3—Those fit only for certain employment when approved and supervised by the medical department
Class 4—Those unfit for any employment

Certain individuals such as those afflicted with diabetes, borderline hyperthyroidism, and diseases that seriously impair hepatic, renal, and circulatory function should be excluded from potentially hazardous occupations in a plant, but these men can often be placed where they will not bring danger upon themselves or other workmen in the plant, and where opportunities for lead exposure will be limited or negligible. One group of applicants whose acceptance may be questionable is made up of those previously employed under conditions of lead exposure, the severity of which cannot be determined or estimated by the examiner. Among these may be capable and experienced men who are very desirable employees and would be acceptable if the order of magnitude of their previous lead exposure could be determined. In such instances, preëmployment lead analyses to determine the facts in this regard will be invaluable aids to their proper placement. These men may thus be put tentatively in class 3, given employment, and examined periodically until the physician is sure that it is safe for them to continue in the assigned occupation.

PERIODIC EXAMINATIONS

Periodic examinations as referred to herein, are those made at regular intervals to evaluate the hygienic status of the individual worker, as well as others made at irregular intervals. The latter include medical examinations made before transfer from one department to another, and those carried out in connection with injuries and illnesses and prior to reinstatement thereafter.

In making periodic examinations, the first responsibility of the examining physician in a lead industry is to detect early evidence of potentially hazardous lead absorption in order to prevent injury to the health of workmen. These periodic examinations also afford an excellent opportunity for health promotion among employees. While on the lookout for early lead poisoning, the physician may detect incipient stages of such diseases as tuberculosis, heart disease, and cancer, and is in a favorable position to recommend remedial measures. These examinations should not be carried out hastily and without regard for the circumstances and the feelings of the workmen. Satisfactory information cannot be obtained unless correct relations exist between the physician and the workmen. Subjective complaints constitute exceedingly useful data under proper conditions; they must be interpreted in the light of the complainant's attitude, and this is possible only if there is a sound basis of mutual understanding between the doctor and the employee.

The frequency with which regular periodic examinations should be made is largely dependent upon the severity of the lead hazard, yet each situation must be considered on its own merits. If the extent of the lead exposure has not been determined, or if the atmospheric lead concentration is known to exceed 1.5 mg. per 10 cu. m., it is desirable to examine employees who are exposed to lead in industry for the first time, at relatively frequent intervals over a period of time (12 to 18 months) sufficient to demonstrate their reaction to their occupational environment. Those exposed to an atmospheric concentration of less than 1.5 mg. of lead per 10 cu. m. need not be examined regularly more than once or twice a year. Experienced workers whose potential lead exposure is moderate, somewhat variable and unpredictable, should be examined once a month, whereas a weekly examination may be advisable in the case of employees who are potentially exposed to serious lead hazards that are difficult to control.

The detection of prodromal or incipient lead intoxication requires not only familiarity with the characteristic effects of lead, but general knowledge of disease processes. The problem of differential diagnosis here is not different in principle from that in any other type of medical practice, except that the legal implications of any diagnosis may involve the necessity of furnishing substantial proof that it is correct. The basis of the diagnosis of lead poisoning will be discussed in detail later, and need not be dealt with at this time, but attention is directed to certain matters that have practical importance. When illness develops in a workman who has had hazardous or potentially hazardous lead exposure, the physician should do more than merely satisfy himself that such illness is or is not due to lead absorption. Good medical practice and effective medicolegal procedure may well require not only the conviction or exclusion of lead as the etiologic factor, but also the demonstration of the actual nature of the illness. If the latter is difficult of accomplishment, there is all the more reason for a thorough-going effort in that direction. The proper time to make use of special diagnostic procedures and expert medical consultation, whether related to the detection or exclusion of lead as a factor in illness, or whether devoted to the diagnosis of some obscure disease, is *not* when a *claim for damage or compensation has* been made, *but when the illness is in* progress. The plant physician should therefore take advantage of such recognized medical procedures when confronted with a diagnostic problem that requires them, not only because this is the logical expression of his medical judgment, but also because in the long run this is the best way to settle potential medicolegal controversies and to avoid the bitterness and wasteful expenditures associated therewith.

Laboratory Facilities

A well organized medical department in an industry in which there is a potentially hazardous lead exposure should have laboratory facilities for adequate clinical-microscopic examination of the blood and urine of exposed workmen. The equipment of the laboratory and the training of the personnel should be such as to insure the accuracy of all work done. A wide variety of other laboratory procedures commonly required for diagnostic purposes may be carried out in such a laboratory, or such information may be acquired from outside sources when needed.

In view of the importance of lead analyses, provision may well be made whereby such analyses can be done as required. This poses a difficult prob-

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lem, in that such work cannot be done in most lead plants because of the danger of gross contamination of samples in process of analysis, and because of the expense involved in setting up satisfactory facilities under adverse conditions. A laboratory for this purpose must be rendered dust-proof and fume-proof, and proper precautions must be taken against the introduction of dust on the clothing or person of workmen. Otherwise, it is necessary to have the laboratory at a sufficient distance from the rest of the plant, and indeed from the entire industrial section of the community, to escape contamination. It may be advisable to delegate responsibility for the analytical work to a laboratory that is independent of the plant. The obstacles here .are considerable but are not insurmountable if there is a complete understanding of the nature of the information which is to be obtained, and a thorough comprehension of the difficulties to be overcome. It must be recognized, however, that if adequate provisions are not made for obtaining results of *a* very high order of accuracy, there is no point whatever to the effort. Erroneous data will be not only valueless, but actually misleading. One means of checking the adequacy of the analytical facilities is to analyze a series of samples obtained from unexposed persons from time to time. Unless the results of such analysis are found to be in consistent agreement with normal standards, the quality of the analytical work must be regarded as unsatisfactory.

RECORDS

The personal preference of the physician and the local requirements are likely to determine the exact manner of recording the medical information obtained on workmen. Various forms have been described and illustrated by organization such as the American College of Surgeons and the National Industrial Conference Board. These forms have been designed for medical service in industry and embody features found by long experience to be useful. Other record forms have been developed by industrial physicians in accord with their specific needs. One of these is given here as an illustration. Any form adopted must be simple for speed, yet sufficiently complete for adequate study of the worker. The record should be amenable to statistical study and adequate for all medicolegal purposes. As a minimum, the forms should include the name of the applicant or employee, his address, Social Security Number, plant identification number, nationality, race, sex, marital status, previous history of illnesses and injuries, previous occupational history with dates and with information on the type of control of any hazardous lead exposure that may have existed, date of birth, date employed, data of physical examination with physical defects, physical fitness rating, defects on leaving employment, and date of leaving employment.

The data of re-examinations may be recorded on separate forms or combined with the initial record. As illustrated, this portion of the record form may be on the reverse side of the sheet or card used for the pre-employment examination. A series of blank vertical columns is often used to carry serial notations at intervals over a considerable period, with reference to such items as the date, weight, general appearance, and the digestive, neuromuscular, and vascular findings, together with laboratory data. As the form is filled out from left to right, the trend of symptoms and signs is readily apparent. Space may well be provided for descriptive clinical notes, and certain important data may be plotted graphically. Additional space may be used to record the dates of all dispensary visits, com-

plaints, physical findings, diagnoses, treatments, and time lost from work.

The manner of handling medical records is a matter of considerable importance from both professional and practical aspects. If a record is to be complete and satisfactory from the medical viewpoint, it must be regarded as the tangible expression of the customary confidential relationship between physician and patient. As such it is strictly in the custody of the physician and should be available to others only with the consent of the worker or under such other circumstances as are prescribed by law and ethical professional practice. Adherence to this policy with respect to records and other confidential information of a medical character provided by workmen to the physician, will go far toward the development and maintenance of a proper professional relationship between the physician and the management on the one hand, and the physician and the workmen on the other.

In addition to the maintenance of complete records on individuals, the plant physician should assemble the data on all the workmen at regular intervals (monthly or quarterly) and summarize the results of his study of these data.

MEDICAL RECOMMENDATIONS AND POLICIES

The medical examination of an individual workman may give results which require action on his behalf. It is not the purpose of this report to discuss illnesses and disabilities, other than those due to lead absorption, and the treatment of lead poisoning will be considered later. However, certain courses of action are open to the industrial physician when he recognizes the existence of danger to the health of an employee, or when incipient lead intoxication develops in the absence of acute illness or disability. It may be that early evidences of lead absorption in a single workman will reveal the existence of a previously unsuspected lead hazard. If so, suitable preventive measures may be taken, and if these are adequate, no other step may be required. (The workman may have been indulging in an innocent or wilful infraction of the rules for safe procedure, in which case there may be weaknesses in methods of instruction and supervision to be corrected.) It may be satisfactory to transfer the workman to a point at which his lead exposure will be reduced or eliminated. It may be necessary, however, to make sure not only that all chance of occupational lead exposure is brought to an abrupt end, but also that temporary freedom from all work is granted, in which case the employee must be given temporary leave, with subsequent reinstatement. It may even be necessary to advise complete and permanent discontinuance of employment under conditions of lead exposure.

When the assembled observations on a group of workmen, or upon the entire population of a plant, indicate the existence of unhealthful conditions—specifically, in this instance, evidences of dangerous lead exposure-the physician has no choice but to recommend such studies as will reveal the source and character of the exposure, or such remedial measures as will eliminate the hazard if it is known. The adequacy of such measures can be determined by subsequent examination of the environmental conditions, by engineering procedures, and also by observations on the men. Thus the data of periodic examinations, when subjected to proper study, can be employed as a regularly recurring and valid demonstration of the effectiveness of the methods of control of lead exposure. This more than anything else is the function of the plant physician in the lead industries. He should, in addition, undertake to recognize incipient or lead poisoning before it has disability, but there is noth armamentarium that will enal this means completely to wa consequences of lead exposu latter is actually dangerous. therefore, is to demonstrate ence of such exposure in orde need for its elimination will indicated.

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take to recognize incipient or prodromal lead poisoning before it has produced disability, but there is nothing in his armamentarium that will enable him by this means completely to ward off the consequences of lead exposure, if the latter is actually dangerous. His duty, therefore, is to demonstrate the existence of such exposure in order that the need for its elimination will be clearly indicated.

There is one practical means of controlling or, at least, of reducing the lead exposure of workmen, that does not depend primarily upon reducing the dissemination of lead compounds in the working environment. This consists in limiting the duration of the exposure of the individual employees. The quantity of lead absorbed into the body is dependent both upon the severity of the exposure and the time over which exposure occurs. The length of the working day and the number of work days per week, are of considerable importance, therefore, in relation to the magnitude of the exposure. However, because of the fact that inhaled and swallowed lead is available for absorption for some hours or days after the exposure has ended, the total length of employment under conditions of lead exposure is of much greater consequence. It is for this reason that the rotation of workmen into and out of exposed areas, at definite intervals. has been found to be an effective means of reducing or eliminating lead poisoning under conditions in which lead exposure is difficult to control, or when because of urgent and valid need for production, the control of environmental conditions is temporarily below par. Precise information is not available for prescribing rules whereby the length of exposure and the duration of the interval of freedom from exposure can be related to a specific level of lead exposure, but from both theoretical knowledge and practical experience, it can be said that the period of freedom from exposure should be at least as long as the period of exposure, to be of maximum benefit. This means of controlling lead exposure is not recommended as the most desirable and it is not practicable in many industries, not only because of the unusual conditions of employment it imposes, but also because working areas sufficiently free of lead exposure are rarely available to such an extent as to provide for the rotation of the men. Nevertheless, the procedure is sound in principle and as a means of providing safety in times of stress, and until other measures of control can be effected, it will serve a useful purpose.

Engineering Control in the Lead Trades

Our purposes in the paragraphs under this heading are to call attention to certain principles which have an important bearing upon the success or failure of efforts made to control industrial lead exposure by mechanical means, to point out certain facts based upon experience, and to encourage the use of available sources of detailed information on various aspects of the problem. Among the references of this type given in the Appendix, texts and articles will be found containing more or less standard specifications for safe and healthful conditions in industrial plants in respect to illumination, temperature control, ventilation, and general sanitary facilities.

General Considerations with Respect to Lead Exposure

Mention has been made in a previous section of this report of the methods employed by the engineer in

measuring the severity of lead exposure, and of the presently accepted engineering standard for safety in the lead trades in terms of lead available for inhalation by men working for a normal length of time per day and per week. This standard sets the upper limit of permissible lead concentration in the air, when determined by standard methods of sampling and analysis, at 1.5 mg. Pb per 10 cu. m. This is regarded by many engineers as a virtually all-inclusive standard, in that its achievement is likely to call for the application of all types of hygienic control with a high degree of effectiveness. On the other hand, considerable difficulty has been encountered in certain of the well known lead industries, in reaching and maintaining such conditions. There has been some tendency, therefore, among those who have attempted unsuccessfully to attain this standard, to regard it as ideal and visionary, while in many industrial establishments, no attempt has been made to apply such a standard. It seems necessary here to emphasize the practical value of this standard as one that can and should be met. At the same time, it should not be forgotten that lead poisoning can occur from the ingestion (swallowing) of lead compounds. Therefore, the care taken to prevent the inhalation of harmful quantities of lead should **not** result in disregard of necessary and effective measures for the control of lead ingestion. Due attention must be given to lunchroom, washroom, and changeroom facilities and to the instruction and supervision of workmen in matters of personal hygiene and cleanliness. These measures will not prevent lead poisoning if the respiratory lead exposure continues at a dangerous level but, on the other hand, control of the respiratory exposure alone will fail to eliminate lead poisoning if the increment of lead absorption from the alimentary tract is of sufficient magnitude.

It should also be recognized in times of pressure for production that the factors of lengthened hours of work, increased numbers of inexperienced employees, increased wear and tear on machinery and equipment, decreased frequency of repairs and replacements, and increased bulk of materials handled, may combine to convert relatively safe conditions into hazardous ones. Under such circumstances it becomes necessary to increase the effectiveness of control measures by every available means, or to change the processes of production, or to decrease the duration of the exposure of the men.

There are also times when the necessity and the opportunity present themselves to eliminate lead exposure completely from an industrial process by substituting other materials for lead. More frequently the methods of the process can be changed in such a way as to eliminate or reduce the lead exposure. It is important, therefore, that the engineer who is attempting to control the lead exposure of a plant, should have such knowledge of processes and materials as will enable him to suggest changes in them or at least to raise pertinent questions concerning them for the consideration of those in charge of production. His role will be the easier in this regard if he has a share in determining the methods of production, and for this reason in some industrial organizations, the engineering department is made equally responsible for production and safety.

Plant Design and Construction

As indicated previously, the time to deal with the potential lead exposure of a manufacturing plant, from the engineering point of view, is at the time the plant is designed and built. This, obviously, is not always feasible, but many plants are remodeled or rebuilt

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DESIGN AND CONSTRUCTION

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periodically, to improve or increase production or to decrease production costs, and at such times detailed attention should be given to factors that will minimize lead exposure. A number of items require special consideration and forethought in order to avoid costly and makeshift modifications later.

Isolation of the More Hazardous Occupations

Certain types of work involve unusual opportunities for exposure to dust, fume, or spray. If these occupations are isolated from others, intensive efforts can be concentrated on control measures in these areas and on these men, at minimum cost, and with maximum effectiveness.

Location and Arrangement of *Equipment*

If the specific hazards of an industrial process are fully understood by the designer or builder of a plant, the equipment can often be laid out so as to reduce or eliminate these hazards. The arrangement of ventilation systems that will work properly, that will not encroach unduly upon space needed for other purposes, nor interfere with the effectiveness of otherwise satisfactory heating equipment, nor pollute the outside atmosphere and perhaps provide a more generally disseminated lead exposure, poses a series of problems that can be dealt with most effectively when a plant is being built. The same is true of the disposition of manufacturing equipment, which often can be so localized as to be easily ventilated but may be so scattered as to give rise to almost insurmountable difficulties. Likewise the types of floors, windows, and fixed equipment determine the ease or difficulty of cleaning and housekeeping, and these factors often make the difference between safety and continued hazard. It is not to be expected that the building of a plant will understand these hygienic problems. It is important, however, that he recognize their existence and make use of the knowledge and experience of an engineer who does understand them. Thus plans can be made to have dusty types of work carried out on benches of slotted metal equipped with exhaust ventilation, or on metal grill-work floors overlying water and supplied with downdraft suction.

Provision for *Adequate Sanitary and Medical Facilities*

Locker-rooms, washrooms, lunch-rooms, and medical facilities must be planned carefully in the light of information which only trained and experienced persons can be expected to possess. Their type and location will have much to do with their effectiveness. It is not to be supposed that habits conducive to cleanliness and the avoidance of unnecessary lead exposure can be cultivated effectively in a group of workmen unless convenient and comfortable means to that end are provided.

With respect to locker-rooms and bathing facilities, it should be mentioned that in most of the lead-using industries, workmen should change all of their clothing on beginning their work, changing back again and bathing thoroughly at the end of their day's work. This requires two sets of lockers, one for the work clothing, the other for regular clothing. Some separation of the space in which the two sets of lockers are set up will aid in maintaining cleanliness in the area in which the regular clothing is kept, and the showers should be so arranged that it is unnecessary for the workmen to return after bathing into the area in which soiled work-clothing is kept. Proper arrangement of these facilities will help greatly in the maintenance of cleanly conditions. The lockers should be of the self-ventilating type, and can

best be set on a pedestal above the floor level, so that the floor can be scrubbed or hosed. Facilities for laundering the work-clothing will also be required as a general rule.

Lunchrooms should be arranged with an eve to convenience and comfort and, above all, to freedom from contamination with lead compounds. Adequate space must be provided there or elsewhere for the lunch-boxes of those who carry their lunch, and for keeping milk or other beverages (aside from water) that are consumed on the premises. It is a great advantage if hot beverages can be served, and a still greater one if a hot meal can be made available in the middle of the day or shift. Inasmuch as all eating in workrooms must be avoided, the availability of an attractive, comfortable, and clean lunchroom is an important factor in the cultivation of good habits of personal cleanliness among the workmen.

Toilets should be available in adequate number and in convenient locations. They should be maintained in a state of strict cleanliness. Likewise drinking fountains of proper design should be conveniently distributed.

The incorporation of satisfactory facilities of the foregoing types into a plant that has been operating without them for some time, requires careful study and the exercise of knowledge and ingenuity. Likewise, the maintenance of such facilities in a proper state of cleanliness and efficiency, calls for continued effort on the part of caretakers, and vigilance on the part of supervisors.

