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Industrial Dusts, Their Sources, Effects and Control

SAFETY DIVISION

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Supervisor of Safety and Industrial Relations

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DEPARTMENT OF LABOR AND INDUSTRIES

J. W. Hoover, Director

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Safety Division

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INDUSTRIAL DUSTS
Their Sources, Effects and Control

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1940

DEPARTMENT OF LABOR AND INDUSTRIES

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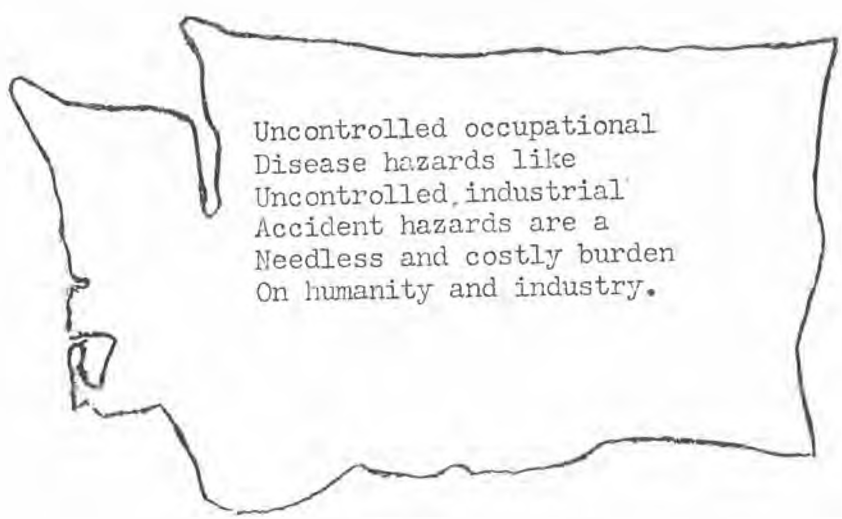

STATE OF WASHINGTON

FOREWORD

Occupational diseases, though at present much in the public eye and mind, are not some newly discovered "bugaboo". On the contrary, such diseases have existed in one form or another for thousands of years. For instance, there is good reason to believe that even as far back in history as the Stone Age the cave men frequently suffered from the effects of the industrial disease now familiarly known as "silicosis". Through the fashioning of their weapons, tools, cooking utensils, etc., from various stone formations containing the dust now called "free silica", these prehistoric dwellers were probably subject to the same exposure to lung disease as many of our present-day industrial workers. As civilization progressed and historical records were kept, we find more and more evidence of diseases due to dusts, and some of the early Roman writers report of the terrible effects of certain dusts on the lungs of workers engaged in cutting stones and granites for the roads and buildings of ancient Rome. We then hear relatively little more about such diseases until some several thousands of years later when we skip to the coal fields of Wales and the gold mines of South Africa, where we find the miners literally dying off "like flies" from the effects of exposure to large quantities of dusts. It was at this period that the problems of dust diseases first began to receive their rightful attention, and as a result many revolutionary changes were made in order to protect these workers from what had become to be known as the "industrial scourge". Along with this increase of recognition of the injurious effects of the dusts encountered in the mining industry, there then arose a further recognition among other industries where intense dust was found. As a result many improvements were also introduced in these industries for the control of such dusts. How many workers suffered from their effects and how many needlessly sacrificed their lives before this period of recognition was reached is not definitely known, but the number must have been tremendous. Today, however, there is little excuse for any worker to have to suffer from any serious dust exposure, because the dangers are now widely known and modern engineering has developed systems of control which in the majority of cases can eliminate most dust hazards.

So far, we have talked only of those occupational exposures and diseases resulting from the inhalation of dusts. However, although the effects of such diseases are more commonly known than others, partly because of their past record of damage and partly because of the publicity given them, there are a great many other occupational diseases caused by exposure to various poisons found in industry. Such poisons which consist essentially of various gases, fumes, and vapors are the more or less direct result of the chemical age in which we are now living, with its continual development of new materials and processes and the creation of synthetic substitutes through improved chemistry. The use of these chemicals, combined with the ever-increasing demand for high-speed production methods has cast another shadow along the health horizon of our workers, and one which cannot be disregarded as was the problem of industrial dusts. Fortunately, however, there is little danger of such negligence repeating itself because the disastrous and costly experience gained from uncontrolled dusts has succeeded in awakening a consciousness that the occupation plays a most vital role in our national health problem. As a result of this awakening, the workman of today is rapidly coming to enjoy better working conditions and better health than ever before. There is still much to be learned and much to be put into practice before it can be said that the industrial health problem is completely under control, but a knowledge of the work to be done and steps taken in the right direction cannot fail to bring a successful solution.

Unlike industrial accidents such as cuts, bruises, fractures, etc., the effects of occupationally acquired diseases are much more subtle in their action and ultimate injury. In fact, it is only in the rarer cases, with the exception of dermatoses (or skin diseases) that the action of occupational poisons are acute, resulting in immediate and obvious manifestations of injury. In such instances the element of exposure is usually readily discernable, and steps can be taken to guard against a similar occurrence. Injuries of this nature are in general the least to be feared because the magnitude of the exposure usually gives ample warnings of the danger. In contrast to such rarer cases of acute poisonings, there are the more or less unapparent and relatively hidden exposures, the effects of which are generally chronic in action over a considerable period, and which may take their drain on health, harmony and life during a span of months or years until the accumulated damage is often times irreparable. In these latter cases there is not only the possibility of partial or total disability or even premature death following continuous exposure to certain poisons, but there is also the toll paid by the workman, and in many cases his family, from the effects of constant poor health, which, while not apparently serious enough, at least to the worker, to cause him to consult a physician or to take a lay-off from his job, yet may negatively effect his disposition, ambition and general attitude. In many cases the sub-par health condition of the worker may be present as frequent headaches, colds, extreme nervousness, or a general rundown or tired-out feeling, all of which he may attribute to something he ate, last night's party, not enough sleep, or perhaps sitting in a draft, but rarely to what in many cases may be the cheif cause--his occupation.

In the attempt to prevent and control occupational disease hazards it is frequently difficult to convince certain of the workers that protective measures at hand or precautions recommended are of any degree of importance with respect to their present or future health and well-being. In like manner it is also frequently difficult to convince some employers that certain protective apparatus or machinery must be furnished at a certain operation in order to provide protection, and that such equipment when present will not only result in the better health and higher efficiency of his employees, as well as increased harmony of relations with them, but will also ultimately have a favorable effect on his compensation burden. These are the factors that must be ironed out if any effective system of control is to be expected; i.e., first, the workman must be educated to realize the extent and nature of his exposure, the effects of such exposure, and to take advantage of the means of protection furnished by the employer to resist exposure. Second, the employer must be convinced that occupational disease legislation providing for the compensation and protection of his workers and their families was not designed for the sole purpose of imposing on him another burden in order that he might be forced out of business as rapidly as possible, but in order that his workers might enjoy the same health and longevity as the workers of other non-hazardous industries. The employer must also realize that by furnishing such protection he may obtain decreased compensation and operating costs, and that by providing a safe place for his employees to work, they will be happier and more efficient, and that he himself can derive a great measure of satisfaction in the knowledge of the large amount of good he is accomplishing.

As yet, nothing has been said of the vital part which the present day industrial physician plays in the control of occupational diseases. His part is mainly one of recognition or diagnosis, wherein the nature of the disease and its origin may be discovered, thus serving as a warning that corrective measures are necessary. Because his role is of such importance in the prevention and control of industrial diseases, the physician should question the worker thoroughly as to his occupation. Or in the words of Ramazzini,

"Medici munus plebeios curantis est interrogare quas artes exerceant."

which translated means,

"The duty of a doctor attending the common people is to enquire what trades they practice."

There should certainly now be no doubt that the problem of occupational disease is with us to stay. Proof of this is seen in that twenty-one states now have passed occupational disease legislation in some form, and that others are now in the process of preparing similar legislation. It has already been shown that the cost of preventing occupational diseases is considerably less than the cost of paying compensation for them, and the sooner that industry realizes this fact, the more benefits they will reap, not only for their employees but for themselves as well.

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Introduction

We have heard a great deal lately about dust diseases in general, principally the lung disease familiarly known as "silicosis". And yet there is considerable ignorance about these dust diseases, not only among the men who experience them but among those responsible for their control. Particularly is this so with regards to silicosis. For years the word, "silicosis," has gone hand-in-hand with the word, "fear". To contract silicosis in any degree was supposed to mean certain, ultimate death. At the first signs of the disease, the man was taken from his work and promptly labeled an invalid. When compensation was provided, he was fortunate; when it was not, it was a tragedy.

Today, however, a new school of thought is advancing its claims. By its reasoning, the silicotic is no longer looked on with pity as a hopeless sufferer. Nor is the mere suggestion or finding of silicosis enough to prevent him from continuing his gainful employment. Instead, the silicotic is treated like any other individual who is unfortunate enough to have contracted a disease. That is, he is watched and checked carefully from time to time by a competent physician. If he can be protected from further exposure, this is done. If he cannot, he is moved to an occupation in a different section of the plant. Only when he is obviously unable to continue his work is he taken from his employment and even then his case is far from hopeless.

This new line of thought which is based upon the research and findings of some of the world's greatest authorities is definitely an encouraging one, both for industry and the workmen as well. However, it must not be lost sight of that its very foundation is made up of three simple words, recognition, treatment, and control. Without these essential steps, the theory cannot be made practical.

Where the necessity of the recognition, treatment, and control of dust diseases in general, especially silicosis, has been recognized, the problem is much simpler. Unfortunately, however, occupational diseases are comparatively unknown in certain areas and the situation thus becomes more difficult in these sections. This is especially true in some of the Western states, including Washington, where occupational disease legislation is comparatively recent. In the State of Washington we have found that our chief difficulty arises from the ignorance of industry concerning the necessity of controlling operations which lead towards exposure to disease. The general trend of thought has been that occupational diseases are chiefly a by-product of the large industrial centers in the East and Middle-West and are comparatively or totally non-existent here.