Ventilation

It is neither feasible nor desirable to enter into a comprehensive discussion of ventilating and exhaust systems and devices for the control of lead exposure. A number of publications are readily available for reference both as to principles of design and specific applications. (See classified bibliography in the Appendix.) In view of the number of plants in which attempts at control of lead exposure by ventilation are made by incompletely informed and relatively inexperienced persons, it is necessary to point out certain general facts, in an effort to forestall the repetition of common errors.

In general, the mere dilution of lead dusts or fumes in workrooms by the introduction of fresh air is unsatisfactory. It is preferable to pick up such dusts and fumes at their point of origin by means of exhaust lines, thereby removing them from the workrooms, and to dispose of them by filtration or precipitation or by conducting them to points at which they can do no real or alleged harm either within the plant or beyond its confines.

Air introduced or drawn in to replace exhausted air, or for purposes of dilution, must be free of significant contamination with lead or other toxic materials. Inlets must be so located as to eliminate any possibility of such contamination, or must be protected by suitable filters. Otherwise the contaminated air exhausted at one point may be returned into workrooms and recirculated. If filters are used the air supply must be tested periodically as a check on the efficiency of filtration.

Provision should be made for heating facilities that will permit the full use of ventilating equipment in cold weather without undue exposure of workmen to cold air currents.

Local and general ventilating systems should be so designed in relation to the construction of workrooms (windows, doors, and other openings), and with respect to dampers and other control devices, as to eliminate opportunity for interference or tampering on the part of workmen.

All ventilating systems should be subjected to smoke tests or to similar tests which will demonstrate the e
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Housekeeping

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which will demonstrate the efficiency of the ventilation and reveal points, if any, of undue turbulence or dead air spaces. They should also be checked carefully for the adequacy of their control of lead exposure by the analysis of representative air samples.

HOUSEKEEPING

The elimination of sources of lead-bearing dust is obviously of the utmost importance in industrial plants. For this reason the choice and application of methods of cleaning requires careful consideration. All accumulation of dust on floors, work-benches, rafters, window ledges, and the like should be cleaned up frequently. (Such accumulation should be prevented as far as possible by the use of receptacles and by the removal of dusts and debris at their source.) In general the use of brooms and brushes is undesirable and avoidable, and the availability of brooms in dusty areas is usually evidence of lack of thoughtful attention to problems of housekeeping. When sweeping is permitted, water or oil or other material that will effectively allay dust must be employed.

Two general types of cleaning equipment are to be recommended, namely—vacuum systems, and washing down with water or in some instances other liquids. It is to be remembered that wet floors are likely to be slippery? and that precautions will be required to prevent injuries on this account. Vacuum systems may be of the portable or built-in types. The use of hose lines for wetting-down otherwise dusty materials and for keeping floors and working areas clean, involves care in the construction of floors, drainage systems, and catch basins for the settling of lead-containing materials. Likewise, the effective use of vacuum-cleaning equipment is dependent upon the smoothness and accessibility of floors, window ledges, and other surfaces on which dusts may collect.

The importance of intelligent and continuous good housekeeping lies chiefly in the fact that it eliminates certain types of lead exposure that are wholly unnecessary, by methods that are simple and relatively inexpensive. The routine of house cleaning should be planned carefully and should be strictly enforced by regular supervision.

PERSONAL RESPIRATORY PROTECTIVE EQUIPMENT

Necessity for the use of individual respiratory protective equipment should be avoided by effective methods of environmental control so far as possible, not only because it is desirable to limit the precautions required of individual workmen for their protection against lead absorption, but also because all such devices reduce the efficiency and comfort of the wearer. Nevertheless, there are occupational exposures that can scarcely be avoided without the use of masks or respirators, and there are periods of intermittent or irregular exposure, and times of stress or emergency, when no other means of protection are feasible. Rapid progress has been made in the development of respiratory devices, so that many types of equipment are available, most of which are adapted for specific uses. The United States Bureau of Mines approval-schedule for dust, fume, and mist respirators was first promulgated in August, 1934, and their requirements were adopted later by the American Standards Association. Thus the standards of efficiency of the equipment manufactured for such purposes have been well established, and respirators approved for specific purposes can be accepted as satisfactory, when properly employed.

All respiratory protective equipment should be selected for use by persons familiar with the available types and their specific applications. Such equip-

ment must be kept in perfect condition. Some regular system for inspection, maintenance, and replacement must be set up under the control of trained and responsible personnel, and careful supervision in the use of such equipment is required. In many plants this inspection and servicing of respiratory protective equipment is best centered in the medical department.

Supervision of Workmen

Reference has been made in the previous paragraph to the necessity of supervision in the use of masks and respirators. In general, workmen must be trained, not only in the use of such equipment, but in the technical details of many other procedures that involve opportunities for hazard. They must be instructed not to eat or to drink milk and other beverages in workrooms between meals or at meal times, and not to keep food and milk near them while at work. After they have been instructed, supervision is required to maintain compliance with satisfactory practices. It is not always recognized that the technic of avoiding various types of hazard requires understanding, attention, and precision on the part of workmen to a degree that is often equivalent and sometimes in excess of that necessary for the performance of their work. When it is further appreciated that the dangers of lead absorption are insidious and that many of the precautions against such dangers are a source of delay, inconvenience, and discomfort, it is unrealistic to hope or expect that the full responsibility for his own safety be accepted by the worker. Accordingly, the operations of a plant, including the use of various measures of safety, may well require careful study, to the end that the technic required to accomplish the best over-all results may be prescribed in detail and in sequence. Safety measures may thereby be incorporated within and become a part of operating procedure, with responsibility on the part of workmen, foremen, and all other operating personnel, for following the procedure agreed upon. In this connection the activities of janitors or cleaners and maintenance men should not go unheeded. The opportunities for lead exposure on the part of these men may be as great or even greater than that of others. They must be carefully trained and properly supervised.

Safety Instructions and Regulations

In certain of the states, various types of instructions and notices to workmen are required by law to be posted in conspicuous places in industrial plants. Engineers responsible for plant hygiene must be familiar with these requirements. Additional instructions can usually be provided to advantage, whether in book form or in placards, calling the attention of workmen to the specific hazards of their occupation, giving specific instructions as to the means of avoiding these hazards, and prescribing general regulations in matters of personal hygiene. Such regulations and advice as may be given in this form should be based on the fullest consultation between the production personnel, the engineer, and the physician, to the end that they shall be simple, reasonable, practicable, and in accord with legal requirements. In occupations that call for complicated or precise technical procedure, and in the chemical manufacturing industries in general, it has been found to be excellent practice to prepare an operating manual, in which the various steps of all procedures are set down. These need to be reviewed from time to time and modified, to maintain the most satisfactory practices. Such a manual includes all precautionary measures. The main points of procedure, and the primary safety regulations, may be outlined in abbreviated form and posted for reference in the form of placard advantages of such readily a instructions in training new em in carrying out the day's work, supervising the activities of a g men, are obvious.

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breviated form and posted for ease of reference in the form of placards. The advantages of such readily available instructions in training new employees, in carrying out the day's work, and in supervising the activities of a group of men, are obvious.

Among the instructions in personal hygiene for workers in lead industries, specific regulations in the matter of washing before meals, bathing before leaving, changes and disposition of clothing, use and care of protective equipment, and the handling of tobacco and food in workrooms should be prescribed in detail. In addition to the careful consideration required to draw up such regulations, a useful purpose is served by them in that both employee and employer are kept aware of their specified responsibilities, the one for carrying out instructions, the other for providing and maintaining the necessary facilities.

PLANT SURVEYS, ANALYTICAL STUDIES, AND REPORTS

In addition to having a large responsibility for the activities mentioned in the foregoing paragraphs, the engineer who has a share in the responsibility for plant hygiene should carry out complete periodic inspections of the plant. All changes in operating technic or equipment should be known to him and should be studied to determine their effect upon the lead exposure. Maintenance and repair work should be supervised or at least observed critically, not only because of the hazards to the repairmen, but also because of the faults in the equipment that require repair and the opportunities for increased lead exposure inherent in such faults. Air analyses will be required periodically to maintain accurate information on the trend of the lead exposure, and additional analyses will be indicated from time to time when equipment or operations are changed. Reports on all of these matters should be made in writing to designated persons in the plant. Copies of such reports should go to the medical department, if the plant organization is not such that the reports are made directly to the physician in charge. Such reports are likely to be most effective if they carry specific conclusions and recommendations backed by adequate data and based on complete familiarity with plant processes and conditions.

Hygienic Control in Small Plants and Shops

The problem of controlling lead exposure in small plants and shops is admittedly difficult, not because the means of control need be different in principle from those employed in large plants, but rather because of the relatively great burden of cost involved in the application of adequate protection against varied types of lead exposure. An even greater and more fundamental obstacle lies in the fact that the accomplishment of satisfactory results depends upon the dissemination of adequate information among the owners and the operating heads of such plants, and among the physicians in the communities in which such plants are located. That is to say that the problem is not generally understood, and that the technical knowledge and the professional skill required to solve it are not generally available.

It is important to recognize that the large proportion of industrial workers are employed in small plants and shops, and that the character of the work in many of these plants is highly diversified and variable. The opportunities for lead exposure are varied and numerous, and while a given type of

lead exposure may not be as constant over a period of years as it is in certain parts of a large plant with its specialized and perhaps segregated occupations, the over-all lead exposure of individuals may be quite severe without being so recognized. Moreover, the number of persons variably exposed to lead in the aggregate of small plants and shops is probably much greater than the total number of lead workers in large industries. There can be no question, therefore, that the environmental conditions in small plants have a very important relationship to the health of the industrial population of the nation and that the need for adequate medical supervision of the workmen in these plants is great.

There are several possible methods of approach to the problem, all of which are being employed to a greater or lesser degree. Various governmental agencies (divisions of industrial hygiene in state departments of health or labor departments, and in the U. S. Public Health Service) have provided trained personnel whose services are available for plant surveys and consultation. A number of educational institutions have set up facilities for investigation, as well as undergraduate and postgraduate courses of specialized training, and in some instances have developed consulting services for dealing with industrial problems. The American Medical Association and certain of the state medical associations and other organized medical groups have sponsored postgraduate courses of training in industrial medicine. Insurance companies have developed various hygienic facilities and services. Organizations representing industrial management or industrial workmen have sponsored experimental work and technical and professional services for their membership. Several privately organized medical and hygienic services have been created to care for the regular or occasional requirements of industrial establishments. Most of these organizations exercise an educational or consulting function, and all are contributing in some measure to the solution of the problem. Most of them (excepting a few of the last-mentioned type) have one serious fault in relation to the'handling of the daily or frequently recurring hygienic problems of these plants, that they do not provide for regular medical and engineering services and for the maintenance of familiarity with the operations and workers in a plant.

The general principles and procedures for the control of lead exposure are the same regardless of the size of a plant. What has been said in earlier paragraphs concerning the design of plant facilities, ventilating, and housekeeping, applies equally to large and small plants and should be studied by the managers of small plants. If only good housekeeping could be employed in small plants, a great advance would be achieved. However, as previously suggested, it is the primary purpose of this discussion to consider how a small industrial organization can obtain the help of competent medical and engineering personnel at a reasonable cost, and so achieve the degree of hygienic control that is reached in some of the larger establishments. It would seem that there are at least two courses of action open to the management of small plants, viz.-(1) that of sharing the services of a local or nearby medical and engineering organization with a number of other plants, and (2) that of engaging the part-time services of a private practitioner of medicine, while delegating the engineering control of exposure to those who are responsible for production. Which of these methods will work out more satisfactorily in a given situation will depend upon local conditions and facilities. The availability of adequately trained physicians and engineers for the accomplis of the task in either of these two depends upon effective and r accessible means for specialized p sional and technical training. means are not available to the of the present need but there are that the need is being recognize' that this field of medical and health education and practice may

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and engineers for the accomplishment of the task in either of these two ways, depends upon effective and readily accessible means for specialized professional and technical training. Such means are not available to the extent of the present need but there are signs that the need is being recognized and that this field of medical and public health education and practice may soon take a place that is in keeping with the magnitude and importance of the work that is to be done. It is doubtful whether there is any other field of investigation and instruction in which representatives of industry, of organized medicine, and of medical education and research could pool their interests and resources with greater benefit to the public health.

Occupational Lead Poisoning

The Diagnosis of Lead Poisoning

There is need at present for the application of sound principles of clinical medicine in the diagnosis, not only of lead poisoning, but of occupational diseases in general. The tendency to resort to short-cut and makeshift methods based on a few allegedly specific criteria, especially those of the laboratory (microscopic blood findings and the results of analyses on the blood or urine in the case of lead), is not uncommon, and is responsible for many of the diagnostic errors made by industrial physicians. Equally troublesome as a cause of unnecessary friction between employer and employee, and the source of fruitless litigation, is the readiness of many physicians engaged in general practice to attribute any type of illness to the effect of exposure to some noxious substance, if such a substance enters into or is allegedly used in some manner in the occupation or place of employment of the patient. Many of the claims for compensation for lead poisoning that arise in this manner have wholly inadequate medical and factual support, and therefore are disputed. Some of the claimants are entitled to compensation for disability, and should have expeditious and adequate medical backing for their claims, as well as satisfactory medical care. These claims must often await further investigation before they can be granted, and too often the information required to determine the nature of the illness cannot be obtained, because it was not sought at the proper time. Other claims have no foundation, a diagnosis having been arrived at on the assumption that there was occupational exposure, without benefit of an inquiry which would have disproved the assumption, and without employment of the physical diagnostic methods that would have revealed the real cause of illness.

The point of the foregoing remarks is that the diagnosis of industrial diseases, specifically of lead poisoning, can and should be arrived at by the exercise of the same care and skill that is commonly employed in dealing with other disease processes. There is nothing mysterious or clairvoyant in the diagnostic procedure. The only important difference between ordinary medical practice and that concerned with lead poisoning and many another industrial disease is that the physician is often called upon to substantiate his diagnosis in a court or compensation hearing. He must, therefore, in fairness to his patient and to society, avail himself of accepted methods of procedure, and base his diagnosis on facts rather than assumptions and arbitrary judgments. This makes no greater demand than should be made upon him in his practice in general since it represents only

the usual means by which the existence of one disease process is revealed and others are excluded. A somewhat greater penalty may be exacted, however, for haste or carelessness or lack of skill in dealing with cases that come to litigation, in that some degree of humiliation is likely to be visited upon the physician who is poorly prepared to support his diagnosis.

It is evident from the foregoing comments that there is ample reason for discussing the principles and procedures involved in the diagnosis of lead poisoning, from the viewpoint of both the industrial physician and the private practitioner of medicine, and with an eye to the requirements of good medical and medicolegal practice.

THE MEDICAL HISTORY AND ITS SIGNIFICANCE

The Occupational History

The specific importance of the medical history, in the diagnosis of occupational lead poisoning, relates to the type, severity, and duration of the lead exposure. The facts in this regard will be accessible to the industrial physician, hence no elaboration is required in his case, except to stress the necessity of his being completely familiar with all the operations and activities of the plant, and with the work of the employees. The physician in private practice, on the other hand, is unlikely to have the information which will enable him to appraise the severity of the lead exposure of his patient, and it is not safe for him to assume that the workman who comes to him with complaints can give him an accurate and adequate account of the hazards of his employment. In general, the statements of the patient in this respect provide clues which must be followed up, not facts upon which a judgment can be based.

The physician who has had experience with industrial plants and processes may be able to elicit highly useful information by carefully questioning his patient concerning the details of his work, the exact manner in which he performs it, and the precautions which he takes. He may also learn something of the occurrence of cases of illness in other workmen. He should take note of the entire occupational history recounted by the patient from the time he first began to work, noting other opportunities for exposure to lead or other noxious materials, and without fail he should record the details of the different types of work done by the patient in the present plant or industry, with the dates and the reasons for the changes in employment, if pertinent. The last day of employment, and the actual nature of the work done during the period of several weeks immediately preceding illness, should be inquired into with particular care, so that these matters may be related to the time of onset and the course of the present illness.

The interpretation of the occupational history must be made with care and judgment, It may be, and often is, of little value. It may be necessary to obtain information about the plant at first hand. In fact, it is usually advisable to do so, not only for the purpose of arriving at a sound conclusion in the case in question, but in consideration of the safety of other workmen. If this is not possible or desirable, it may be necessary to check the significance of the lead exposure of the patient by determinations of the lead content of blood and/or urine, interpreting these carefully and remembering that the longer he has been away from his work, the lower will be the lead levels. If the time interval since the last exposure has been long, it may be useful to check the severity of the exposure associated with the patient's occupation by analyzing samples of the blood and urine of other men who have been working uninterruptedly un
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THE PHYSICAL EXAMINAT

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interpretation of the occupational y must be made with care and ent. It may be, and often is, of value. It may be necessary to mation about the plant at hand. In fact, it is usually ad- e to do so, not only for the pur- of arriving at a sound conclusion case in question, but in con- tion of the safety of other work- If this is not possible or de-, it may be necessary to check gnificance of the lead exposure of atient by determinations of the content of blood and/or urine, reting these carefully and remem- that the longer he has been away his work, the lower will be the evels. If the time interval since st exposure has been long, it may eful to check the severity of the re associated with the patient's ation by analyzing samples of the and ... ing of other men who have been working uninterruptedly under the same conditions. The significance of such analytical data will be discussed in detail later, but they are referred to here to point out their specific rôle in the diagnosis, to stress the fact that it is unnecessary to rely upon hearsay evidence as to the severity of a recent lead exposure, and to emphasize the statement previously made that the time to obtain sound information is early in the course of illness when such information is available.

The General Clinical History

The clinical history should contain full information concerning the current illness of the patient, and should be detailed with respect to any prodromal symptoms or immediately precedent illness, the nature of the onset, and the course of development. Care should be exercised not to employ leading questions until the patient has given all the spontaneous information he can provide.

The medical history of the patient must be inquired into fully. Previous illnesses, general abnormalities of the systems, the status of the general health in the past, weight changes, habits with respect to rest, diet, and beverages, are all important, and should be looked into. Only by attention to these details can an unprejudiced and comprehensive picture of the patient's condition and illness, and his opinion about them, be obtained. From these the discerning physician will be able to visualize the symptom complex that presents itself, and to establish its relationship to any previous pattern of disease, if such has existed.

THE PHYSICAL EXAMINATION

The physical examination should be made carefully and comprehensively, in the full recognition of three important facts, namely-(1) that the physical signs of abnormal lead absorption are few at most, (2) that the clinical history tory as given by the patient may be incomplete or otherwise open to misinterpretation, and (3) that the worker in a lead trade is quite as subject to other occupational intoxications and to non-occupational diseases as other persons. The symptoms of uncomplicated lead poisoning are most likely to attract the attention of the examiner to the gastroenteric tract as the focal point for differential diagnosis; somewhat less frequently involvement of the neuromuscular structures may be subjectively noted as weakness, pain (arthralgia or myalgia), or some type of dysfunction, and shown objectively by abnormal reflexes, myotatic irritability, weakness or paralysis; rarely, there may be symptomatic evidence of cerebral effects, the differential diagnosis of which always presents difficulties. It is obvious from the mere mention of these three most distinct types of lead intoxication, that care must be taken to exclude other disease processes that induce direct or indirect effects upon the gastroenteric tract, the peripheral nerves, and the central nervous system. A cursory examination in which attention is given only to certain signs which are commonly believed to be more or less specific of lead intoxication, is therefore inadequate, and is unworthy of the training and skill of a competent and conscientious physician.

With special reference to signs of lead absorption, due care should be given to the examination of the mouth. The condition of the teeth and gums should be noted and described, and the presence or absence of a blue deposit in the gingival margin should be determined. There should be no doubt on this score, but if there is doubt, proper steps should be taken to resolve it. The inexperienced examiner may confuse the bluish line of congestion in chronic gingivitis with a " lead line," and so report a " lead line " when none is present. (In this connection, it is

pertinent to call attention to this not infrequent error on the part of dentists, some of whom appear to believe erroneously that a severe and intractable gingivitis in a workman in an alleged lead trade is in itself the result of lead absorption.) It may happen that the discolored surface of a tooth shows through the edge of the gum and resembles a " lead line." Occasionally in the case of Negroes and certain other dark-skinned peoples, the normal pigment deposits are so located as to simulate lead deposits in the gum. Moreover, other metals that form a black sulfide may be deposited in the gums; bismuth is especially to be taken into account, since its therapeutic use is increasingly frequent. The elimination of all these possibilities for error must be accomplished. The use of a hand lens and excellent illumination is often necessary. The effects of gingival congestion can be offset by gentle pressure with a transparent applicator (e.g., glass slide). A lead line, if present, will show up as finely punctate bluish-black deposits in the gum tissue. The localized discoloration of a tooth may be counteracted by mechanical removal of the brown or black deposit, or by interposing a thin white instrument between the surface of the tooth and the gum. The normal pigmentation of the oral mucous membrane may be identified by its appearance and its location, since it is usually yellowish-brown in color, and is rarely found on the lingual side of the gum tissue. The latter is a fortunate circumstance, since the most frequent site for the early appearance of a " lead line " is in the extreme edge of the gum on the lingual side opposite the lower bicuspids and molars. Deposits of bismuth sulfide must also be differentiated from those of lead sulfide. Here also the medical history of the patient may assist greatly, but it may be necessary to resort to analysis of the excreta or of the gum tissue itself to determine the source of the depmit.

Other points in the physical examination that merit special attention are concerned with the signs of abnormality of the gastroenteric tract. and the nervous system. The differential diagnosis of abdominal disease is often difficult, but there can be no valid excuse for the frequent assumption that any abdominal pain in a worker in a lead-using industry is lead colic. Careful examination is as necessary as in the case of any other patient.

A neurological examination is an essential part of the diagnostic procedure in all cases in which the peripheral nerves or the central nervous system are involved. A general examination of the cranial and segmental nerves, with respect to sensory and motor responses, can be carried out simply and briefly. Tests for weakness made by opposing the strength of the examiner to that of the corresponding muscle groups of the patient will usually suffice, while observation and palpation will serve to reveal muscle atrophy or its absence. Mental aberrations will have made themselves apparent in the early steps of history taking, as will also abnormalities of speech and emotional response. The neurological picture may require expert interpretation, and, if so, assistance should be sought to the end that a correct conclusion be arrived at and proper treatment instituted.

Physical Signs of Special Importance in Lead Poisoning

Lead intoxication may exist without any of the physical signs *to* which reference is made in the following discussion. Moreover, none of the described signs is specific or pathognomonic of lead poisoning. Nevertheless, so much emphasis has been laid upon them that they deserve special consideration.

1. Pallor-The ashen pallor frequently seen in lead poisoning may or r
be associated with anemia. N
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The skin is likely to be cold an
what clammy, and the nail bed
too pale, may be slightly cyanc
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blood pressure, both systol
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The pallor, therefore, is an e
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2. *Weakness-The* extent of g
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3. *Physical* signs *of abdominal*
colic-When abdominal pain
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seen in lead poisoning may or may not be associated with anemia. No doubt anemia when present contributes something to the lack of color, but the pallor is not the result of injury to the blood or the blood-forming tissues. The skin is blanched, especially in the upper part of the body, i.e., the face (especially the lips) and the upraised hands. The pallor is especially noteworthy in the early morning hours in the ambulatory patient, and in association with colic in the patient in bed. The skin is likely to be cold and somewhat clammy, and the nail beds, if not too pale, may be slightly cyanotic. In the patient with a substantially normal circulatory system (i.e., without obvious evidence of vascular disease or other organic bases for hypertension), the blood pressure, both systolic and diastolic, is low, and the pulse is usually slow. The body temperature, in the uncomplicated case, is also subnormal. The pallor, therefore, is an expression of inadequate peripheral circulation.

2. Weakness-The extent of general or localized muscular weakness is often difficult to determine with accuracy, since so much depends upon the voluntary effort of the patient. Nevertheless, localized muscular weakness in lead poisoning is often demonstrable, and when it is associated either with atrophy or with obvious hypertonus or hypotonus in the muscle, or with a doughy consistency of the muscle on palpation, or with myo-edema, it may be accepted as having objective support. There may be no objective evidence of general muscular weakness or even of poor nutrition, so that the striking feature of the condition is the discrepancy between the muscular development of the patient and his apparent strength when tested.

3. ***Physical signs of abdominal pain and*** colic-When abdominal pain in mild lead poisoning is somewhat vaguely perceived as an unlocalized heaviness or perhaps as a feeling of weight around or below the umbilicus, there are likely to be few if any visible or palpable evidences of abnormality. There may be fecal masses and some tenderness to palpation along the course of the colon.

When a typical episode of lead colic is in progress, the patient is obviously in agonizing pain, is bathed in cold sweat, has a gray-green pallor, and is likely to be doubled up in bed with clenched hands pressing upon his abdomen, or threshing about attempting to find some position which will relieve his pain. At the peak of a spasm he is unable to speak, but can only groan and writhe, straining and bearing down, increasing the abdominal pressure like a woman in labor. Between spasms, examination of the abdomen reveals no evidence of distension, but some suggestion of visible masses in the mid-abdomen (not of the ladder-like type seen in intestinal obstruction). These are doughy and more or less discrete on palpation and are obviously intestinal coils separated by constriction. There is little or no spasm or rigidity of the abdomen between attacks of colic, and the tenderness is not of a type that suggests peritoneal pain. During a spasm the abdomen has a board-like rigidity.

4. Paralyses-Paralysis in lead poisoning in the adult involves the upper extremities primarily, and is usually localized in the extensor groups of the forearm and hand. It may be unilateral or bilateral, and if unilateral, it usually affects the side most used. There may be corresponding extensor lesions of the feet and legs, but this is rare almost to the point of nonexistence in the experience of most present-day industrial physicians. There are few if any sensory changes, and the paralysis is not preceded or accompanied by neuritic pain, but there are associated circulatory changes and changes in the temperature of the skin of the affected part. Vibratory sensibility may be im-

paired, and the acuity of tactile and thermal sensibility may be appreciably diminished, probably by reason of circulatory changes. The extensor reflexes are absent, voluntary movements of extension cannot be carried out, and atrophy of the affected muscles develops promptly to such an extent as to be noted by inspection, palpation, or mensuration.

Extensor weakness, with variable degrees of impairment of voluntary action, may exist for considerable periods of time without ensuing paralysis, or it may develop prior to the onset of paralysis, or it may continue for some time or indefinitely after the disappearance of paralysis. The paralysis may be apparently complete for *a* short time only, to be followed by some return of voluntary motion and perhaps by prompt and complete resumption of normal function and reflex action. On the other hand, some impairment of function and reflex action may continue for weeks or months following a brief period of paralysis. Still another variant is the unabated and permanent persistence of the paralysis. The important characteristics of this type of peripheral neuritis are that it is painless, essentially motor, and limited to the extensor distribution.

5. Physical signs in *lead encephalopathy* -Lead encephalopathy may be characterized at the onset by a heavy stupor followed by coma, with or without convulsions. It may show itself as excitation, confusion, mania, and convulsions, followed by coma. Various combinations of the above features may alternate with each other for variable periods of time, to be followed by recovery or death. The entire picture may be less severe, and of short duration, with headache, dizziness, confusion, and either a troublesome insomnia or some degree of somnolence. At all events it is a diffuse cerebral intoxication in which there are usually signs of increased intracranial pressure. The cerebrospinal fluid may be under moderately or considerably increased pressure, and may show a slight increase in cellular elements and globulin, although the latter changes are features of lead encephalopathy in the child rather than in the adult. The ocular fundi rarely show important changes, but there may be general or localized pallor. The signs of intracranial hemorrhage or of other localized lesions are absent.

LABORATORY DATA

The services of the laboratory should be called upon not to yield the diagnosis, but to supplement the medical history and the results of the physical examination, to the extent that is required by good medical practice and by medicolegal considerations. In view of the prominence that has long been assigned to microscopic blood changes in relation to lead absorption and lead poisoning, the hematological examination should include, at least, enumeration of the erythrocytes and leucocytes, determination of the hemoglobin content, examination of stained films for establishing the relative numbers of various types of leucocytes and for detecting other microscopic abnormalities, such as changes in the shape and size of the erythrocytes, and quantitative estimation of the number of erythrocytes that show some form of basophilic granulation. By this means various blood dyscrasias may be detected, and a diagnosis of lead poisoning will be given support, or rendered doubtful or perhaps untenable. With respect to the examination for basophilic granulation of the erythrocytes or " stippling," it should be pointed out that a report of the finding of " occasional stippled erythrocytes," " a few stippled erythrocytes," or " stippled erythrocytes present" is without significance in either a diagnostic or legal sense. Unless there is some quantitative
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The Diagnostic Significance o
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less there is some quantitative expression which can be related to an established normal standard, such reports are of little or no value.

The value of clinical urinalysis as part of a general diagnostic study of a patient need not be emphasized here. The presence or absence of albumin, sugar, blood, and other cellular elements should be determined, together with any other facts indicated as necessary by the history or the physical examination. Other laboratory procedures may be employed in accordance with the requirements of the case. Analyses for lead carried out upon samples of blood or urine may be indicated, and if the history of lead exposure is uncertain in its meaning, such analyses are likely to be required to substantiate the diagnosis, not only in the mind of the examiner, but also for legal purposes.

Mention must be made of one laboratory procedure that has suffered misuse in relation to the problem of lead absorption in the adult. The roentgenographic evidence of lead deposits in the skeleton of the growing child, while not entirely specific, has given rise to one of the most convenient and expeditious means of detecting lead exposure among children. Unfortunately the metabolic conditions in the adult skeleton are quite different, with the result that no localized deposits of lead yield shadows that can be interpreted. Therefore, unless some new and unforeseen technic is developed, the detection of skeletal lead absorption in the human adult by this means cannot be achieved.

The Diagnostic Significance of Certain Laboratory Results

There has been much confusion and some controversy concerning the significance of the results obtained by the microscopic examination of the blood, and by the analysis of tissues, blood, cerebrospinal fluid, urine, and feces for their lead content. It is advisable, therefore, to point out the limitations in the usefulness of such data, and to clarify their meaning for diagnostic purposes.

1. *Basophilic granulation of erythrocytes, or* " stippling "-The finding of stippled erythrocytes in stained films of the peripheral blood of a patient is not evidence that he has lead poisoning or that he has absorbed abnormal quantities of lead. Stippling of the erythrocytes up to a limit of 800 or even 1,000 per million erythrocytes, may be a normal phenomenon, since the blood of apparently normal, healthy individuals shows stippled erythrocytes in such numbers at times. (This is equivalent to 10 to 12 per fifty oil immersion fields that average 250 erythrocytes per field.) There is considerable variation among individuals and in the same individuals from time to time, and therefore, considerable care must be exercised in the interpretation of results in the individual case. An increase in stippled erythrocytes over the numbers commonly found in normal persons, or over the numbers known to be normal for a given individual, is found in a variety of conditions. Blood destruction from any cause that does not seriously injure the bone marrow, results in an increase in young forms of erythrocytes in the peripheral blood, including reticulocytes and stippled erythrocytes. Thus increased stippling is seen regularly in secondary anemias following hemolytic infections and hemorrhage. Exposure to a number of volatile solvents, among others benzol and gasoline, also gives rise to increases in stippling, as does exposure to radium. In certain of the blood dyscrasias, especially myelogenous leukemia, the number of stippled erythrocytes may be very large. To add to the difficulties of interpretation that follow from the foregoing facts, the individual hematopoietic reponse

to lead absorption shows wide variation. A group of persons with a certain severity of lead exposure can usually be differentiated from another group with greater or lesser severity of exposure on the basis of the numbers of stippled erythrocytes found in blood films made from the respective groups. Even here, however, a large proportion of the results lie within the limits seen in groups of normal persons, and there is no well defined relationship between the extent of the stippling and the severity of the lead exposure in the individual.

Two points of practical importance for diagnostic purposes must be emphasized: (1) some degree of stippling of the erythrocytes is almost certain to be present in the blood during the active period of lead intoxication; (2) the number of stippled erythrocytes found in the blood during an episode of lead intoxication (as differentiated from the period before symptoms of illness are present, or from the period after their subsidence) is likely to be very much greater than can be found generally in the blood of normal persons, or in that of the individual in question during asymptomatic periods. Both of these points require some elaboration.

A very acute type of lead intoxication following promptly upon a massive exposure to lead compounds, such as the acute encephalopathy of tetraethyl lead poisoning, or the acute and perhaps fatal poisoning that follows the ingestion of a single large dose of a lead salt, may induce no microscopic changes in the blood during the critical period of illness. (Usually the blood changes come later if the patient survives.) *Aside from these rare cases, the occurrence of stippling in active lead* **poisoning** *is so regular that the failure to find it, when one makes use of adequate methods of staining and examination* **of** *the blood, should create grave doubt that lead is the agent responsible for an intoxication that is under study.*

In a large proportion of cases of lead poisoning, a large increase in the number of stippled erythrocytes in the peripheral circulation occurs in coincidence with the onset of symptoms, or perhaps immediately preceding the onset. This abrupt rise above the previous normal level ranges from 700 to 800 stippled erythrocytes per million erythrocytes to 35,000 or even 40,000 stippled erythrocytes per million, this variation depending more upon differences in individual response, apparently, than upon differences in the rate and magnitude of the lead absorption. There is also a prompt and fairly rapid decrease in the numbers of stippled erythrocytes as the symptoms of intoxication subside.

It follows from these facts that the examination of blood films for diagnostic purposes should be made during the episode of intoxication in order to have diagnostic value, and, furthermore, that neither the presence nor the absence of stippled erythrocytes is of diagnostic importance (in relation to lead poisoning) at any other time, unless the numbers present exceed the upper limit of the normal range (800 to 1,000 stippled erythrocytes per million erythrocytes).

2. Lead in tissues, blood, cerebrospinal fluid urine, *and* feces-In view of the information that is available as to the concentration of lead in the tissues, the blood and the excreta of human beings under a variety of environmental and occupational conditions, it is clear that an increase in the lead concentration of these materials, above the range of normal values, indicates the occurrence of abnormal exposure to lead compounds. (Whether or not such exposure has an occupational origin must be determined by other means.) Moreover, the degree of the potential hazard of the exposure is indicated by the ex-

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	Liver	*Spleen*	*Kid*
Minimum	***0.04***	0.01	0.
Maximum	0.28	0.07	0.
Arith. Mean	0.12	***0.03***	0.

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tent of the discrepancy between normal values and those found in the case under examination, i.e., high lead concentrations indicate severe exposures. However, the existence of lead poisoning in the given case is not demonstrated by lead analyses, either on the basis of the quantities of lead found in the blood, the urine, or the body as a whole, or by the manner in which the lead is distributed in the tissues of the body. (On the other hand, the non-existence of lead poisoning may be clearly demonstrated by finding normal lead concentrations in the blood, urine, or tissues, in close time relationship to a period of alleged exposure.) *Abnormal lead findings, therefore, mean only that there has been an abnormal lead absorption, and by this means they tend to reveal the existence and the degree of severity* of *lead exposure.* Any attempt to interpret such results otherwise, in the present state of our information, is unwarranted.

a. *Lead* in *the* tissues-Attempts have been made to determine the extent of the lead absorption of patients by the analysis of small samples of the skin. The results of such analyses are likely to be misleading, however, because of the variable behavior of the skin in absorbing lead in competition with other tissues of the body, and also because the factor of external contamination of the skin and its appendages is difficult to eliminate satisfactorily. Suffice it here to say that the background of information concerning the significance of lead in the blood and urine has been laid securely, and these, therefore, are the preferable materials to analyze during the life of the patient

It has also been suggested that the analysis of vital teeth may give satisfactory evidence of the severity of the lead exposure of individuals during the period of weeks or months preceding the removal of such teeth. However, the evidence on which the interpretation of such analytical results must be made is not adequate at present, and moreover, information from this source could scarcely be obtained justifiably, unless the removal of teeth was advisable for other reasons.

The practical diagnostic usefulness of lead determinations on the solid tissues of the body is limited to post-mortem examination. By comparison of the analytical results with those obtained on the tissues of unexposed persons, it is possible to establish the general magnitude of the lead absorption of the deceased during the period of weeks or months preceding death. The range of normal lead concentrations in the various tissues of the adult human being has not been established in an entirely comprehensive manner, and therefore slight deviations should be interpreted with caution. Nevertheless, the following figures on the tissues of North Americans with no occupational or unusual lead exposure, may be used as the basis of comparison. The concentrations are given in milligrams of lead per 100 grams of fresh or formalin-fixed tissue.

	Liver	*Spleen*	*Kidney*	*Heart*	*Lung*	*Brain*	*Muscle*	*Flat Bone*	*Long Bone*
Minimum	0.04	0.01	0.015	0.01–	0.01	0.01	0.01–	0.21	0.67
Maximum	0.28	0.07	0.16	0.07	0.06	0.09	0.17	1.11	3.59
Arith. Mean	0.12	0.03	0.05	0.03	0.03	0.04	0.03	0.65	1.78

Persons who have been moderately or severely exposed to lead compounds for a considerable period immediately preceding death will have much higher lead concentrations in all of these tissues. If the exposure to inorganic lead compounds has been brief and

severe, the elevation of the lead concentrations in the soft tissues above normal levels will be proportionately greater than that in the bones, although greater absolute concentrations of lead will likely be found in the bones, except in acute and promptly fatal poisoning (such as follows the ingestion of a fatal dose of a soluble lead compound). However, if the exposure has been prolonged, the skeletal tissues will show the greatest increase; while the lead concentration in the soft tissues, especially the liver and kidneys, will be only moderately increased (two to eight times the normal levels).