While it is admitted that the frequency of occupational diseases may be less in the State of Washington than in certain other areas, the fact should be recognized that this is largely due to a reduced man hour, in that there are not as many men employed in dust producing trades. However, although it is true that such industries appear less frequently in this state than others, it should not be assumed that because of this, our workers engaged in dusty trades are any less exposed. In fact, it is possible that the opposite may be true. In large manufacturing centers where the working population is relatively large, naturally, the incidence of disease is increased with the consequent result that it has been more forcefully brought to the attention of those in a position to effect its control. Because of this, important steps have been taken in many large areas by employers, physicians, and engineers to reduce the exposure hazard to a minimum. It is not logical to believe that say, in an unprotected sand blasting operation of a foundry employing 5 men, that the exposure to harmful silica is any less dangerous than in a similar sand blasting operating of a foundry employing 10 men. It is true that conditions being identical, there will be more susceptibility to silicosis among the group of 10. However, the percentage of workers in each group susceptible to the disease should be the same. The obvious conclusions to be drawn from this are that regardless of the humber of workers exposed, the percentage of exposure, for similar conditions, remains constant. It is not meant to condemn nor criticize those who are non-believers in the serious import of occupational diseases in industry as it is an entirely natural reaction in those not familiar with this problem. However, it is hoped that this attitude can be changed through the gradual education of those vitally concerned and that their wholehearted cooperation can be enlisted.

In the preparation of the following writing, the author is deeply indebted to D. Harrington, Chief of the Health and Safety Branch of the U. S. Bureau of Mines and Sara J. Davenport, Principal Translator, U. S. Bureau of Mines, who have compiled a vast amount of invaluable technical data from the works of some of the world's most foremost authorities. Additional valuable data has been obtained from the following sources; the works of J. J. Bloomfield, Sanitary Engineer, and J. M. Dallavalle, Assistant Sanitary Engineer, both of the U. S. Public Health Service; the writings of Frederick L. Hoffman, LL.D. for the U. S. Department of Labor; the reports of the International Labor Office of the League of Nations; and the vastly important studies of the medical examiners of the Metropolitan Life Insurance Co. Further gratitude is also due to Isador Lubin, commissioner of the Bureau of Labor Statistics, U. S. Department of Labor, for his splendid cooperation in placing in the hands of the writer the material needed for a report of this nature. There are, in addition, many others to whom further appreciation is due, but unfortunately it would be impractical to personally acknowledge all of these sources.

I have tried to approach the problem from the standpoint of an engineer, endeavoring to utilize the large source of authentic information available, with the purpose of first; creating a recognition of the need for prevention and control of pneumoconiosis in the State of Washington, second; to point out the value of medical science in the diagnosis of existing diseases and third; to show how proper medical supervision in the selection of workers for hazardous occupations and the periodic physical examination of same will go far to alleviate this industrial health problem.

Because of the great variety of organic and inorganic dusts present in industry, some of which are of such highly toxic qualities as to produce rapid systemic damage, for example, lead and its compounds, and deserving of separate discussion because of their importance, this report is devoted only to those dusts of an inorganic nature that contribute to the condition known as pulmonary fibrosis. In this respect, special emphasis has been placed on the disease known as "silicosis" because it is generally recognized that silica dust is the most dangerous of all the fibrosis producing dusts. Because of the conflicting claims of many authorities concerning this disease, both the new and the old theories will be discussed so that the reader may be able to grasp the entire picture more clearly.

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Chapter I

Non-Recognition of the Occupational Disease Problem.

In spite of the extensive campaigns being conducted throughout the United States and other countries on the subject of occupational diseases, there is yet an apparent lack of general recognition concerning this problem. This fact is borne out by the following excerpts taken from authoritative writings. For Example, Harrington and Davenport (1) write;

"Dust diseases are much before the public at present, and there is good reason to believe that the information on the subject available to the layman is extremely meagre; even those rated as experts usually have a more or less theoretical conception of the diseases, their causation, remedies, and prevention, rather than actual experience with them. Until recently, little attention has been given to prevention, and the usual attitude of the engineer upon whom the main reliance for prevention ultimately must devolve has been to "let sleeping dogs lie", or more definitely, to "let well enough alone". However, the "laissez faire" attitude no longer is tenable, and in the past few years numerous conditions have caused those engaged in industry, including mining, to bring the subject before the public with a view to ascertaining the facts upon which to formulate remedial measures, primarily preventive."

Further, Hoffman (2), in discussing a program for the prevention of tuberculosis induced by dusts in industry, says;

"In this program, as in so many other notable efforts, the sanatorium treatment of the disease is overemphasized as a public question, when prior consideration should be given to preventive measures giving promise of practical results. The policy of the State should not be to begin with the first recognition of developed disease in the patient, but to recognize pretuberculosis possibilities or predisposing conditions, the effective control of which alone can justify the hope of far-reaching results."

Hamilton (3), in summarizing her investigations regarding industrial poisons, writes;

"The sources of our knowledge of industrial poisoning in the United States are neither full nor, for the most part, accurate. We lack the sickness insurance system which obtains in all industrial countries in Europe and which brings to light the incidence of illness of all kinds in all groups of workers. * * * The Census reports are of deaths only, not illness, and the death records lose much of their value because of a poor classification of workers, which puts in the same category men doing work of very different degrees of danger, as for instance paper hangers and painters. * * * It has been my task for many years to examine records of hospitals and dispensaries and to interview physicians in many parts of the country in my search for information about a given poisonous trade. Not one hospital in twenty has records which yield the sort of information which the student of industrial toxicology craves and yet this is not elaborate. If the recording interne would only treat the poison from which the man is suffering with as much interest as he gives to the coffee the patient has drunk and the tobacco he has smoked, if he would ask as carefully about the length of time he was exposed to the poison as about the age at which he had measles, the task of the searcher for the truth about industrial poisons would be made so very much easier."