It should be borne in mind that if the lead exposure of an individual had ceased to exist long before his death (i.e., one year or more), the analytical findings in his case would likely be within the normal range or so near it as to be of little or no value in appraising the lead exposure. There might well be some elevation of the lead concentration in the skeleton, and especially in the long bones, but even this elevation would not be great as compared with that found when death occurs shortly after the cessation of hazardous lead exposure, and it would not be associated with high lead concentrations in the tissues of the body in general.

The unusual distribution of lead compounds in acute fatal poisoning from tetraethyl lead and similar compounds justifies brief consideration. If death has occurred within a week or 10 days following a single brief exposure, high concentrations of lead will be found in the liver, kidney, brain, suprarenal gland, and adipose tissue, and to a lesser degree in the other soft tissues, with but slight, perhaps negligible, elevation of the lead concentration in the osseous tissues. If exposure to these compounds has occurred over a period of months just prior to death, the pattern of the lead distribution will resemble that resulting from the absorption of inorganic lead compounds modified by the effects of such absorption of tetraethyl lead as may have occurred during the 2 or 3 weeks preceding death.

From the foregoing remarks, which cannot be expanded to cover all of the variations in the types, the severity, and the time relationships of lead exposure, it will be apparent that the interpretation of the analytical data must be made with considerable caution. The diagnosis of death from lead poisoning, or the conclusion that lead was a contributory factor in a fatal illness, cannot be arrived at merely from analytical results on the tissues, since the concentration of lead in the tissues can be, and not infrequently is, considerably increased above normal levels without demonstrable harmful effects. The actual occurrence of lead intoxication can be established only on the basis of observations made before death occurred, that provide satisfactory clinical evidence of the existence of such disease. The analytical data can only reveal the general magnitude of the lead exposure that existed; they may demonstrate that the lead absorption was sufficient to be compatible with the diagnosis of lead intoxication, or they may prove that the lead absorption was wholly insignificant and that the diagnosis of lead intoxication is untenable.

b. *Lead in the cerebrospinal fluid*- The relationship between the general level of lead absorption and the concentration of lead in the cerebrospinal fluid has not been determined with sufficient accuracy and in a sufficient number of normal and exposed cases to provide a proper basis for the interpretation of analytical results. Other objections to the choice of this body fluid for lead analysis are that it cannot always be obtained, the quantities available for analysis are small, while the lead concentrations are quite low, and the

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opportunities for contamination of the sample in process of collection are great. Special chemically clean containers and special spinal-puncture needles that have been subjected to special methods of cleaning and sterilization must be employed. (When such precautions have been taken, the lead concentration in the cerebrospinal fluid has rarely been found to exceed 0.01 mg. Ph per 100 ml. in the case of persons severely exposed to lead.) Add to these considerations the fact that no relationship has been or seems likely to be established between the lead concentration in the brain or blood and that in the spinal fluid, and the case against the choice of this fluid for analytic examination seems to be complete.

c. Lead in ***the*** feces-Lead analyses on the feces are of value only during the period of lead exposure or within the period of hours or days required for emptying the gastroenteric tract after the discontinuance of the exposure. Analysis of feces obtained on the day after a typical working day gives exceedingly useful information as to the severity of the conditions of exposure, for reasons that have been discussed in an earlier section of this report. It conveys no information at all concerning the lead content of the tissues of the body, and because of the appreciable and variable lead content of the food which may have been consumed, it fails to portray the magnitude of the true alimentary lead excretion. Accordingly this material should be chosen for analysis only when there is some reason for desiring to determine the alimentary intake of lead, whether through deposition of inhaled dusts in the nasopharynx or by ingestion.

d. ***Lead*** in ***the*** blood-The analysis of the blood for lead gives invaluable information as to the general level of the lead exposure that has recently been experienced. A previous section of this report has described the precautions that must be taken in the collection of samples. It must be reëmphasized, however, that only grossly misleading information can be obtained by the analysis of samples taken with less than adequate care. Moreover, analyses should be made only by well trained and experienced chemists, who have carefully designed and well equipped laboratories, and who carry out such analyses frequently, regularly checking their reagents, equipment, and surroundings.

Blood lead concentrations in the individual are subject to but little variation from hour to hour, except in response to brief, intense lead exposure, and therefore samples may be obtained for analysis at any time of day. The normal lead concentrations in the blood, as previously indicated, range from 0.01 to 0.06 mg. per 100 gm. of whole blood, with only occasional values in excess of 0.04 mg. Results in excess of 0.07 mg. per 100 gm. of whole blood are indicative of lead exposure within some recent period, while results in excess of 0.10 mg. per 100 gm. show that the exposure has been considerable. Results approximating 0.50 mg. per 100 gm. are unusual but may occur when the industrial (or other) exposure is quite severe. Results much above this level are open to question as to their accuracy, and except in very rare instances of overwhelming accidental exposure, results in excess of 1.00 mg. per 100 gm. must be regarded as evidence of contamination of the sample in the process of collection or analysis. Doubtful results should be checked by the analysis of additional samples, or by analysis of the urine, or by both means.

The lead concentration in the blood diminishes after the cessation of exposure, at first at a comparatively rapid rate and then more slowly. The length of time required for the reduction to normal levels depends upon the extent

and the duration of the lead absorption. Interpretation of the findings must be made, therefore, on the basis of dependable information as to the length of the exposure and the time interval since the termination of the exposure.

e. Lead in *the* urine-The results of analyses for lead carried out on properly collected samples of urine are by far the most valuable data by which to judge the severity of the lead exposure of a patient. This is true not only because of the comprehensive character of the available information on the lead content of the urine under different conditions, but also because the change in the rate of the urinary lead excretion in response to lead absorption is greater proportionately than the change in the lead, concentration of the blood.

Urine samples should be collected under conditions that are as nearly physiological as may be possible under the circumstances. If feasible, therapeutic procedures should be avoided during periods in which samples are being collected, and specifically attempts to modify the excretion of lead or water by therapeutic or artificial means should be avoided. The best evidence of the severity of the precedent lead exposure of a patient is the rate, of his urinary lead excretion under physiological conditions. The urine must be collected with great care against contamination. The methods employed generally in hospitals for the collection of samples of urine cannot be used in collecting samples for lead analyses. The urine must be voided into containers that are chemically clean, and it must be protected at every point against contamination with dusts or any foreign material until it reaches the analytical laboratory. Rubber or metal catheters that are to be used for the collection of samples must first be shown to be free of lead in their composition and must be cleaned and sterilized by methods that will prevent their contamination by even minute traces of lead. In general in diagnostic work, it is desirable to obtain multiple samples, and if the results are high, this is imperative. The opportunities for contamination of samples in their collection are so numerous that unless detailed precautions are taken samples will regularly be contaminated with many times the quantities of lead that are actually voided in the urine. For this reason these matters must not be left to chance, nor should complete confidence be placed in the issuance of verbal or written instructions. Supervision is required. Even so, it is advisable to check one sample against another, and this can be done conveniently by taking samples of blood and spot samples of urine simultaneously. If analyses of the blood and urine give concordant results (in the physiological sense) the chance that error has occurred in the collection of the samples is slight. The importance of these points may be appreciated by noting certain published results which by inspection alone may be seen to have no physiological significance. The range of urinary lead excretion is somewhat limited; lead concentrations exceeding 0.50 mg. per liter of urine are quite infrequent and are associated only with unusually severe types of lead exposure; concentrations in excess of 1.00 mg. per l. have been found only with the greatest rarity, in association with brief massive exposures. In general, therefore, unusually and excessively high results indicate that the samples were contaminated during their collection or analysis; such results must have corroborative support before they can be accepted for practical or medicolegal purposes.

When it is feasible to do so, urine samples of large volume should be collected so as to avoid the diurnal variations in lead concentration. It may be desirable to express the lead excretion in terms of time, in which case, should be collected for 24 hour or multiples thereof. General entirely satisfactory to give re the basis of the lead conce: Small samples (spot samples proximately 100 ml.) may be e with satisfactory results if care to avoid either highly concent dilute urine (samples of averag specific gravity will be sufficient sentative) . They have the ad which is sometimes important, t can be voided directly into th container in the presence of aminer, and if adequate care against the inclusion of dust an contact of the stopper of the c with any foreign object during lection, they are above any s of having been contaminated reaching the laboratory.

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in terms of time, in which case, samples should be collected for 24 hour periods or multiples thereof. Generally, it is entirely satisfactory to give results on the basis of the lead concentration. Small samples (spot samples of approximately 100 ml.) may be employed with satisfactory results if care is taken to avoid either highly concentrated or dilute urine (samples of average normal specific gravity will be sufficiently representative). They have the advantage, which is sometimes important, that they can be voided directly into the proper container in the presence of the examiner, and if adequate care is taken against the inclusion of dust and against contact of the stopper of the container with any foreign object during the collection, they are above any suspicion of having been contaminated before reaching the laboratory.

The upper limit of the normal lead concentration in the urine approximates 0.08 mg. per 1. for samples of 1 1. or more, and 0.12 mg. per 1. for spot samples of about 100 ml. in volume (allowing for some degree of concentration of the sample). Lead in concentrations below 0.15 mg. per 1. has doubtful significance, especially if the lead exposure had continued up to or nearly to the date on which the sample of urine was obtained. Hazardous lead exposure usually induces lead excretion at levels above 0.15 mg. per l., and the large proportion of cases of lead poisoning examined during an episode of intoxication show concentrations between 0.15 and 0.30 mg. per 1. As pointed out previously, the total range of urinary lead excretion is limited. Concentrations in excess of 0.50 mg. of lead per 1. of urine are encountered infrequently, and always require verification by additional analyses.

The lead content of the urine diminishes fairly rapidly at first and then gradually for some weeks or months or even years after discontinuance of exposure, the slope and duration of the decrease depending upon the severity and duration of the lead absorption. Some experience and careful consideration of the details of the occupational exposure are needed, therefore, for adequate interpretation of analytical data. The time interval between the collection of the sample and the last day of exposure is especially important in relation to results of intermediate or borderline significance. It must be reiterated for emphasis, that such data may be employed only to interpret the severity of the lead exposure, and not to determine the existence or the severity of lead intoxication. There is no level of urinary lead excretion which, in itself, is certainly indicative of illness in a patient.

CLINICAL TYPES OF LEAD POISONING

The onset of symptoms of actual illness in lead poisoning is usually abrupt, although careful inquiry may establish the occurrence of certain prodromal symptoms. For this reason the term " chronic lead poisoning " is in large part a misnomer, which has arisen from the fact that episodes of acute intoxication may recur in the same individual under suitable circumstances, and from the assumption that some degree of illness or intoxication must exist in the intervals between episodes. The onset may be somewhat insidious, but in general it is related by the victim to a particular date, and only rarely has there been slowly developing illness or disability for more than a few days or perhaps a few weeks, if the conditions of employment are such that the employee is free to make complaints, and if the medical care and supervision is effective. " Chronic lead poisoning," so-called, in which the employee continues in his employment despite repeated mild episodes of lead poisoning, is neglected lead poisoning. It is increasingly infrequent in its occurence

in well managed and supervised industry, and the term should disappear from the nomenclature of the industrial physician.

In order to clarify further some of the terminology that has been a source of confusion, it should be pointed out that " lead absorption " is not a vague subclinical type of lead intoxication. If toxic effects of lead absorption can be recognized as existent, the condition should be referred to as lead poisoning or *lead intoxication*. If, on the other hand, an examination gives evidence that lead has been absorbed into the body, either in normal or abnormal quantities, yet without any demonstrable or actual illness, there should be no implication that illness exists. 'The facts in the matter may not be easily determined, but this difficulty cannot be resolved under cover of specious terms such as " lead absorption," " latent lead poisoning," or " subclinical lead poisoning." Either there is evidence of poisoning or else there is not. In this sense it is not misleading to refer to lead poisoning as prodromal or incipient or well established, or to define its severity as mild, sub-acute, or acute.

The clinical types of lead poisoning, as referred to herein, are not classified on the basis of their duration or their severity, except in so far as these are incidental, but on the basis of the systems that are most obviously involved. In these terms, three more or less distinct types of lead poisoning are seen currently in American industry, plus mixed types that combine various features of two or perhaps all three. The three types are, (1) that involving the alinientarv tract primarily, (2) that involving the' neuro-'motor mechanisms chiefly, and (3) that affecting most seriously the brain.

The Alimentary Type

This is by far the most frequent type of industrial lead poisoning. It is characterized by intermittent abdominal discomfort, with a feeling of heaviness in the region around or below the umbilicus. It culminates in frank colic in the more severe cases. There is usually obstinate constipation at the onset and perhaps for some days or weeks before the onset. Rarely there is a brief period of diarrhea at the onset, followed by constipation. Almost always there is constipation after the illness is fully developed. There is loss of appetite, especially in the morning hours, and frequently nausea and vomiting. There is likely to be a bad taste in the mouth, occasionally described as " metallic." When there is hunger, there may be a feeling of fullness after taking a little food, and it is at this time or after taking beverages, that vomiting is most likely to occur. The appetite is likely also to be capricious. There is lassitude, especially upon rising from sleep, often diminishing during the day or after moving about. This is especially prominent if there has been insomnia or disturbed sleep. General weakness (usually seen as inability to carry on the accustomed work) will exist and to a large degree will be proportional to the interference with appetite, digestion, and rest. There is likely to be some arthralgia, and there may be some general stiffness and aching or perhaps localized myalgia. Dizziness and headache may also be cause for complaint.

Associated with these symptoms there will often be a gingival lead line as evidence of abnormal lead absorption, if there is pyorrhea. There may be signs of malnutrition, pallor, ill-defined abdominal tenderness on palpation, or the signs associated with frank colic as previously described.

There will be basophilic stippling of the erythrocytes, and usually to an extent that is clearly above the range of normal values. There may be a re-

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will be basophilic stippling of rocytes, and usually to an ex- is clearly above the range of values. There may be a reduced erythrocyte count and a reduction in the hemoglobin content of the blood, but the findings in this regard may be entirely within normal limits. The urine will be acid in reaction in the uncomplicated case, and there may be a trace of albumin, although this does not follow necessarily. The lead content of the blood and the urine will be elevated, the concentration in the blood being in excess of 0.07 mg. per 100 gm. of whole blood, that of the urine being at least 0.12 mg. per 1. (in a 24 hour sample) in mild cases, and usually well above 0.15 mg. per 1.

The Neuromuscular Type

This type of lead poisoning differs from that described above in that the gastroenteric symptoms, although not wholly absent, are less disturbing, while the chief complaint arises from the weakness, or perhaps the paralysis, of the extensor muscle groups of the forearm and hands. Arthralgia, myalgia, aching and stiffness of other muscle groups is likely to be more severe in this type of intoxication than in the alimentary type, and headache, vertigo, insomnia and disturbed sleep may be quite prominent, in keeping with the greater severity of the lead exposure and absorption that are usually responsible for this type of lead poisoning. Weakness of the extensor muscles is apt to appear some weeks before true palsy develops. This is important inasmuch as recovery under proper treatment from such weakness is a matter of weeks rather than months as in the case of palsy. True lead palsy is uncommon in present-day American industry. It is usually the result of prolonged and comparatively severe lead exposure, and the clinical history in most cases gives evidence of repeated episodes of intoxication of a milder type.

The physical findings in cases of this type have been discussed

If the case is seen at the onset of the disability that causes interruption of work, the laboratory findings will correspond to those described under the alimentary type. The blood changes, with respect to reduction of the erythrocyte count and the hemoglobin content, are likely to be much greater, and the lead concentration in both blood and urine is certain to be well above borderline values.

The Encephalopathic Type

Cerebral lead intoxication is the most serious manifestation of lead poisoning, and also the rarest, except in the case of children, among whom it is the prevalent type. It occurs in the adult only as the consequence of rapid and heavy lead absorption, and therefore, as the hazards of the lead trades are brought under more effective control, it tends more and more to disappear. By reason of the physical and chemical properties of certain organic lead compounds, of which tetraethyl lead is the only commercially important representative at present, absorption of these compounds into the body and specifically into the central nervous system occurs with rapidity, and therefore cerebral lead poisoning is the only type that is seen. In the case of the inorganic lead compounds, comparable concentrations of lead are absorbed into the brain only under the severest conditions of exposure to lead by inhalation of vapor, fume, or dusts.

The onset of lead encephalopathy is usually abrupt, although the severity of the cerebral involvement may progress over a period of days. The illness of the patient is usually grave from the onset. The physical findings have been discussed previously and need not be repeated. The laboratory findings do not differ from those described in other types of lead poisoning, except that the lead concentrations in the blood and urine will be higher

than they are generally found to be in other types of lead poisoning, in correspondence with the greater severity of exposure required to induce this serious and often fatal form of the disease. (In tetraethyl lead encephalopathy, as pointed out previously, stippling and other microscopic blood changes are commonly absent.)

Mixed Types of Lead Poisoning and Unusual Lesions

Industrial lead poisoning as it is commonly seen, is to some degree a composite of all types referred to above. Some degree of involvement of the gastroenteric tract is almost always seen (except in tetraethyl lead poisoning, in which constipation, abdominal discomfort, and colic do not occur to any noteworthy degree). Indeed, 90 per cent or more of all cases (other than those caused by tetraethyl lead) have abdominal pain as their chief complaint, while constipation and loss of appetite are almost always present. Careful questioning of patients also shows that mild cerebral symptoms occur in all types of cases with considerable frequency. Insomnia is one of the striking features of early encephalopathy. It is not uncommon in other types of lead poisoning, quite without relation to the disturbing effects of pain. Headache, vertigo, and visual disturbances also occur in all types of saturnism. Thus, there is evidence that the toxic effects of lead are fairly diffuse and that there are usually functional disturbances of the alimentary tract, the muscular apparatus, the nervous system, and the blood-forming tissues, in any toxic episode.

Certain lesions which are of importance because of the unusual degree of disability which they induce, should be mentioned in passing. Optic neuritis, for example, in both intra-ocular and retro-bulbar forms, has occurred in lead intoxication. It is rare and many physicians with wide experience in the lead trades have never seen a case. The causative factor in optic neuritis is often uncertain, and there can certainly be no justification for attributing this lesion to the effects of lead absorption, unless there are other evidences of significant lead absorption and of lead poisoning.