Importance of Occupational Disease Recognition

That the subject of occupational diseases is receiving increasing recognition as a vital factor in the health of our industries is shown by the following discussions. Hoffman (2), in discussing the health problem of granite stone workers writes;

"If the dust hazard is the causative factor in the enormous respiratory disease mortality of granite and other stone workers and if preventive means are possible by which the dust menance can be brought under control, it is for the state, for the labor organizations, and for the industries concerned to see to it that what can be done about it is done without needless delay."

J. J. Bloomfield and J. M. Dallavalle (4) of the U. S. Public Health Service write;

"In recent years, the subject of the health of workers in dusty trades has been receiving considerable attention from the students of industrial hygiene and others interested in the various phases of this problem. When one realizes that the workmen employed in the dusty trades comprise the

the largest group exposed to any one industrial hazard, it is quite apparent that the importance of this problem has not been overestimated. Furthermore, it is now well established that exposure to certain kinds of dusts, such as those containing considerable amounts of quartz, has increased the morbidity and mortality rate from respiratory diseases; while metallic dusts, such as lead and its compounds, have been associated with general systemic poisoning of workers."

In continuing this discussion, Dublin and Vane, (5) writing for the U. S. Bureau of Labor Statistics, say;

"The occupation is now recognized as of the very first importance as a factor in the causation of disability and even of death. We see this reflected in the frequent revisions of compensation laws to include an increasing number of occupational diseases. * * * With their attention directed to occupation as a possible factor, industrial physicians are able to diagnose a great many obscure cases which previously had puzzled even the most competent clinicians. In this way they discover a great many more cases of disease of occupational origin than had been before thought possible. Thus, in 1917, about 150 cases of lead poisoning were discovered at the Massachusetts General Hospital, which are more than were recorded by this clinic during the 5-year period prior to the adoption of the more intensive methods of study. It is generally recognized that patients come to physicians with pains and complaints of an indefinite character, and it is only when consideration is given to the occupation and its possible effects that many of these cases are cleared up."

Because of the important works of the foregoing authors and many others, much valuable progress has been made with respect to this problem in the United States. However, at best this progress has as yet been slow when compared to the great strides in prevention and control already made by various European countries with similar problems. Such countries as Great Britain, Germany, Italy, Australia, the Netherlands, and South Africa have long recognized the prevalence of occupational diseases and the necessity of their scientific control. As a result of their increased experience with such problems, far-reaching and beneficial workman's compensation laws have been initiated. Consequently it may be said that, in general, the workmen of these countries have heretofore enjoyed a much higher degree of protection and compensation than have those of our own industries. However, thanks to the earnest and humanitarian efforts being exerted by our own Federal Government, insurance and casualty companies, and unselfish authorities and specialists who are devoting their resources to this increasingly vital problem, the wide gap which once existed between the United States and other countries in this health and compensation program is rapidly being lessened. It remains now only a question of time when industry as a whole will recognize the importance of such a movement, and lend to it their full support and cooperation. However, before such recognition can be hoped for, there is much work yet to be done. There is considerable prejudice and opposition that must be overcome. Those who believe that such laws are a necessary evil and others who consider them as an unnecessary evil must be educated to believe in the benefits of such laws. Sometimes this opposition comes, strangely enough, from the very workmen these laws are designed to protect, but more frequently from those upon whom the financial burden evolves. Those who are forced to bear these costs must be taught to believe that occupational disease legislation is not for the purpose of imposing excessive and unjust burdens, but is formulated to provide for the protection and security of our workers in industry--to insure them of the healthful working conditions which they rightly deserve, and to guarantee them the span of life enjoyed by workers of other classes.

Definition and Classification of Dusts

According to Webster's Unabridged Dictionary, dust may be defined as fine, dry particles of earth or other matter so comminuted (pulverized) that they may be raised and wafted by the wind; that which is crumbled to minute portions; fine powder. Dusts also may be generally defined as the fine, solid particles given off as the result of certain manufacturing processes or from the handling and treatment of articles commonly used in everyday life. The size of these dust particles may range from .5 microns to 150 microns in diameter--a micron being equal to 1/25,000 of an inch. However, the particular dusts which are usually recognized as capable of harm are those which have a particle size of from .5 to 10 microns. It is these dusts, which are often times invisible to the naked eye, that the workmen and employers are prone to regard as harmless. Such particles readily pass through the mouth and nose, through the bronchial passages, past the protective filters nature provides, and lodge in the alveolar tissue or lung cells. Once lodged in the remote parts of the lung structure, they cannot usually be dislodged by hawking or coughing. It is these particles that succeed in reaching the lungs that must be reckoned with in the prevention of dust diseases.

The hygenically significant dust particles may be listed under three classifications as follows:

(a) Dusts which are specifically toxic and comparatively rapid in their manifestations, but which do not cause lung fibrosis.

(b) Dusts which cause lung fibrosis (pneumoconiosis) after several years' exposure.

(c) Dusts which are toxic in their action but do not manifest themselves in rapid systemic changes nor produce characteristic pulmonary fibrosis. Among these dusts are included those of wood, bone, shell, flour, grain, tobacco, leather, feathers, straw, wool, cotton, felt, and jute. While these dusts are not generally given the same weight of importance as other of the commonly known injurious dusts, their significance as a conveyor of tubercular and other bacilli as well as their capacity to promote definite respiratory and organic disorders should not be lost sight of.

Toxic Dust

There exists a somewhat general confusion as to the definition of toxic dusts. The following explanation will, it is hoped, clarify this point to some extent. A toxic dust may be defined as any dust which in any way injures any part of the average body or reduces in efficiency the normal functions of any part of the body.

Organic and Inorganic Dusts

Organic Dusts are those which are derived from living organisms, dealing in general with the compounds produced in plants and animals and many other carbon compounds of artificial origin. Such dusts include those of wood, bone, shell, flour, grain, tobacco, leather, feathers, straw, wool, cotton, felt, and jute. (6)

Inorganic Dusts are those composed of matter other than animal or vegetable and include such as silica, sand, carbon (coal, soot) brick dust, marble, granite, terra cotta, cement, asphalt, enamel, glass, quartz, lime (gypsum, plaster), merschaum, phosphate (fertilizers), emery, diamond dust, metal filings (lead, brass, iron, steel, etc.), arsenic, and mercury. (6)

Terminology of Dust Diseases

The following terminology of dust diseases of the lungs (7) is now used by most writers on the subject (From Harrington and Davenport (1):

Pneumoconiosis -- A general term covering all dust diseases of the lungs, fibrous or non-fibrous. (From Greek pneumon, lung and konis, dust).

Silicosis -- A fibrosis caused by free silica (or quartz) and the best known scientifically of the dust diseases of the lungs.

Silicatosis -- A type of fibrosis found after exposure to certain mineral dusts and assumed to be caused by various silicates. It is distinct from the sharply defined, coarse, nodular fibrosis caused by silica dust.

Anthracosis -- A dust disease of the lungs found in coal miners; it is ill-defined and is presumed to depend on inorganic dust in coal. The lungs are black.

Siderosis -- A term applied to a fibrosis of the lungs found in metal workers. The condition is ill-defined. The lungs are yellow or red from metallic oxides generally iron.

Asbestosis -- A fibrosis of the lungs with characteristic microscopical stigmata (sign of defect) due to breathing asbestos dust, a silicate of magnesium.

Silicosis

Although, the disease known as silicosis falls under the general classification of pneumoconiosis, it is usually specifically dealt with under the title of silicosis because this term is less unwieldy and usually describes accurately the particular disease under discussion, namely that arising from the inhalation of free silica. Some writers still do describe this disease under the heading pneumoconiosis or phthisis, but these seem to be rapidly giving way to the term silicosis.

Pathology

The lung may be said to resemble a large sponge with a large number of small air passages. Its function is to permit an interchange of gas between the blood and external air. That is, the lung or sponge draws in air from the atmosphere and in turn supplies it to the many small boood vessels which are connected to these air passages or cells, where it is absorbed into the blood stream. As the lung is in free communication with the atmosphere, it is more or less exposed to the action of impurities present in the external air both of a particular and gaseous nature. However, nature has provided certain mechanisms to protect the lung from the accumulation of foreign matters. The nose which provides the initial opening into the respiratory system is the first line of defense and this organ is lined with a thick filter of coarse hair which effectively removes most of the larger impurities. Behind the nose is a series of winding passages with moist walls which trap many of the smaller particles. In addition, the other portions of the respiratory tract, the pharynx, the trachea, and the bronchi are lined with cells containing minute vibratory cells, called cilia. These cilia are small wavelike hairs which by their action tend to carry particles lodging on their surface away from the lung and back toward the surface.

Particles that succeed in passing these traps penetrate directly into the terminal air spaces of the lungs. Lurking between these air spaces are a number of cells called phagocytes or scavenger cells. These cells are the watchdogs of the lung and their duty is to rid the lung of any foreign particles that succeed in passing the barriers. As the particles enter the air spaces, they are seized by the every watchful phagocytes and carried off and deposited into a special drainage system known as the lymphatics. The lymphatics are minute vessels or ducts which serve to convey the foreign substances deposited by the phagocytes to special waste basins known as lymph nodes. From this point, the particles tend to be removed from the lung and to pass into the waste system of the body.

The above action is that which takes place in a normal lung with ordinary amounts of lung pollution. However, as the amounts of dust reaching the lung become excessive, then the trouble begins. Natures's protective mechanisms are no longer able to entirely cope with the abnormal burden being imposed on them and their efficiency gradually decreases. The phagocytes are forced to work overtime continually in removing the particles from the air cells of the lungs and their effectiveness becomes less until soon they are succeeding in removing only a part of the foreign substance. Those particles which are not removed from the lung cells remain there and slowly begin the process known as fibrosis. Likewise, the drainage basins, or lymph nodes find themselves confronted with a similar problem, namely that they are unable to throw off as waste the increasing amount of substance being deposited by the lymphatics or waste conveying ducts. In silicosis, these lymph nodes are the first to show signs of fibrosis.