Paralyses involving the extrinsic muscles of the eyes are seen occasionally, and weakness of these muscles with visual disturbance is not rare in association with lead encephalopathy.

Retinal hemorrhage may also occur in lead poisoning, in association with other symptoms and signs af lead intoxication.

A series of other neurological lesions such as those of multiple sclerosis, certain types of progressive muscular atrophy with and without cord lesions, and various other lesions of the spinal cord, have been attributed to the toxic effects of lead absorption, from time to time, if for no other reason than that there was actual or alleged exposure to lead compounds at the time of their appearance, and that their etiologic background was obscure. These will be referred to later in dealing with the differential diagnosis.

Differential Diagnosis

The diagnosis of lead poisoning is arrived at on the basis of (1) the facts with respect to the lead exposure, (2) the clinical picture of the illness as revealed by the patient's history and symptoms and by the physician's careful physical examination, and (3) the results of laboratory procedures that confirm the potentially hazardous character of the patient's exposure to lead compounds. Obviously the exclusion of other disease processes from complicity in the clinical picture can be accomplished only by considering the entire clinical status of the patient, so that the foregoing statement represents an over-simplification of the pr
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IFFERENTIAL DIAGNOSIS

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over-simplification of the procedure. For this reason it seems necessary to deal briefly with a number of lesions that give rise to symptoms and physical signs which resemble those of lead poisoning to some degree, and which if not recognized may result disastrously.

The alimentary type of plumbism must first be differentiated from acute lesions of the gastroenteric tract that may require prompt surgical intervention, chiefly acute appendicitis, acute cholecystitis and cholelithiasis, acute renal colic, gastric or duodenal ulcer with perforation, intestinal obstruction, and acute pancreatitis. Here differentiation is usually made with little difficulty but it is to be remembered that the neglect of a surgical condition is fraught with more serious consequences to the patient than the failure to identify lead colic, and on this account it is better to err on the side of surgical exploration, than to give undue weight to the apparent significance of the lead exposure. The diagnosis of acute surgical lesions of the abdomen is dealt with adequately in standard works and requires no extensive consideration here. It is referred to merely to indicate the necessity for careful study of the condition that presents itself in the lead worker. As indicated previously, the pain of lead colic is intermittent, and in the intervals between acute spasm it is usually relieved by firm pressure, in contradistinction to acute inflammatory or obstructive lesions. The absence of localized or general involuntary rectus muscle spasm and of "rebound" tenderness at this time is highly significant. Moreover, the pain radiates but little, and therefore, is differentiated from characteristic gall bladder disease or renal colic. The pain of lead colic is also relieved promptly, in most instances, by the intravenous administration of calcium chloride or calcium gluconate in appropriate dosage, a procedure that is harmless in surgical conditions, and which, therefore, may be employed for differential diagnosis as well as for therapy. Investigation of the sclera, skin, and blood, for jaundice, and of the urine for bile or blood, and the microscopic examination of the blood, will usually complete the differentiation. Jaundice is seen infrequently in present-day industrial lead poisoning. Only neglected or far advanced cases, with extensive blood destruction, have jaundice, and an erythrocyte count and a stained blood film will provide the required information here. A normal or only slightly elevated leucocyte count with a normal or practically normal differential count gives further evidence of the absence of inflammatory lesions, as does also the normal or subnormal temperature. Hematuria is almost never seen in lead colic. Its occurrence militates strongly in favor of renal colic as the source of pain.

The elimination of peptic ulcer may usually be made by the medical history and by the localization of the pain, while perforation can be differentiated by the suddenness of its onset and the subsequent continuous pain. (An exception to this statement must be made in the case of posterior perforation which often brings relief of previous pain.)

Intestinal obstruction in the lead worker provides a difficult diagnostic problem. Here the blood picture may assist, and if there is no stippling, lead colic may be eliminated. The vomiting is more persistent and voluminous in obstruction, and the changes in blood chemistry will usually clinch the diagnosis. In this as well as in other abdominal conditions, roentgenograms may give prompt and specific information concerning the locus and nature of the lesion.

Mention of coronary occlusion as requiring differentiation need only be made in passing. Tabetic crises may also resemble lead colic but are dif-

ferentiated by the characteristic neurological signs. It is sometimes difficult to differentiate between the milder types of colic and the discomfort associated with spasticity of the colon. In such instances the history and the blood picture will usually answer the question. Lead analyses may be required, however, and in some cases a decision may rest upon the results of therapy.

If the severity of the lead exposure is in question, lead analyses on the blood and/or urine will provide useful information. Results within the normal range rule out lead poisoning. On the other hand, the mere existence of abnormal findings, with respect to lead, must, not be given undue weight, for they do not, in themselves, carry the implication of lead intoxication, especially among persons known to be exposed to lead compounds in their work. Therefore, the appropriate procedures for differential diagnosis must be carried out.

The differential diagnosis of polyneuritis is manifestly difficult. In contradistinction to neuritis induced by a host of agents, including other metals, arsenic, viruses, infections, malnutrition, and alcoholism, certain features tend to characterize lead neuritis. First, is the site of involvement, which in the case of lead is remarkably constant; second, is the lack of sensory involvement, including the absence of neuritic pain; and third, is the existence of a history of significant exposure to lead. Lead neuritis occurs as the consequence of severe and usually prolonged lead exposure. Other symptoms of lead intoxication are likely to be present and usually have existed from time to time over a period of weeks or months. Signs of lead absorption in the form of a lead line on the gums or high lead levels in the blood and urine are certain to be present at the onset, and the hematologic changes are usually prominent. Because of the generally prolonged character of the severe lead exposure some degree of anemia is usually found and the stippling of the erythrocytes, while perhaps not so extensive as that associated with a sudden attack of lead colic, is significantly increased above normal values at the time of onset. In uncomplicated lead neuritis there is a normal or subnormal temperature.

Lead encephalopathy must be differentiated from neurosyphilis, cerebral arteriosclerosis, diffuse encephalitis due to viruses and infections, from unlocalized brain tumors, from other types of cerebral intoxication including those caused by alcoholism, over-dosage with bromides and hypnotic drugs such as barbital and chloral, from exposure to carbon monoxide and mercury, from uremia, and from the cerebral manifestations of pellagra. The diagnosis may usually be made without great difficulty by careful consideration of the occupational and medical history, by observation of the ***course*** of the disease, and by well chosen laboratory studies. Unquestionably severe lead exposure is required to cause lead encephalopathy in the adult, and if it can be established that the exposure was slight or of borderline significance, lead can be eliminated as the etiologic factor in a case under consideration. The severity of the lead exposure can be determined by lead analyses if not otherwise. The lead concentrations in the blood and urine, to be of any significance in relation to cerebral involvement at the time of onset in the adult, must be well above normal or threshold levels. The cerebrospinal fluid shows little abnormality other than an inconstant increase in its pressure. Microscopic blood findings may be negligible ii the exposure was brief and overwhelming. Otherwise stippling of the erythrocytes will be found, with or without anemia. The importance of precise knowledge of the exposure of the individual to lead or to other t terials cannot be overempha: connection with this type poisoning. ***Assumptions*** *concer* ***exposure are unjustified and a*** *(* ***made without*** *benefit* ***of*** *depen* formation concerning ***such*** *exp* *its effects* ***as revealed by*** *an* ***tissues, blood,*** *or excreta,* ***is a irresponsibility*** on ***the part physician, except as it*** *represen* ***a working*** impression.

Reference has been made p to certain lesions of the central system which have an obscu logical background, and which fore, are likely to be explained tical purposes in a given cas basis of any toxic or infectio on which suspicion may happe The occurrence of such lesions which may be mentioned sclerosis, combined scleroses spinal cord, certain other un lesions of the spinal cord, anc forms of progressive muscular in a lead worker presents a problem. Indeed, any diseas known origin is likely to creat lem. (A case of typica myelogenous leukemia has bee to be responsible for a heated legal controversy when it ch develop in a worker allegedly to lead.)

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Reference has been made previously to certain lesions of the central nervous system which have an obscure etiological background, and which, therefore, are likely to be explained for practical purposes in a given case on the basis of any toxic or infectious agent on which suspicion may happen to fall. The occurrence of such lesions (among which may be mentioned multiple sclerosis, combined scleroses of the spinal cord, certain other unclassified lesions of the spinal cord, and various forms of progressive muscular atrophy) in a lead worker presents a complex problem. Indeed, any disease of unknown origin is likely to create a problem. (A case of typical acute myelogenous leukemia has been known to be responsible for a heated medico-legal controversy when it chanced to develop in a worker allegedly exposed to lead.)

Clearly it is not always possible to determine the effects of lead absorption in exciting or contributing to the development of disease of uncertain origin, and it is proper and necessary to give the unfortunate and disabled workman the benefit of any reasonable doubt in such cases. Nevertheless, there should be valid evidence of abnormal lead absorption and some of the characteristic effects of lead intoxication, on which to base the opinion that the unusual effect in question could reasonably be explained as atypical lead poisoning. Certainly there should be even clearer evidence of significant exposure to lead in the atypical or bizarre case, than that required to support the diagnosis in the usual or typical case.

This discussion would be incomplete without some reference to the problem of the malingerer, and especially the malingerer who has had the benefit of more or less expert advice in the preparation and presentation of his story. True malingering is rare, but its technic ranges all the way from the indefinitely continued complaints of inability to work on the part of a man who does not wish to earn his livelihood, to the deliberate fraudulent design of an individual who induces or prolongs his lead intoxication by taking repeated doses of lead compounds. The recognition of the latter situation is not difficult, if the patient is suspected and put under close observation, for despite the best of advice, his efforts are likely to be too clumsy for success.

The former problem is not so easily solved, since the interpretation of purely subjective symptoms may well be difficult, and since neuroses are not unknown among the sequelae of lead intoxication.

No rule or set of technical procedures can be prescribed that will lead to the recognition of all types of malingering. Cases open to such suspicion should be studied carefully and with open mind, in the attempt to discover and remove obscure causes of illness, and to get to the bottom of the problem. Expert advice may be required to arrive at a decision concerning such cases. When a decision has been reached, it should be acted upon, openly and decisively, in order that the issue may be brought to a conclusion. By such means the diagnosis may be tested and confirmed or found wanting. By such means also neuroses may be prevented and cured in certain instances and recognized as such in others.

THE PROBLEM OF ASSOCIATED DISEASE

The existence of complicating disease in association with lead poisoning may not be ignored, either from the viewpoint of organic disease as a contributing factor in susceptibility to lead poisoning, or in relation to the equally vexed problem of the influence of lead intoxication on the progress and outcome of chronic or acute illness of other types. In so far as the problem of susceptibility is concerned, one of the functions of preëmployment and periodic examinations is to recognize the existence and development of organic disease processes and to place the victims of such disease in occupations which do not involve potentially hazardous exposures to noxious materials. If this function is fulfilled, much of the difficulty will be avoided. A second feature of the question is the rôle of intercurrent infections and other acute disease processes with sudden onset, as well as bouts of alcoholic excess, in precipitating an episode of lead intoxication. There is little doubt in the minds of many industrial physicians that lead poisoning is often initiated by such factors. Without attempting either to confirm or reject this concept, it may be said that such cases develop only when the conditions of exposure are such that lead intoxication may reasonably be expected to occur among the workmen without contributory factors-that is, when the lead exposure is known to have little or no margin of safety. Regardless of this fact, however, current medical opinion on this important point only emphasizes the need for good medical care of exposed workmen.

The influence of lead poisoning in the production or acceleration of chronic diseases is at best a controversial question. That some degree of increase in the rate of lead *absorption*, above average normal levels, has any effect upon the course of such diseases has not been demonstrated, and is a matter of pure conjecture. As to the rôle of lead poisoning or lead absorption in relation to the so-called degenerative diseases of middle and later life, opinion differs. The evidence upon which lead has been accused especially by earlier writers, of responsibility for the production of vascular disease, is open to serious question. That localized damage to blood vessels, chiefly capillaries, may result from rapid lead absorption, is without question. Witness, for example, the occasional occurrence of retinal and other localized capillary hemorrhage in lead poisoning. But that general injury to the blood vessels, incurred through lead absorption, results in general hypertensive vascular disease, is a wholly different matter for which there is no adequate evidence at present. Likewise extensive chronic renal damage, as the result of excessive lead absorption, has not been demonstrated, and even in the case of children the production of chronic nephritis, perhaps better described as diffusely scarred kidneys, cannot certainly be attributed to the effects of an episode or multiple episodes of lead poisoning. The facts in these matters must await further careful clinical investigation. It may be expected that the careful and detailed study of workmen who are exposed to lead to some extent over long periods of time will answer these questions.

THE COURSE AND SEQUELAE OF LEAD POISONING

Recovery from lead poisoning is usually complete, leaving no partial or complete disability. In the uncomplicated gastroenteric type, regardless of the severity of the colic, spontaneous recovery occurs in a few weeks, the colic usually subsiding in **1** week to 10 days. Some degree of malaise and weakness may persist for longer periods of time, but even after severe exposure, all the symptoms may be expected t
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The period of recovery from neuritic lesions is much longer as a rule. If the clinical picture is characterized by weakness of the muscle groups involved, without paralysis, there may be prompt and complete recovery. Or paralysis may ensue, and may persist for short or long periods, or indefinitely. In general, the prognosis for complete recovery is good, unless there have been repeated episodes of lead poisoning over a period of years. Recovery may require from 2 months to 2 years. The longer the paralysis persists, the greater is the likelihood that the disability will be permanent; the greater also is the likelihood of neurotic complications. The disability, if permanent, is usually limited to the paralytic lesion. In any case, after from 4 to 18 months, all other signs of lead absorption will have disappeared, including the presence of abnormal quantities of lead in the blood and excreta, and the intoxication, as well as the agent responsible for it, will have vanished, leaving only the effects, if any, of irreparable damage to the nervous system. At this time a diagnosis can be made only on the basis of the history of the case, together with other information obtained at the time of the acute illness.

Lead encephalopathy may result in death in from a few days to 3 weeks, or in partial or complete recovery within 6 weeks to 6 months. In the adult, recovery is usually complete if death does not occur within the first 2 or 3 weeks. (In the case of children the prognosis for complete recovery is not good.) Nevertheless, there may be mental impairment, or residual effects of cerebral injury, especially an intensification of certain borderline or psychotic mental or behavior patterns. Residuals in the form of recurrent epileptiform seizures have been described. The diagnosis of this condition can be made only from the history and from previous medical records. In connection with the question of irreversible injury to the brain from the absorption of lead compounds, it is of some significance that no permanent cerebral sequelae have been recorded in the more than 80 cases of tetraethyl lead poisoning that have been studied. This type of lead poisoning is always characterized by cerebral symptoms and the absorption of considerable quantities of lead by the brain tissue. It would seem, therefore, that the organic cerebral damage induced by presence of lead in the brain substance is usually slight in the case of adults that survive acute lead intoxication.

No permanent sequelae of lead poisoning have been shown to exist, other than those described above, except in the rare case of hemorrhagic or neuritic lesions of the eye. The ultimate degree of ocular damage in such instances is not materially different from that resulting from corresponding lesions induced by other toxic agents.

Neuroses, whether characterized by undue anxiety or by hysterical manifestations, must presumably be regarded as sequelae, although they are not likely to cause permanent disability. The anxiety of certain patients is extreme, and the stress arising from their illness and their economic situation, and from the antagonisms that may develop between themselves and their employees, may be very great. More-

over, many of these patients are easily susceptible to suggestion. Therefore, stocking-leg and sleeve-like paresthesias and anesthesias are seen not infrequently, as well as other typically hysterical forms of behavior. These should not be misinterpreted as malingering.

Adequate treatment, and the proper and prompt settlement of compensation claims, both of which may be necessary to relieve the condition and to establish the diagnosis beyond cavil, are often rendered quite difficult by the circumstances associated with compensation claims and hearings, and therefore these cases may be badly handled from the medical point of view, with unsatisfactory results to all persons concerned.

The Management and Treatment of Lead Poisoning

The first step in the treatment of lead poisoning is to make sure that the lead exposure has been brought to an end. This would be self-evident but for the fact that industrial workmen may be seen with prodromal symptoms that do not lend themselves to immediate interpretation. There are also mild cases with but slight symptoms and no disability, in which a transfer to work involving no exposure, plus medical observation, may be all that is required by way of treatment. In these instances the continuance of occupational lead exposure at any level may be dangerous and should be avoided.

The treatment, proper, must be divided into two categories; (1) that given during the acute episode of poisoning, and (2) that required or indicated after subsidence of the acute attack. During the acute attack it is important to give vigorous treatment for the relief of the immediate symptoms. (The promotion of lead excretion at this time by means of potassium iodide, ammonium chloride, and similar medicaments is contraindicated.) The abdominal pain which is usually the most prominent and disturbing symptom is best relieved by the intravenous injection of large doses of calcium, employing calcium gluconate (10 ml. of a 20 per cent solution), or calcium chloride (5 ml. of a 10 per cent solution). The injection should be given slowly, 4 or 5 minutes being required for the whole amount. A feeling of great heat by the patient, and occasionally vomiting, indicate that enough has been given. Calcium chloride must be given entirely in the vein, for it produces great soreness and sloughing if it is injected into the, soft tissues. Calcium gluconate, however, does not have this disadvantage, and after the intravenous injection, a similar amount may be given intramuscularly to prolong its effective action. This treatment usually relieves an acute colic, and frequently patients who have been writhing in pain relax and go to sleep. The pain may recur, and may require further injections for its control, but within 24 hours the pain of an uncomplicated colic will usually have subsided. This type of treatment is much to be preferred to the use of sedatives in controlling the pain. A hot water bottle may be added if it gives comfort. Atropine in large doses, or nitroglycerine, may be employed for their effect in reducing the tonicity of smooth muscle. Morphine is rarely needed, but may be used if the diagnosis is definite and if the pain is not effectively controlled otherwise.

By this time, and partially by therapeutic means, the diagnosis will have been arrived at, and if there is no evidence of an inflammatory or obstructive lesion, catharsis should be induced, not only to aid in the elimination of

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further pain, but also to remove the relatively large quantity of lead that is almost certain to be present in the alimentary tract, and thereby to prevent further alimentary lead absorption. From this time on the regular evacuation of the alimentary tract should be promoted for this primary and important purpose. Mild catharsis, by means of small doses of magnesium sulfate, will usually be sufficient, but if this is not successful, larger doses should be employed. Enemas may be given advantageously in resistant cases. In any case the bowel should be cleared of its contents and kept open.

The patient should be put on an ample diet and a generous supply of liquids at the earliest possible time. Milk is advantageously used and may be the only food tolerated for a day or two. It may well be continued in generous quantities even after the diet has been restored to normal, not only because of its ample supply of minerals, chiefly calcium and phosphorus, but also because it will aid greatly in supplying water for the promotion of urinary excretion, thereby accelerating the removal of lead from the body.

The existence of serious cerebral symptoms may call for a type of treatment that is different in principle and in detail. The control of excitement, mania, or convulsions calls for sedation, for which large and adequate doses of the barbiturates have been found to be preferable to morphine. Death apparently results in such cases from a combination of cerebral edema, tissue starvation, general dehydration, and exhaustion. Supportive treatment is required, therefore, and fluids in the form of hypertonic salt solutions, glucose or sucrose solutions should be administered as required whether by rectum, subcutaneously or intravenously. If the excitement of the patient can be controlled so as to prevent exhaustion, and if requirements in nourishment and fluids can be maintained, recovery is likely. The course of the disease during this period may be very stormy, however, and careful supervision and prompt repetition of treatment may be required for 10 days to 2 weeks to prevent the return of the more serious symptoms.

After the disappearance of the acute symptoms of whatever type they may be, attention should be given to the requirements of convalescence. Opinions differ with respect to the desirability and the feasibility of de-leading, as a therapeutic measure. Experienced clinicians hold that there is danger of the recurrence of lead intoxication during the period in which the lead content of the body remains high, in that such recurrences may follow in the wake of acute infections, alcoholic excesses, and surgical procedures that require the employment of a general anesthetic. In this belief, they advise the use of methods for de-leading the patient, and for eliminating such a portion of the lead as may be readily available for rapid excretion. Their experience leads them to believe that the period of convalescence and disability is shortened thereby and that return to a gainful occupation is expedited. Other students of the problem believe that the recurrence of lead poisoning without further lead exposure is rare after the complete subsidence of the episode of intoxication, that the excessive quantities of lead are eliminated spontaneously from the body, and that the current methods of de-leading do not remove lead from the body at a materially increased rate or to a practically important degree. The latter concept results in the dismissal of the patient after his recovery, after instructing him to avoid further occupational lead exposure, and after advising him as to general care of his health, especially in matters of diet and personal habits. The proponents

of de-leading have urged that the dangers of this procedure are negligible when carried out properly, and that the period of disability from lead poisoning, in their experience, can be shortened. It seems advisable, therefore, to describe the method in such detail as will enable it to be employed and put to the test of further use.

The treatment for de-leading should not be started until all acute symptoms have disappeared, or in the case of neuritic lesions, until they are no longer progressing. It should be used in the case of patients who have had a recent exposure rather than in those whose exposure has been prolonged and of low intensity. The advisability of attempting to de-lead patients who have had an attack of lead encephalopathy, is seriously open to question. The first procedure is to put the patient on a low calcium intake. The latter consists of eliminating all milk, eggs, and green vegetables from the diet, and as the elimination of milk must be complete, it cannot be used in cooking or in the making of breadstuffs. As a result, it is frequently necessary to substitute milk-free crackers for bread. This diet must be maintained throughout the course of treatment. It is not a difficult diet for adults, for it includes clear soups, meats, white and colored (not green) vegetables, macaroni, rice, fruits, and butter and fats as desired. After the patient has been on this diet for about 3 days the addition of a drug to increase further the calcium excretion should be started. The easiest technic is to use ammonium chloride, inasmuch as the ammonium is changed largely to the neutral urea, thus making hydrochloric acid available for the purpose of further removing calcium from the body. It is best to start with a 1 gm. dose 3 times a day during meals. This may be done in either of the following ways: 1 teaspoonful of 20 per cent solution of ammonium chloride dissolved in a full glass of water may be sipped with the meal, or three 5 gr. enteric-coated tablets of ammonium chloride may be taken with the meal. Either technic prevents the irritating effect on the stomach mucosa produced by crystalline ammonium chloride. During the first week or so the dose of ammonium chloride is gradually increased until a maximum of 6 or 8 gm. is taken a day. When the ammonium chloride produces a moderate acidosis, the patient may lose his appetite or develop a headache and then the dose is cut down to a slightly lower level. The treatment is then maintained for about 4 weeks; during this time the patient does not feel very well, has no great appetite, and loses weight, but these symptoms disappear when the treatment is discontinued, and then the patient promptly feels much better.

If, during this treatment, the patient should have a recurrence of symptoms, such as lead colic, it is best to discontinue the ammonium chloride for a few days, but the low calcium diet should be continued, if possible. Recurrence of symptoms is very rare if the treatment is entered upon in the slow way described. They may recur, however, if a low calcium diet and large doses of ammonium chloride are given all at once.

Other methods of de-leading such as the use of acid drinks or parathyroid extract are much more difficult, and probably not much more effective. After this course of treatment, the patient should be returned to and maintained on a well rounded diet high in calcium and phosphorus and vitamins. At least two glasses of milk daily are highly desirable.

In association with this treatment, the usual accessory therapy should be maintained. Constipation should be prevented. Ample water intake is necessary to prevent dehydration from

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The treatment of the organic sequelae of lead poisoning is limited to the adequate care of the paralyses that may exist. Some success has been reported in hastening recovery from these lesions by the administration of large doses of vitamin B complex. This treatment would appear to be indicated throughout the course of the treatment of neuritic lesions. The prevention of malposition and contractures should be accomplished by proper splinting, and periods of massage and active and passive motion are desirable to shorten the period of disability. The massage and exercise should not be carried out during de-leading procedures.

When the patient has recovered, the problem of the medical practitioner and consultant has reached its conclusion; that of the industrial physician has only reached its most difficult phase. The latter must now determine where the workman can be reemployed without further danger to his health. Much will depend upon the nature of the lead exposure that caused the poisoning of this workman. If it was accidental, in the sense that a brief and unanticipated exposure resulted from unusual or faulty plant operations, the cause of the trouble may have been eliminated. If it was the result of the introduction of a new process, the hazards of which had been unrecognized, this difficulty may have been solved. To generalize, therefore, if the lead exposure which was responsible for the illness has been recognized and eliminated, there is no reason why the workman should not return to his former occupation. Otherwise he should be given another job that does not involve the hazard of lead exposure, or if such a job is not available, he should be given opportunity and assistance in finding a safe occupation elsewhere. These procedures are especially applicable if the lead exposure previously suffered was the result of carelessness or ineptitude in the matter of following the regulations required for safety in the occupation in question. This point should not be over-emphasized, since it provides much too easy a basis for putting the responsibility for lead exposure upon the workman. Nevertheless, it must be recognized as a principle, that in certain potentially hazardous occupations, reasonable care and precision of technic is the price of the safety of a workman and perhaps of his fellows as well; in fairness to himself and to his associates, an unreliable or inept workman may not be returned *to* such occupations.

The proper handling of problems of the foregoing types requires judgment, as well as professional and social sensitivity and responsibility. There can be *no* doubt that the best and fairest solution of most of such problems lies in the application of effective methods for the detection of dangerous conditions of lead exposure in industry, and for the elimination of such conditions whenever they arise by such means as may be necessary to the circumstances.

APPENDIX

Classified Bibliography

(This bibliography is not intended to be all-inclusive, but is believed to he sufficiently informative.)

Statistics on Lead Poisoning in the United States of America

1924—Hamilton, Alice: The prevalence and distribution of industrial lead poisoning. *J.A.M.A.*, *83*:583.

1935—Lanza, A. J.: Epidemiology of lead poisoning. *J.A.M.A.*, *104*:85.

1937—Mortality statistics for the United States, 1935, compared with 1930 and 1934. U. S. Pub. *Health Rep.*, *52*:551.

1938—Hoffman, F. L.: Lead poisoning in 1936 and earlier years. U. S. *Monthly Labor Review*, *46*:420, and U. S. Dept. of Labor, *Serial No. R. 669.*

1940—Bloomfield, J. J., *et* al.: A preliminary survey of the industrial hygiene problem in the United States. U. S. *Pub. Health Bull. No.* 259.

Natural Occurrence of Lead in Soil, Rocks, Volcanic Dusts, Surface and Subterranean Wafers

1850—Malaguti, Durocher, and Sarzeaud, Ann. de *chim. et phys.*, 3rd ser., *28*:129. Cited by F. W. Clarke, *loc. cit.*, p. 124.

1892—Dana, J. D., and Dana, E. S.: *System of Mineralogy.* John Wiley and Sons, Inc. New York. Pp. 165, 170.

1901—Hartley, W. N., and Ramage, Hugh: The mineral constituents of dust and soot from *various sources. Proc. Roy. Soc., London 68*:97.

1913—Lindgren, Waldemar: Mineral *Deposits.* McGraw-Hill Book Co. New York. Pp. 7, 9, 41, 89.

1914—Clarke, F. W., and Stciger, G.: The relative abundance of several metallic elements. *J. Washington Acad. Sci.*, *4*:58.

1915—Shaw, C. F., and Free., E. E.: (Lead in Coast Range soils.) Report of Selby Smelter Commission. U. S. Bureau of Mines Bull. No. 98, p. 461.

1917—Phillips, A. H.: *Analytical search for metals in Tortugas marine* organisms. Pub. Dept. Marine Biol., Carnegie Inst. Washington. Vol. 11, No. 251.

1924—Clarke, F. W.: The data of geochemistry. U. S. Geological Survey, Bull. No. 770, p 29.

1926—Chapman, A. C., and Linden, H.: On the presence of lead and other metallic impurities in marine crustaceans and shell fish. *Analyst*, *51*:563.

1927—Mellor, J. W.: *Comprehensive Treatise on Inorganic and Theoretical Chemistry.* Longmans, Green and Co., London. Vol. VII, Chapter XLVII, p. 492.

1931—Hevesy, G., Hobbie, R., and Holmes, Arthur: Lead content of rocks. *Nature, London: 128*:1038.

1933—Kehoe, Robert A., Thamann, Frederick, and Cholak, Jacob: On the normal absorption and excretion of lead. I. Lead absorption and excretion in primitive life. *J. Zndust. Hyg.*, *15*:256.

1933—Bertrand, G., and Okada, Y.: The presence of lead in arable soil. *Compt. rend. Acad. d. sc.*, *196*:826.

1937—Jones, J. S., and Hatch, M. B.: The significance of inorganic spray residue accumulations in orchard soils. *Soil Sci.*, *44*:37.

1940—Kehoe, Robert A., Cholak, Jacob, and Story. Robert V:. A spectra-chemical study of the normal ranges of concentration of certain trace metals in biological materials. *J. Nutrition*, *19*:579. and Supplement

Occurrence of Lead in Food Materials

1881—Gautier, A.: On the continuous absorption of lead from our daily food. *Bull. Acad. d. méd.*, *Paris*, 2nd ser., *10*:1325

1902—Dufour-Labastide, A.: Lead poisoning in children. Thesis of Paris.

1903—Meillère, G.: Lead poisoning. Thesis of Paris, p. 93.

1925—Berg, R.: The occurrence of unusual elements in human food and excreta. *Biochem. Ztschr.*, *165*:461.

1928—Bishop, W. B. S..: The occurrence of lead in the egg of the domestic hen. *M. J. Australia*, *1*:480 (1928); *1*:96, *792* and *2*:660 (1929).

1930—Schmidt, Paul, Seiser, Adolf, and Litzner, Stillfried: *Lead Poisoning.* Urban u. Schwarzenberg. Berlin. p. 12.

1931—Zbinden, Christian: Traces of certain elements in milk and their detection bv the spectrographic method. *Lc Lait*, *11*:113.

1931—Bertrand, Gabriel, and Ciurea, V.: Lead in the animal organism. *Compt. rend. Acad. d. sc.*. *192*:990.

1931—Fox, H. M., and Ramage, Hugh: Spectrographic analvsis of animal tissues. *Proc. Roy. Soc. London. 108B*:157.

1932—Bibliography on heavy metals in food and biological material (from the beginning of the year 1921 to date). II. Lead. *Analyst*, *57*:775.

1933—Kehoe, Robert A., Thamann, Frederick, and Cholak, Jacob: On the normal absorption and excretion of lead. III. The sources of normal lead absorption. *J. Zndust. Hyg.*, *15*:290.

1938—Monier-Williams, G. W.: Lead in food. *Reports on Public Health and Medical Subjects No. 88.* H. M. Stationery Office, London.

1940—Kehoe, Robert A., Cholak, Jacob, and Story, Robert V.: Editorial review: Manganese, lead. aluminum, copper and silver in normal biological material. *J. Nutrition. 20*:85.

1940—Kehoe, Robert A., *et al.*: Experimental studies on the ingestion of lead compounds. *J. Zndvst. Hyg. & Toxicol.*, *22*:381.

1941—Neal, Paul A., et al.: A study of the effect of lead arsenate exposure on orchardists and consumers of sprayed fruit. *u. s. Pub. Health Bull. No. 267.*

Normal Values for Lead in the Tir Cerebrospinal Fluid. and Excreta Beings

1931—Barth, E.: Investigations on the of human bones. *Virchows A Anat.*, *281*:146.

1933—Kehoe, Robert A., Thamann, I Cholak, Jacob: On the norm and excretion of lead. I. Le and excretion in primitive lif absorption and excretion in n can life. IV. Lead absorptic tion in infants and children *Hyg.*, *15*:257.,273., 301.

1935—Tompsett, S. L.: The lead cont tissues and excreta. *Biochem.*

1936—Scott, G. H., and McMillen, J. graphic analyses of human *Proc. Soc. Exper. Biol. & Me*

1937—Bagchi, K. N., and Ganguly, H. urine and feces. *Indian J. 25*:147.

1938—Gant, V. A.: Lead poisonir " normal " occurrence of lead of the human bodv: the " centration of lead in bodv fl Med., *7*:616.

1938—Scott, G. H., and McMillen, J. graphic determination of lead normal human subjects. *Am 195*:622.

1939—Bagchi, K. N., Ganguly, H. D J. N.: Lead in human tissues. *Research*, *26*:935.

1940—Kehoe, Robert A., Cholak, Jaco Robert V.: A spectrochemical normal ranges of concentrati trace metals in biological mate *trition*, *19*:579 and Supplemen

1940—Kehoe, Robert A., Cholak, Jaco Robert V.: Editorial review. lead, tin, aluminum, copper normal biological *material. 20*:85.

1941—Webster, Stewart H.: Lead an gestion and excretion in man. *Health Rep.*, *56*:1359. Diu of urinary lead excretion. Z Twenty-four-hour output of c constituents in persons exp arsenate spray residue. *Ibid.* lead and arsenic content of u persons with no known exp or *arsenic. Zhid.* p. 1953.

1942—Kaplan, Emanuel, and McDona Blood lead determinations as partment laboratory service *32*:481.

1943—Kehoe, Robert A.: Industrial I and Lead Poisoning. Chapt *Principles and Practice of In cine*, edited by Fred J. Wamp & Wilkins Company, Baltimo 240.

Methods for Analysis of Biologic (Applicable Also to Dust)

1935—Wilkins, E. S., Jr., et al.: De minute amounts of lead in terials. A titrimetric-extrac *Indust. & Engin. Chem.*, Anal

1935—Cholak, Jacob: The quantit graphic determination of lead *Am. Chem. Soc.*, *57*:104.

1935—Cholak, Jacob: Quantitative determination of lead in

ve, but is believed to be

ıd, G., and Okada, Y.: The presence
ɜad in arable soil. *Compt.* rend. *Acad.*
c., 196:826.
J. S., and Hatch, M. B.: The signifi-
e of inorganic spray residue accumula-
in orchard soils. Soil *Sci., 44*:37.
Robert A., Cholak, Jacob, and Story,
ert V:. A spectra-chemical study of
normal ranges of concentration of cer-
trace metais in biological materials.
'utrition, 19:579. and Supplement

of Lead in Food Materials

', A.: On the continuous absorption of
from our daily food. Bull. *Acad. d.*
, Paris, 2nd ser., *10*:1325
-Labastide, A.: Lead poisoning in
ren. Thesis of Paris.
e, G.: Lead poisoning. Thesis of
ı, p. 93.
R.: The occurrence of unusual elements
human food and excreta. *Biochem.*
hr., 165:461.
, W. B. S..: The occurrence of lead
ıe egg of the domestic hen. *M. J. Aus-*
ı, *1*:480 (1928); *1*:96, 792 and *2*:660
9).
t, Paul, Seiser, Adolf, and Litzner,
ried: *Lead Poisoning.* Urban u.
'arzenberg. Berlin. p. 12.
ı, Christian: Traces of certain elements
ıilk and their detection by the spectro-
ıic method. *L e Lait, 11*:113.
ıd, iel, and Ciurea, V.: Lead in
an ɔrganism. *Compt. r e n d . Acad.*
:., :990.
H. M., and Ramage, Hugh: Spectro-
hic analysis of animal tissues. *Proc.*
Soc. London. 108B:157.
raphy on heavy metals in food and
gical material (from the beginning of
year 1921 to date). II. Lead. *Analyst,*
75.
Robert A., Thamann, Frederick, and
ak, Jacob: On the normal absorption
excretion of lead. III. The sources
ormal lead absorption. *J. Indust. Hyg.,*
90.
-Williams, G. W.: Lead in food. *Re-*
on Public Health and Medical Sub-
No. 88. H. M. Stationery Office,
Ion.
Robert A., Cholak, Jacob, and Story,
ert V.: Editorial review: Manganese,
aluminum, copper and silver in normal
gical material. *J. Nutrition, 20*:85.
Robert A., *et* al.: Experimental studies
the ingestion of lead compounds. *J.*
st. Hyg. & Toxicol., *22*:381.
Paul A., *et* al.: A study of the effect
ıad arsenate exposure on orchardists and
ımers of sprayed fruit. *U. S. Pub.*
th Bull. No. 267.

Normal Values for Lead in the Tissues: Blood, Cerebrospinal fluid, and Excreta of Human Beings

1931—Barth, E.: Investigations on the lead content of human bones. *Virchows Arch. f. path. Amt., 281*:146.

1933—Kehoe, Robert A., Thamann, Frederick, and Cholak, Jacob: On the normal absorption and excretion of lead. I. Lead absorption and excretion in primitive life. II. Lead absorption and excretion in modern American life. IV. Lead absorption and excretion in infants and children. *J. Indust. Hyg., 15*:257, 273, 301.

1935—Tompsett, S. L.: The lead content of human tissues and excreta. *Biochem. J., 29*:1815.