How Fibrosis of the Lungs is Produced - For many years it was believed that the fibrosis condition characteristic of silicosis was caused by the irritating action of the hard, crystalline quartz or free silica on the lung tissues. While this view has some merit, most modern authorities are of the opinion that silicosis is not the result of a physical action but of a chemical one. Just how this chemical action takes place is not definitely known but the result is that the silica present in the lung tends to dissolve in the lung tissue. As this chemical process continues, the normal lung tissue is gradually replaced by a form of scar tissue. With the continued exposure to harmful quantities of fibrosis producing dust, naturally more and more of the healthy lung cells are converted into this hard, crystalline formation. The ultimate result then of this deleterious process is the formation of what is known as a "silicotic lung".

There are several other theories advanced by authorities as to the action of silica in producing silicosis but the foregoing principle is sufficiently substantiated by reliable medical testimony to insure its reasonable accuracy.

The Sericite Theory of Silicosis - Although most writers seem to agree readily that silicosis is the direct result of inhalation of free silica, there remain a few who do not accept this theory. For example, Jones (8), after considerable investigation among stoneworkers and miners came to the conclusion that silicosis was not the result of "free silica" or quartz but of a substance known as sericite, a silicate. Jones sums up his conclusions by saying that the mineral residues he has obtained from silicotic lungs show definitely that it is not quartz or any kind of free silica that forms the bulk of these residues. He suggests that silicosis is not mainly due to free silica, as has hitherto been accepted, but to silicate minerals occuring in the form of minute fibers loosely held together in the rocks so that, during handling, drilling, and blasting, they are readily freed into the atmosphere and inhaled into the lungs.

This theory is, as yet, relatively new but it is believed by some writers to be worthy of consideration.

The Carbon Dioxide Theory of Silicosis - One authority, Edge (9), advances the theory that silicosis may be caused directly as the result of gas bubbles of carbon dioxide in immense quantities, contained in minute cavities in the quartz. Mr. Edge's theory is based on the belief that these gas bubbles in the quartz cavities are under a tremendous pressure of more than a half ton to the square inch and that when these quartz particles are dissolved in the lung tissues, a tremendous pressure is suddenly released. The compressed carbon dioxide, when released, would almost instantaneously expand to about 400 times the volume which it occupied in the cavities. Just what would happen if these quartz particles disintegrated and discharged their pressure into the lung cells does not seem to be clearly known but the possibilities are believed by some to be food for thought.

Whether or not silicosis is the result of free silica alone, sericite, or carbon dioxide gas bubbles exerting abnormal pressures, is a subject worthy of a discussion of its own. However, the predominance of medical evidence points to "free silica" as the predisposing factor in the promotion of this dust disease, and on the basis of almost conclusive testimony, this theory, at least for the present, must be accepted as the most reliable.

The Effects of Lung Fibrosis - So far, only the factors producing pulmonary fibrosis have been discussed. It now remains to be seen just what effect this fibrotic condition may have on the human system.

These changes in the normal lung structure, according to Goodrich (10), which seem to accurately describe the result, make the lungs less elastic, increase their bulk, make aeration of the blood less efficient, and decrease circulation through the lungs. As a result, a more vigorous respiratory effort is necessary to supply the blood with an adequate amount of oxygen and to remove the accumulated carbon dioxide in the blood. An increase in inspiratory effect is needed to create greater negative pressure within the chest in order to draw into the less elastic lungs the same amount of air, and an increase in the normal air volume is needed because of the decreased aeration of the damaged alveolar structures (lung cells) and the impaired circulation through these alveoli. As the volume of the lungs increased from the continuing deposit of silica and the increasing amount of fibrous tissue, the chest gradually is held, and later fixed in a position of partial inspiration, and breathing becomes more and more diaphragmatic. Even diaphragmatic breathing eventually becomes less efficient because of the usual development of a basal pleurisy which causes the inelastic lungs to adhere to the upper surface of the diaphragm. (1)

The Relationship of Tuberculosis to Silicosis - It is seldom that a fatal case develops from silicosis alone. Post-mortem examinations usually reveal that death was due to complications from other respiratory infections such as tuberculosis or pneumonia. The silicotic lung seems to provide a very fertile field for bacterial infections to begin their work. Most writers seem to agree that this is probably due to the irritation of the respiratory tissues by the inhaled dust particles which weakens the mucous membranes and renders them susceptible to infection. Also, the toxic effects of certain inorganic dusts on the tissues may be a contributing factor. (11)

There can be do doubt that the silicotic lung is a weakened tissue and as such is less able to resist the attacks of infectious bacilli than the normal lung. There are those who also believe, and reasonably enough, that the infected lung, in turn, accelerates the progression of silicosis. If the latter is true, then the inhalation of silica dust into the lungs evolves into a "vicious cycle". That is, the silica first promotes infection and the infection in turn promotes silicosis. It would seem, that under such conditions, the exposed worker would have very little chance.

Symptoms of Silicosis

The following symptoms (1) of silicosis are based on the findings of 9,662 examinations of 7,722 employees at the Picher Clinic of the Bureau of Mines (12).

Shortness of breath has been generally recognized as the principal symptom of silicosis. This dyspnea or shortness of breath accompanies exertion in the earlier stages of silicosis and increases progressively until in the later stages it often prevents any labor. The apparent distress on exertion frequently noted in silicotics who deny shortness of breath seems out of proportion to the very slight rise in pulse rate taken 2 minutes after exertion.