1936—Scott, G. H., and McMillen, J. H.: Spectrographic analyses of human spinal fluid. *Proc. Soc. Exper. Biol. & M e d . , 35*:287.

1937—Bagchi, K. N., and Ganguly, H. D.: Lead in urine and feces. *Indian J. M. Research, 25*:147.

1938—Gant, V. A.: Lead poisoning. I. The "normal" occurrence of lead in the tissues of the human body: the "normal" concentration of lead in bodv fluids. *Indust. Med., 7*:616.

1938—Scott, G. H., and McMillen, J. H.: Spectrographic determination of lead in blood from normal human subjects. *Am. J. M. Sc., 195*:622.

1939—Bagchi, K. N., Ganguly, H. D., and Sirdar, J. N.: Lead in human tissues. Indian *J. M. Research, 26*:935.

1940—Kehoe, Robert A., Cholak, Jacob, and Story, Robert V.: A spectrochemical study of the normal ranges of concentration of certain trace metals in biological materials. *J. Nutrition, 19*:579 and Supplement.

1940—Kehoe, Robert A., Cholak, Jacob, and Story, Robert V.: Editorial review. Manganese, lead, tin, aluminum, copper and silver in normal biological material. *J. Nutrition, 20*:85.

1941—Webster, Stewart H.: Lead and arsenic ingestion and excretion in man. U. S. *Pub. Health Rep., 56*:1359. Diurnal variation of urinary lead excretion. *Ibid,* p. 1834. Twenty-four-hour output of certain urinary constituents in persons exposed to lead arsenate spray residue. *Ibid,* p. 1910. The lead and arsenic content of urines from 46 persons with no known exposure to lead *or arsenic. Ibid.* p. *1953.*

1942—Kaplan, Emanuel, and McDonald, John M.: Blood lead determinations as a health department laboratory service. *A.J.P.H., 32*:481.

1943—Kehoe, Robert A.: Industrial Lead Exposure and Lead Poisoning. Chanter in: *The Principles and Practice of Industrial Medicine,* edited by Fred J. Wampler. Williams & Wilkins Company, Baltimore. Pp. 202-240.

Methods for Analysis of Biological Material (Applicable Also to Dust)

1935—Wilkins, E. S., Jr., *et* al.: Determination of minute amounts of lead in biological materials. A titrimetric-extraction method. *Indust. & Engin. Chem.,* Anal. Ed., *7*:33.

1935—Cholak, Jacob: The quantitative spectrographic determination of lead in urine. *J. A m . Chem. Soc., 57*:104.

1935—Cholak, Jacob: Quantitative spectrographic determination of lead in biological material. *Indust & Engin. Chem.* Anal. Ed., *7*:287.

1935—Willoughby, C. E. Wilkins, E. S., Jr., and Kraemer, E. 0.: Determination of lead. Removal' of bismuth interference in the dithizone method. *Indust. & Engin. Chem.,* Anal. Ed.. *7*:285.

1936—Clifford, P. A., and Wichmann, H. J.: Dithizone methods for the determination of lead. *J. Assoc. Off. Aar. Chem., 19*:130.

1937—Horwitt, M. K., and Co&ill, G. k.: A titrimetric method for the quantitative estimation of lead in biological materials. *J. Biol. Chem., 119*:553.

1937—Cholak, Jacob, Hubbard, D. M., McNary, R. R., and Stow, R. V.: Determination of lead in' biological materials. Comparison oi spectrographic, dithizone and s-diphenylcarbazide methods. *Indust. & Engin. Chem.,* Anal. Ed., *9*:488.

1938—Fairhall, Lawrence T.: Precision methods in the determination of the heavy metals *A.J.P.H.. 28*:825.

1938—Cholak, Jacob, and Story, R. V.: Spectrographic analysis of biological material. III. Lead, tin, aluminum, copper and silver. *Indust. & Engin. Chem.,* Anal. Ed., *10*:619.

1939—Bambach, Karl: Determination of lead by dithizone. Modifications and improvements of the Hubbard-Clifford-Wichmann method as applied to biological material. *Indust. & Engin. Chem.,* Anal Ed., *11*:400.

1940—Association of Official Agricultural Chemists: *Official and Tentative Methods of Analysis.* 5th ed. Washington, D. C.

1941—Oshry, H. I., Ballard, J. W., and Schrenk, H. H.: Spectrochemical determination of lead, cadmium, and zinc in dusts, fumes, and ores. *J. Optic. Soc. America. 31*:627.

1941—Cholak, Jacob, and Bambach, Karl: Determination of lead in biological material. A polarographic method. *Indust. & Engin. Chum..* Anal. Ed.. *13*:583.

1942—Bambach, Karl, and Burkey R. E.: Microdetermination of lead by dithizone, with an improved lead-bismuth separation. *Indust. & Engin. Chem.,* Anal. Ed., *14*:904.

1942—Feicht, Florence L., Schrenk, H. H., and Brown, C. E.: Determination by the dropping mercury electrode procedure of lead, cadmium, and zinc in samples collected in industrial hygiene studies. U. S. Dept. of Interior, *Bureau of Mines, R. I. No.* 3639.

Methods of Sampling and Analyzing Air for Its Lead Content

1931—Chamot, E. M. and *Mason, C.* W.: *Handbook of Chemical Microscopy* Vol. II, p. 180 (Microchemical qualitative test for lead). John Wiley & Sons, Inc., New York.

1935—Bloomfield, J. J., and DallaValle, J. M.: The determination and control of industrial dust. U. *S. Pub. Zfealth Bull. No. 217.*

1936—Drinker, Philip, and Hatch, Theodore: *Industrial Dust. Hygienic Significance, Measurement and Control.* McGraw-Hi11 Book Co. New York.

1936—Harrold, G. C., Meek, S. F., and Holden, F. R.: A practical method for the rapid determination of lead when found in the atmosphere. *J. Indust. Hyg. & Toxicol., 18*:724.

1938—Littlefield, J. B., Feicht, Florence L., and Schrenk, H.H.: Efficiency of impingers for collecting lead dust and fumes. U.S. De-

partment of Interior. *Bureau of* **Mines *R. I. No.*** 3401.

1938—Barnes, E. C., and Penney, G. W.: An electrostatic dust weight sampler. *J. Indust. Hyg. &* Tozicol., *20*:259.

1938—Air Hygiene Foundation of America, Inc.: Determination of lead in air. Preventive ***Engineering Series Bull. No. 2.*** Part 6.

1938—Moskowitz, Samuel, and Burke,' William J.: Method for the analysis of dust and fumes for lead and zinc. ***J. Indust. Hyg. & Toxicol.,*** *20*:457.

1938—Harrold, G. C., Meek, S. F., and Holden, F. R.: Note on "A practical method for the rapid determination of lead when found in thk atmosphere." *J. Indust. Hyg. &* ***Toxicol.,*** *20*:589.

1939—*Scott's* ***Standard Methods of Chemical Analysis,*** 5th ed. N. H. Furman, editor. D. Van Nostrand, Inc., Vol I.

1939—Schrenk, H. H., and Feicht, Florence L.: Bureau of Mines midget impinger. U. S. ***Bureau of*** **Mines *I. C. No. 7076.***

1939—Commonwealth of Pennsylvania, Department of Labor and Industry: Electrostatic dust sampler as used in sampling lead fumes. Safe ***Practice Bull. No. 57.***

1941—Dreessen, W. C., *et* al.: The control of the lead hazard in the storage-battery industry. U. ***S. Pub. Health Bull. No. 262.***

1941—Jacobs, Morris B.: ***Analytical Chemistry of Industrial Poisons, Hazards and Solvents.*** Interscience Publishers, Inc., New York. (Pp. 160-182, references.)

1941—Case, Lewis B.: Comparison of methods for sampling lead fume. ***A.J.P.H.,*** *31*:359.

1943—Silverman, Leslie, and Ege, John F. Jr.: A filter paper method for lead fume collection. *J. Indust.* ***Hyg. & Toxicol.,*** *25*:185.

1943—Report of Subcommittee on Air Analysis, of Industrial Hygiene Section, American Public Health Association.

Concentration of Lead in the Atmosphere in General, and in That of Streets, Shops, and Industrial Plants Other Than Those of the Lead Trades

1901—Hartley, W. N., and Ramage, Hugh: The mineral constituents of dust and soot from various sources. ***Proc. Roy. Soc., London,*** *68*:97.

1930—***Final Report of Departmental Committee on Ethyl Petrol.*** Ministry of Health, London. H. M. Stationery Office. Pp. 27–34.

1933—Dunn, J. T., and Bloxam, H. C. L.: The occurrence of lead, copper, zinc and arsenic compounds in atmospheric dusts, and the sources of these impurities. *J. Soc.* ***Chem. Ind.,*** *52*:189T.

1933—Bloomfield, J. J., and Isbell, H. S.: The presence of lead dust and fumes in the air of streets, automobile repair shops, and industrial establishments of large cities. ***J. Indust. Hyg.,*** *15*:144.

1943—Cholak, Jacob, and Bambach, Karl: Measurement of industrial lead exposure by analyses of blood and excreta of workmen. ***J. Indust. Hyg. & Toricol.,*** *25*:47.

Concentration of Lead in Atmosphere of Lead Plants and in Their Vicinity

1910—Duckering, G. Elmhirst: Report of an investigation of the air of work-places in potteries. ***Report of Departmental Committee on Lead, etc., in Potteries,*** Vol. II, Appendix XLIX, p. 93. H. M. Stationery Office, London.

1929—Greenburg, Leonard, Schaye, A: A., and Shlionsky, Herman: A study of lead poisoning in a storage-battery plant. U. ***S. Pub. Health Rep.,*** *44*:1666. ***Reprint No. 1299.***

1933—Russell, Albert E., *et* al.: Lead poisoning in a storage-battery plant. U. ***S. Pub. Health Bull. No. 205.***

1937—Tebbens, B. D.: Atmospheric lead contamination from high temperature lead baths. *J. Indust. Hyg. &* ***Toxicol.,*** *19*:6.

1939—Rezin, Paul F., and Drinker, Philip: Volatilization of lead below 800" C. *J. Indust. Hyg. &* ***Tozicol.,*** *21*:461.

1940—Ruf, Harold W.: Studies on the lead hazards in certain phases of printing. I. Actual lead exposures as measured by the amount of lead in printing atmospheres. *J. Indust.* ***Hyg. & Toxicol.,*** *22*:445.

1941—Halley, James W.: Atmospheric concentration of lead fume associated with forging, welding and oxygen cutting of lead-bearing steel, based upon experimental studies. *J. Indust. Hyg. &* ***Toricol.,*** *23*:100.

1941—Dreessen, Waldemar C., *et* al.: The control of the lead hazard in the storage-battery industry. U. S. ***Pub. Health Bull. No. 262.***

1941—Elkins, Hervey B., Ege, John F. Jr., and Ruotolo, Benjamin P.: Evaluation of the lead hazard. Urinary vs. atmospheric lead. *J. Indust.* ***Hyg. & Tozicol.,*** *23*:256.

1942—Littlefield, John B.: Control of a lead hazard. *Indust.* ***Med.,*** *11*:504.

1943—Wisconsin State Board of Health: The lead hazard in the milk-canning industry. Bulletin

1943—Wisconsin State Board of Health: Concentration of atmospheric metal fumes in nonferrous foundries. Bulletin.

Safe Limits of Exposure to Lead in the Air, as Defined by Air Analyses

1912—Legge, Thomas M., and Goadby, Kenneth W.: ***Lead Poisoning and Lead Absorption.*** International Medical Monographs. Edward Arnold, London.

1929—Greenburg, Leonard, Schaye, A. A., and Shlionsky, Herman: A study of lead poisoning in a storage battery plant. U. S. ***Pub. Health Rep.,*** *44*:1666. ***Reprint No. 1299.***

1933—Russell, Albert E., *et* al.: Lead poisoning in a storage battery plant. U. ***S. Pub. Health Bull. No. 205.***

1935—Bloomfield, J. J.: Engineering control of occupational diseases. ***A.J.P.H.,*** *25*:1196 and U. ***S. Pub. Health Rep.,*** *51*:655 (1936).

1938—Mayers, May R., and McMahon, M. M.: Lead poisoning in industry and its prevention. New York State Department of Labor. Special ***Bull. No. 195.***

1941—Dreessen, Waldemar C., ***et*** al.: The control of the lead hazard in the storage battery industry. U. ***S. Pub. Health Bull. No. 262.***

Plant Sanitation, Ventilation, Respirators, and General Environmental Control (See also Codes of Various States)

1923—International Labour Office: ***Studies and Reports*** Series *F* (Industrial Hygiene) No. 9, Geneva.

1930—American Standards Association: Code of lighting factories, mills, and other work places, ***A 11.***

1930—Bureau of Labor Statistics, U. Labor: Code for identification canisters. ***Bull. No. 512.***

1931—Bureau of Mines: List of permi tained oxygen breathing a masks, and hose masks. *Inf.*

1932—Yaglou, C. P.: Physical and aspects of air-conditioning. *H* ***Air Cond.,*** Journal Sec.

1933—United States Department of installation and maintenance 0 ties in places of employ ***Women's Bureau No. 99.***

1934—Bureau of Mines: Procedure for type dust, fume, and mist permissibility. ***Schedule 21.***

1935—American Standards Association: for industrial sanitation in establishments. *Z4,* 1 (Spons Pub. Health Ser.)

1936—American Standards Associat mentals relating to the desig tion of exhaust systems. *P Z9.*

1936Bloomfield, J. J., and DallaV The determination and contro dust. U. ***S. Pub. Health, Bul***

1936—Drinker, Philip, and Hatch, Th ***trial Dust. Hygienic Significa ment, and Control.*** McGraw-I New York.

1938—Air Hygiene Foundation of use and care of respirators Eneineerine Series. ***Bull. No.***

1938—Schrenk, H. H.: List of respira devices approved by the Bur *Inf. Circ.* 7030.

1940—DallaVale, J. M., and Jones, I principles of industrial sanitati *30*:369.

1940—Ministry of Labour and Nat Seats for workers in factor ***Welfare Pamphlet No. 6.*** H. Office, London.

1941—Division of Labor Standards, U ment of Labor: Protecting Pla Practical Points on Industrial Hygiene. ***Special Bull. No.***

1942—Division of Public Contracts, 1 ment of Labor: ***Basic safet*** requirements *for establishmen Walsh-Healy* ***Public Contracts*** Gov. Printing Off., Washingtc

1942—Illuminating Engineering Socie recommended practice of indu Approved by American Standa ***A 11.***

1942—Industrial health service. Pc service-personal health and tions. ***Nat.*** *Saf. News,* ***45,*** 1

1942—Industrial housekeeping. *Nat.* *45*:160.

1943—Dyktor, H. G.: A practical hou gram for industry. ***A.J.P.H.,***

1943—United States Public Health Se Health Service drinkine water manual of recommended wa practice. U. ***S. Pub. Health Reprint No. 2440.***

1943—*American* ***Society of Heating a*** Engineers Guide, 1943 ed.

1943—United States Navy Department time Commission: ***Maximum for safety and industrial heal shipyards.*** U. ***S. Gov.*** Washington.

a

endix XLIX, p. 93. H. M. Stationery e, London.

urg, Leonard, Schaye, A. A., and Shlion- H: A study of lead poisoning in ora .ery plant. U. S. ***Pub. Health***, 4 06. ***Reprint No. 1299.***

, Albert E., *et* al.: Lead poisoning in wage-battery plant. U. S. ***Pub. Health No. 205.***

s, B. D.: Atmospheric lead contamina- from high temperature lead bathe. *J. st. Hyg. & Toxicol., 19*:6.

Paul F., and Drinker, Philip: Vola- tion of lead below 800" C. *J. Indust. & Toxicol., 21*:461.

Iarold W.: Studies on the lead hazards ertain phases of printing. I. Actual exposures as measured by the amount ad in printing atmospheres. *J. Indust. & Toxicol., 22*:445.

James W.: Atmospheric concentra- of lead fume associated with forging, ing and oxygen cutting of lead-bearing based upon experimental studies. *J. st. Hyg. & Toxicol., 23*:100.

n, Waldemar C., *et* al.: The control he lead hazard in the storage-battery stry. U. ***S. Pub. Health Bull. No. 262,***

Hervey B., Ege, John F. Jr., and olo, Benjamin P.: Evaluation of the hazard. Urinary vs. atmospheric lead. *dust. Hyg. & Toxicol., 23*:256.

eld, John B.: Control of a lead hazard. *st. Med., 11*:504.

sin State Board of Health: The lead d in the milk-canning industry. tin

sin State Board of Health: Concentra- of atmospheric metal fumes in non- s foundries. Bulletin.

of Exposure fo Lead in the Air, as Air Analyses

Thomas M., and Goadby, Kenneth W.: *Po ng and Lead Absorption.* Inter- na dical Monographs. Edward d, on.

rg, Leonard, Schaye, A. A., and nsky, Herman: A study of lead poison- " a storage battery plant. U. S. ***Pub. h Rep.,*** *44*:1666. ***Reprint No. 1299.***

Albert E., *et* al.: Lead poisoning in rage battery plant. U. ***S. Pub. Health No. 205.***

eld, J. J.: Engineering control of ational diseases. ***A.J.P.H.,*** *25*:1196 and ***Pub. Health Rep.,*** *51*:655 (1936).

May R., and McMahon, M. M.: Lead "ing in industry and its prevention. York State Department of Labor. ***al Bull. No. 195.***

n, Waldemar C., *et* al.: The control e lead hazard in the storage battery try. U. ***S. Pub. Health Bull. No. 262.***

tion, Ventilation, Respirators, and ronmental Control (See also Codes fates)

ional Labour Office: ***Studier and Re- Series F*** (Industrial Hygiene) No. 9, va.

n Standards Association: Code of ng factories, mills, and other work

1930—Bureau of Labor Statistics, U. S. Dept. of Labor: Code for identification of gas mask canisters. ***Bull. No. 512.***

1931—Bureau of Mines: List of permissible self-contained oxygen breathing apparatus, gas masks, and hose masks. Inj. *Circ.* ***6494.***

1932—Yaglou, C. P.: Physical and physiological aspects of air-conditioning. ***Heat., Pip., &*** *Air* Cond., Journal Sec.

1933—United States Department of Labor: The installation and maintenance of toilet facilities in places of employment. *Bull.,* ***Women's Bureau No. 99.***

1934—Bureau of Mines: Procedure for testing filter-type dust, fume, and mist respirators for permissibility. ***Schedule 21.***

1935—American Standards Association: Safety code for industrial sanitation in manufacturing establishments. *Z4.* 1 (Sponsored bv U. S. Pub. Health Ser.)

1936—American Standards Association: Fundamentals relating to the design and operation of exhaust systems. ***Preliminary ed. Z9.***

1936—Bloomfield, J. J., and DallaValle, J. M.: The determination and control of industrial dust. U. S. ***Pub. Health, Bull. No. 217.***

1936—Drinker, Philip, and Hatch, Theodore: ***Industrial Dust. Hygienic Significance, Measurement,*** and ***Control.*** McGraw-Hill Book Co., New York.

1938—Air Hygiene Foundation of America: The "se and care of respirators. Preventive Engineering Series. ***Bull. No.*** *2,* Part 2.

1938—Schrenk, H. H.: List of respiratory protective devices approved by the Bureau of Mines. ***Inf.*** *Circ. 7030.*

1940—DallaVale, J. M., and Jones, R. R.: Basic principles of industrial sanitation. ***A.J.P.H.*** *30*:369.

1940—Ministry of Labour and National Service: Seats for workers in factories. 3rd ed. ***Welfare Pamphlet*** No. 6. H. M. Stationery Office, London.

1941—Division of Labor Standards, U. S. Department of Labor: Protecting Plant Manpower, Practical Points on Industrial Sanitation and Hygiene. ***Special Bull. No. 3.***

1942—Division of Public Contracts, U. S. Department of Labor: ***Basic safety and health requirements for establishments subject to Walsh-Healy Public Contracts Act.*** U. S. Gov. Printing Off., Washington.

1942—Illuminating Engineering Society: America" recommended practice of industrial lighting. Approved by American Standards Association ***A 11.***

1942—Industrial health service. Personal health service-personal health and working conditions. ***Nat. Saf. News, 45, 150.***

1942—Industrial housekeeping. ***Nat. Saf. News,*** *45*:160.

1943—Dyktor, H. G.: A practical housekeeping program for industry. ***A.J.P.H.,*** *33*:557.

1943—United States Public Health Service: Public Health Service drinking water standards and manual of recommended water sanitation practice. U. ***S. Pub. Health Rep.*** *58*:69—***Reprint No. 2440.***

1943—***American Society of Heating and Ventilating Engineers Guide.*** 1943 ed.

1943—United States Navy Department, U. S. Maritime Commission: ***Maximum requirements for safety and industrial health in contract shipyards.*** U. S. Gov. Printing Off., Washington

1943—Gafafer, William M., editor: ***Manual of Industrial Hygiene.*** Prepared by Division of Industrial Hygiene, National Institute of Health, U. S. Public Health Service. W. B. Saunders Co., Philadelphia.

Engineering Control of Lead Hazard

1938—Mayers, May R.: Lead poisoning in industry and its prevention. New York State Department of Labor, ***Special Bull. No. 195.***

1939—DallaValle, J. M. ***Principles of Exhaust Hood Design.*** U. S. Public Health Service.

1939—National Battery Manufacturers Association: ***Report of Industrial Hygiene Sessions, 15th Annual Convention,*** Chicago.

Bloomfield, J. J.: Discussion of engineering problems in lead hazard, p. 7.

Yant, William P.: Respirators and respiratory protection as applied to the lead battery industry, p. 35.

Cook. Warren A.: Engineering phases of control of lead exposure in small batterv plants, p. 47.

Valiquet, H. H.: Control of lead hazards, p. 75.

1940—Commonwealth of Pennsylvania, Department of Labor and Industry: Occupational disease prevention: Molten lead, lead oxides, white lead and lead dry colors. ***Safe Practice Bull. No. 19.***

1941—Harrold, Gordon C.: The engineering control of lead contaminated environments. ***Indust. Med.,*** 10, Indust. Hyg. Sec., *2*:34.

1941—Dreessen, Waldemar C., *et* al.: The control of the lead hazard in the storage battery industry U. ***S. Pub. Health Bull. No. 262.***

1942—Pierce, William M.: Preventing heavy metal poisoning in industrial operations. ***Chem. & Met. Eng.,*** *49*:141.

Medical Control of Lead Hazards

1933—Gehrmann, G. H.: Prevention of lead poisoning in industry. ***A.J.P.H.,*** *23*:687.

1933—Russell, Albert E., *et* al.: Lead poisoning in a storage-batterv plant. U. ***S. Pub. Health Bull.*** *No. 205.*

1935—Belknap, Elston L.: Control of lead poisoning *in* the worker. ***J.A.M.A.*** *104*:205.

1939—Kehoe, Robert A.: Chemical data and suggested methods of plant control. Natl. Battery Mfrs. Assoc., ***Rep. Indust. Hyg. Sessions,*** *15*:51.

1941—Dreessen, Waldemar C., *et* al.: The control of the lead hazard in the storage-battery industry. U. ***S. Pub. Health Bull. No. 262.***

1941—Elkins, Hervey B., Ege, John F., Jr., and Ruotolo, Benjamin P.: Evaluation of the lead hazard. Urinary vs. atmospheric lead. *J. Indust. Hyg. & Toxicol., 23*:256.

1942—Smucker, Clayton A., and Kistler, John B.: The evaluation of the lead hazard in the decorating department of a glass plant. Relation of urinarv and atmospheric lead determinations. *J. Indust. Hyg. & Toxicol., 24*:1.

1942—Littlefield John B.: Control of a lead hazard.' ***Indust. Med.,*** *11*:504.

1942—Mayers, May R.: Study of fundamentals in prevention of lead poisoning in industry. New York State Department of Labor, ***Indust. Bull,*** *21*:286, and ***Indust. Hyg. Pamphlet*** (1943).

1943—Cholak, Jacob, and Bambach, Karl: Measurement of industrial lead exposure by analyses of blood and excreta of workmen. *J. Indust.* Hyg. & Toxicol.; 25:47.

Barophilic Stippling of the Erythrocytes in Lead Poisoning

1924—Key, J. A.: Lead studies. IV. Blood changes in lead poisoning in rabbits; stippled cells. Am. *J. Physiol.*, *70*:86.

1924—McCord, Carey P., Minster, Dorothy K., and Rehm, Mathilde: The basophilic aggregation test in lead poisoning. Preliminary report *J.A.M.A.*, *82*:1759.

1931—Lane, R. E.: The rôle of punctate basophilia in the control of industrial plumbism. *J. Indust. Hyg.*, *13*:276.

1933—Jones, R. R.: Estimation of basophilic cells (reticulocytes) in blood by examination of ordinary blood film. U. S. *Pub. Health Rep.*, *48*:1011.

1935—McCord, Carey P., Holden, F. R., and Johnston, Jan: The basophilic aggregation test for lead poisoning and lead absorption. ten years after it.5 first use. *Indust. -Med.*, *4*: 180.

1939—Falconer, E. H.: The clinical significance of punctate basophilia in the erythrocyte. *Ann. Int. Med.*, *12*:1429.

1943—Sanders, Lester W.: Measurement of industrial lead exposure by determination of stippling of the erythrocytes. *J. Indust. Hyg. & Toxicol.*, *25*:38.

Diagnosis of Lead Poisoning

1848—Tanquerel des Planches: Lead Diseases. A *Treatise*. Translated by Samuel L. Dana. Daniel Bixby and Co., Lowell, Mass.

1912—Legge, Thomas M., and Goadby, Kenneth W.: *Lead Poisoning and Lead Absorption. International Medical Monographs.* Edward Arnold, London.

1926—Aub, Joseph C., Fairhall, Lawrence T., Minot, A. S. Reznikoff, Paul, and Hamilton, Alice: *Lead Poisoning. Medicine Monographs*, Vol. VII. Williams & Wilkins Co., Baltimore.

1933—Kehoe, Robert A., Thamann, Frederick, and Cholak, Jacob: Lead absorption and excretion in relation to the diagnosis of lead poisoning. *J. Indust. Hyg.*, *15*:320.

1939—Breyer, H. B. G.: Pseudo lead lines in Javanese and Madurese, melanin and ultramelanin. *Beitr. z. path. Amt. u. z. allg. Path.*, *102*:397.

1939—Tompsett, S. L., and Anderson, A. B.: Lead poisoning. Lead content of blood and of excreta. *Lam-et*, *1*:559.

1940—Belknap, Elston L.: Lead poisoning. Criteria for diagnosis. *Indust. Med.*, *9*:505.

1942—Kehoe, Robert A.: Lead absorption and lead poisoning. *M. Clin. North America. 26:* 1261.

1943—Ashe, William F.: Industrial lead poisoning as a clinical syndrome. *J. Indust. Hyg. & Toxicol.*, *25*:55.

1943—Kehoe, Robert A., *et al.*: Experimental studies on lead absorption and excretion and their relation to the diagnosis and treatment of lead poisoning. *J. Indust. Hyg. & Toxicol.*, *25*:71.

1943—Kehoe, Robert A.: Industrial Lead Exposure and Lead Poisoning. Chapter in: *The Principles and Practice of Industrial Medicine*, -edited by Fred J. Wampler. Williams & Wilkins Company, Baltimore, pp. 202-*240.*

Non-Industrial Lead Poisoning

1928—Wright, Wade; Sappington, C. O., and Rantuol, Eleanor: Lead poisoning from lead-piped water supplies. *J. Indust. Hyg.*, *10*:234.

1929—Reitzel, R. J.: Lead poisoning from snuff. *Ann. Znt. Med.*, *3*:378.

1934—Cushing, H. B., Childe, A. E., Rhea, L. J., Rabinowitch, I. M., Mitchell, H. S., and Ross, S. G.: Lead poisoning in children. *Internat. Clin., Ser. 44*, *1*:189–220.

1936—Kruse: What can we learn from the cases of lead poisoning caused by the drinking water in Leipzig? *Ztschr. f. Hyg. u. Infektionskr.*, *118*:143.

1938—Fuchss, H., Bruns, H., and Haupt, H.: *Danger of Lead Poisoning from Water Supplies.* Theodor Steinkopff, Dresden. Summary in Dept. Scient. and Indust. Res. Water Pollution Research. Summary *of Current Literature*, *11*:229 (1938).

1939—Levinson, Abraham, and Zeldes, Mary: Lead intoxication in children. A study of 26 cases. *Arch. Pediat.*, *56*:738.

1940—Conway, Nell: Lead poisoning from unusual causes. A *review* of the literature. *Indust. Med.*, *9*:471.

1941—Hayhurst, Emery R.: An inquiry concerning the cause of the endemial colic of Devonshire, by Sir George Baker, Bart., M.D., F.R.A. and F.A.S. *Indust. Med.*, *10*:260.

1941—Alexander, A. J., and Downing, Robert A.: Lead poisoning in children. Report of an epidemic due to the burning of storage-battery casings as fuel. New *Internat. Clin.*, Ser. *4*, *2*:233.

1942—McDonald, John M., and Kaplan, Emanuel: Incidence of lead poisoning in the City of Baltimore. *J.A.M.A.*, 119:870.

Certain Special Aspects of Lead Poisoning

1925—Weller, Carl Vernon: Some clinical aspects of lead meningoencephalopathy. *Ann. Clin. Med.*, *3*:604.

1925—Kehoe, Robert A.: Tetraethyl lead poisoning. Clinical analysis of a series of nonfatal cases. *J.A.M.A.*, *85*:108.

1927—Reznikoff, Paul, and Aub, Joseph C.: Lead studies. XIV. Experimental studies of lead palsy. *Arch. Neurol. & Psychiat.*, *17*:444.

1932—McKhann, Charles F.: Lead poisoning in children. The cerebral manifestations. *Arch. Neurol. & Psychiat.*, *27*:294.

1933—Winkelman, N. W., and Eckel, John L.: Lead encephalopathy. A clinicopathological study. New *York State J. Med.*, *33*:427.

1935—Machle, W. F.: Tetraethyl lead intoxication and poisoning by related compounds of lead. *J.A.M.A.*, *105*:578.

Treatment of Lead Poisoning

1926—Aub, Joseph C., Fairhall, Lawrence T., Minot, A. S., Reznikoff. Paul, and Hamilton, Alice: *Lead Poisoning, Medicine Monographs.* Vol. VII. Williams & Wilkins Co., Baltimore.

1929—Belknap, Elston L.: Lead poisoning, the diagnosis and treatment of its most common toxic episode, lead colic. *Wisconsin M. J.*, *28*:346.

1931—Bauer, W., Salter, W. T., and Aub, Joseph C.: Studies of calcium and phosphorus metabolism. Xa. Use of calcium chloride to relieve peristaltic pain. *J.A.M.A.*, *96*:1246.

1933—Wilkins, Lawson: Progress in pediatrics. 2. Recent advances in the diagnosis and treatment of lead poisoning. *Internat. Clin., Ser. 43*, *2*:279.

1935—Aub, Joseph C.: Biochemical lead in the body. *J.A.M.A.*, *1*

1943—Kehoe, Robert A.: Industrial Le and Lead Poisoning. Chapte *Principles and Practice of Indu cine*, edited by Fred J. Wample & Wilkins Co., Baltimore. Pp.

1943—Kehoe, Robert A., *et* al.: studies on lead absorption and e their relation to the diagnosis a of lead poisoning. *1*. *Indus Toxicol.*, *25*:71.

Legal Aspects of Industrial Medical Different States

1937—Occupational-Disease Legislation in States, 1936, with Appendix U. S. Bureau of Labor Statistic *652.*

1939—Sappington, C. 0.: *Medicolegal Occupational Diseases.* Indus Book Co., Chicago.

General Reference Works

1912—Legge, Thomas M., and Goadby, I *Lead Poisoning and Lead Abst*

·piped water supplies. *J. Indust. Hyg.*, 34.

, R. J.: Lead poisoning from snuff. *Ir Med.*, *3*:378.

g, Childe, A. E., Rhea, L. J., no 'I. M., Mitchell, H. S., and , S. G.: Lead poisoning in children. *mat. Clin.*, Ser. 44, *1*:189–220.

What can we learn from the cases of poisoning caused by the drinking water eipzig? *Ztschr. f. Hyg. u. Infektionskr.*, 143.

, H., Bruns, H., and Haupt, H.: *per of Lead Poisoning from Water Sup-* . Theodor Steinkopff, Dresden. Sum- *r* in Dept. Scient. and Indust. Res. er Pollution Research. *Summary of ent Literature*, *11*:229 (1938).

on, Abraham, and Zeldes, Mary: Lead ication in children. A study of 26 . . *Arch. Pediat.*, *56*:738.

y, Nell: Lead poisoning from unusual es. A review of the literature. *Indust.* ., *9*:471.

rst, Emery R.: An inquiry concerning cause of the endemial colic of Devon- , by Sir George Baker, Bart., M.D., A. and F.A.S. *Indust. Med.*, *10*:260.

der, A. J., and Downing, Robert A.: poisoning in children. Report of an emic due to the burning of storage- ery casings as fuel. New *Internat.* , Ser. 4, *2*:233.

ald, John M., and Kaplan, Emanuel: lence of lead poisoning in the City of more. *J.A.M.A.*, 119:870.

cial Aspects of Lead Poisoning

Carl Vernon: Some clinical aspects ead meningoencephalopathy. *Ann. Clin.* , *3*:604.

Robert A.: Tetraethyl lead poisoning. cal analysis of a series of nonfatal . *J.A.M.A.*, *85*:108.

off, Paul, and Aub, Joseph C.: Lead es. XIV. Experimental studies of lead .. *Neurol. & Psychiat.*, *17*:444.

nn arles F.: Lead poisoning in ren. The cerebral manifestations. *Neurol. & Psychint.*, *27*:294.

man, N. W., and Eckel, John L.: encephalopathy. A clinicopathological . *New York State J. Med.*, *33*:427.

, W. F.: Tetraethyl lead intoxication poisoning by related compounds of lead. *M.A.*, *105*:578.

f Lead Poisoning

oseph C., Fairhall, Lawrence T., Minot, ., Reznikoff, Paul, and Hamilton, Alice: *Poisoning, Medicine Monographs. VII.* Williams & Wilkins Co., more.

p, Elston L.: Lead poisoning, the osis and treatment of its most common episode, lead colic. *Wisconsin M. J.*, 46.

W., Salter, W. T., and Aub, Joseph C.: ies of calcium and phosphorus bolism. Xa. Use of calcium chloride relieve peristaltic pain. *J.A.M.A.*, 216.

, Lawson: Progress in pediatrics. Recent advances in the diagnosis and ment of lead poisoning. *Internat. Clin.*,

1935—Aub, Joseph C.: Biochemical behavior of lead in the body. *J.A.M.A.*, *104*:87.

1943—Kehoe, Robert A.: Industrial 'Lead Exposure and Lead Poisoning. Chapter in: *The Principles and Practice of Industrial Medicine*, edited by Fred J. Wampler. Williams & Wilkins Co., Baltimore. Pp. 202–240.

1943—Kehoe, Robert A., *et al.*: Experimental studies on lead absorption and excretion and their relation to the diagnosis and treatment of lead poisoning. *J. Indust. Hyg. & Toxicol.*, *25*:71.

Legal Aspects of Industrial Medical Practice in Diff erent States

1937—Occupational-Disease Legislation in the United States. 1936. with Appendix for 1937. U. S. Bureau of Labor 'statistics *Bull.* No. 652.

1939—Sappington, C. O.: *Medicolegal Phases of Occupational Diseases.* Industrial Health Book Co., Chicago.

General Reference Works

1912—Legge, Thomas M., and Goadby, Kenneth W.: *Lead Poisoning and Lead Absorption. International Medical Monograph.* Edward Arnold, London.

1915—Holmes, J. A., Franklin, Edward C., and Gould, Ralph A.: Report of the Selby Smelter Commission. U. S. Bureau of Mines *Bull. No. 98.* Government Printing Office. Washington. D. C.

1926—Aub, Joseph C., Fairhall, Lawrence T., Minot, A. S., Reznikoff, Paul, and Hamilton, Alice: *Lead Poisoning, Medicine Monographs.* Vol. VII. Williams & Wilkins CO.. Baltimore.

1927—International Labour Office: *White Lead. Studies and Reports* Ser. *F* (Industrial Hygiene). No. 11. Geneva.

1930—Schmidt, Paul, Seiser, Adolf, and Litzner, Stillfried: *Lead Poisoning* (Bleivergiftung). Urban u. Schwarzenberg, Berlin.

1934—Flury, Ferdinand: "Lead" (Blei). *Handbuch der experimentellen Pharmakologie* (Heffter and Heubner). Julius Springer, Berlin. Vol. III, Part 3. Pp. 1575–1889.

1934—International Labour Office: (Lead, Lead colours, Lead compounds, Lead poisoning). *Occupation and Health I-Z*, Geneva, pp. 124-142.