Chest Pains were admitted frequently, generally anteriorly or toward the front but more often on one side only. In many instances, the pains seemed of a reflex character. In nearly all cases they were vague and flitting and did not seem to interfere with manual labor. Pains in the shoulder and possibly in the posterior part of the chest probably are considered by many of the men as "rheumatic"; such pains seem partly responsible for the large number of complaints of rheumatism.

Cough is a symptom frequently admitted in silicosis and generally is unproductive or dry.

Expectoration as a symptom was admitted infrequently. When present in uncomplicated silicosis, the sputum usually is clear or has a bluish tinge and is of a viscid, tenacious consistence, very difficult to cough up.

Hemoptysis (spitting of blood) appeared to be more common among silicotics than was expected. In some instances, particularly in second as well as in third-stage silicosis, fibrotic areas may mask a tuberculosis lesion which remains unrecognized until it becomes an open lesion, when the sputum will show the tubercle bacilli, or hemorrhage will call attention to the true condition.

The loss of strength admitted by silicotics in most instances probably was connected with their dyspnea or exertion and was due to respiratory insufficiency. This probability is strengthened by the small number of silicotics with poor physical development (4 of a total of 1,062).

Gastrointestinal symptoms were pronounced in the more advanced cases and loss of appetite was admitted. Other pronounced symptoms in advanced cases of silicosis were constipation, epigastric (stomach) discomfort, and other vague complaints which the men termed "indigestion". The causes of the gastrointestinal symptoms were not ascertained.

The following clinical findings in silicosis, as summarized by Sayers (13) will be of interest to the diagnosing physician and will not be readily understandable by the average laymen. Sayers writes as follows: "The practically constant clinical signs are; A certain lack of elasticity of the chest wall during the movements of respiration, together with a somewhat reduced air entry, and a characteristic alteration of the inspiratory murmur from the normal "vesicular" character to a higher pitched or "harshened", "thinned", and commonly somewhat shortened type, the expiratory murmur, although somewhat prolonged, remaining fainter than the inspiratory:

This type of breath sound is very characteristic, with some modifications, of silicosis in all its stages, and this clinical sign has also the significant character of more of less complete generalization. It is first noticeable at the anterior, lateral, and basal regions. (13)

In the minority of cases, however, the breath sounds may be simply diminished, but breath sounds which are simply diminished or which, on the other hand, are merely somewhat louder or more "pronounced" than normal are not specifically characteristic of silicosis.

Usually there are not accompaniments, but a stray ronchus may be heard here and there.

This complex of physical signs (13) is almost constantly present in cases of a slight degree of "simple silicosis". The cough may be put down to the coincident bronchitis and bronchiolitis, the recurrent pains, to slight intercurrent local pleurisies.

Stages - With respect to the classification of silicotic appearances based upon known pathological changes (1), Pancoast and Pendergrass (14) suggest the following stages:

1. Peribronchial-perivascular-lymph node predominance or type. This may be rapid or slow, usually the latter.

2. Early interstitial predominance. This may be extremely or moderately rapid, depending on the silica intake. It may or may not have an associated slight nodular appearance.

3. Advanced interstitial predominance.

4. Nodular predominance. Rapidly or slowly progressing.

5. Advanced diffuse or terminal fibrosis.
   Conglomerate nodular type.
   Interstitial type.
   Massive fibrotic type.

The above clinical manifestations of silicosis symptoms cannot be regarded as absolutely conclusive because various specialists have their own methods of diagnosis and it would be highly improbable for any two authorities to exactly agree on all points concerned. However, it should be recognized that the above findings are not based on any casual observations but are the result of intensive and exhaustive studies into the field of silicosis by some of the greatest known authorities on this subject. Because of the undenied reliability of this testimony, it should be of considerable assistance to those physicians encountering, for the first time, cases of suspected pulmonary fibrosis.

The recognition of symptoms is a very important step in the control of silicosis by the industrial physician, but this must be regarded as only the first step in the proper handling of the disease. There is no substitute for correct and positive diagnosis after the possible existence of silicosis is discovered, for it is only in this way that the physician can accurately determine whether or not the disease is actually present and to what extent it has progressed.

At this point, it seems advisable to offer a few words of caution to the industrial worker. SELF-DIAGNOSIS should never be reverted to. If even the experienced industrial physician finds it difficult to recognize this disease with all his medical knowledge and equipment at his disposal, it is not at all likely that the average layman could be successful. If the workman believes he is exposed to silica in harmful concentrations and that it is affecting his health, he should immediately consult with a physician qualified in this type of work. He should also tell his employer of his fears. The employer can then call in experienced state industrial engineers so that dust tests can be taken at the point of exposure. The results of these tests will greatly aid the physician in the proper diagnosis of the workman's condition. It may prove that what the worker believed to be silicosis is only a minor ailment which is of no serious consequence. Also, the dust analysis may reveal that the dust which the man believed to be silica, was not silica at all and that his fears were groundless. Above all, the workman should never assume that he is exposed to silica and as a result is contracting silicosis. It is undoubtedly true that many workmen would continue work, without complaint, even if they believed that by doing so they were injuring their health and decreasing their span of life. Such men are afraid to complain of either their health or working conditions for fear of being replaced by younger, more efficient men. Thus through ignorance, these men may fear an exposure that does not even exist. Such a fear may have been created through erroneus information or by a belief that wherever there is dust there must exist silicosis. Fear is undoubtedly the worst enemy of mankind and the fear of disease has probably caused more deaths than disease itself. This state of mind in the workman cannot help but have a serious effect on his health. Today, there is no need for such guesswork. Ample facilities are now provided the worker, through medical aid contracts, medical associations and clinics, so that there is no longer any necessity for him to remain in ignorance. It is hoped that the industrial employee will awake to realize that every possible effort will be made to guard his health if he is only willing to take advantage of the protection offered.

Diagnosis of Silicosis

To those readers, who are not students of medicine or industrial hygiene, the following discussion on the diagnosis of silicosis, will be, for a large part, of little value because of its more or less technical nature. Nor is it essential that the average reader be familiar with the medical terms involved. It is to the diagnosing physician that we must look for medical control and it is for his interest that this is primarily written.

According to the Silicosis (Medical Arrangements) Committee of Great Britain (1), (15), silicosis can be diagnosed even in its earliest stages but the diagnosis is often accompanied by difficulties. For instance, the clinical signs of silicosis resemble to a great extent those of other chronic diseases of the chest. Also silicosis may be complicated by the presence of tuberculosis in any stage. Irvine (16), states that it is impossible to deduce a practical standard of diagnosis from accounts of the disease furnished separately by the pathologist, radiologist, and the clinician. Clinical examination is obviously an essential factor in the decision in any individual case since it provides important information not otherwise available such as; the general and local condition of the patient; the degree of incapacitation, if any; and the presence or absence of complication by active infection or by diseases of other organs.

However, with a disease like silicosis, (16), clinical evidence is in many cases inconclusive and may be misleading. Other means of diagnosis are radioscopy, radiography and as the last result the pathological conditon found after death.

Radiography also has its limitations, as on the one hand, not all forms of pulmonary fibrosis revealed by it are of silicotic origin, and on the other hand, certain types of radiograph, which do not show clear and specific signs of silicosis, may in some circumstances be regarded as affording legitimate evidence as to the presence of the disease.

An accurate and reliable general standard of diagnosis for the disease silicosis can be obtained only by correlation of the results of pathological observations in a large number of cases, with radiographs taken from the chests of the same individuals shortly before death, and with the results of clinical examinations made during life. Also, the final adjudication in any individual case must always incorporate the additional evidence supplied by expert clinical examination, which frequently becomes the deciding facter in borderland cases. (16)

Further valuable information as to the proper method of diagnosis of the disease comes from the examinations at the Picher Clinic (1), (12) which included collection of data on race, family history, personaly history, past history of illness, occupational history and physical, X-ray, and laboratory examinations. A brief summary of some of the results of the examinations follows:

Family History - The incidence of silicosis or silicosis complicated with tuberculosis was found to increase as the family histories of the men were classed as good, average, or poor.

Personal History - The use of tea, coffee or tobacco apparently has no relation to silicosis or tuberculosis; but after silicosis has developed, the use of alcoholic drinks and patent medicines increases decidedly; the men take these to alleviate the symptoms of silicosis so that they can continue work.

A study of age groups in published results of several investigations on silicosis shows that in the early years of the occupational life of those in dusty operations, the incidence of silicosis is low, but with increase in the age group, regardless of length of employment, it increases slightly up to about the age of 40, after which there is a marked increase. Age, therefore, has an important bearing on the occurence of silicosis and should be considered in employing men for work in dusty atmospheres.

Past History of Illness - The data seem to indicate that all infectious diseases of childhood except diphtheria and scarlet fever probably decrease resistance to tuberculosis and silicosis. Men who have had malaria in the past seem to have a high incidence of tuberculosis and silicosis. Tonsillitis, especially if the attacks are recurrent, seems to be associated with tuberculosis but apparently has no relation to silicosis. The highest incidence of tuberculosis, silicosis, or both was among men who reported bronchitis, pleurisy, and asthma. The lowest incidence was among those who reported influenza, pneumonia, coryza, and hay fever. An unknown and distrubing factor in the attempt to discover a relationship between silicosis or tuberculosis and other diseases was the difficulty in determining in many instances whether they occurred before or after silicosis and tuberculosis had been contracted. The data shows that the incidence of physical defects increases among men with silicosis and tuberculosis. Several explanations are offered for this fact; men with silicosis or tuberculosis usually are somewhat older than men in the essentially negative group; the silicotics have a much longer period of service in the mines than the negative subjects; certain physical defects may increase susceptibility to silicosis.

Nasal obstructions and chronic catarrh, enlarged turbinates, adenoids, or other conditions that cause mouth breathing are associated with an increase in the incidence of silicosis. Persons having a vertical hanging heart are more likely to develop tuberculosis or already have it. (12)

Occupational history - A detailed statement of occupation is the most important single item in the history of the silicotic.

Physical examination - No marked symptoms of ill health such as, paleness, loss of subcutaneous fat, or decrease in muscular development appear until silicosis is complicated with tuberculosis.

As silicosis advances, weight shows a slight tendency to increase until the disease is complicated with tuberculosis. This increase may be due to some extent to the increase in age.

An analysis of systolic blood pressure by age groups shows that the blood pressure of the younger men did not change appreciably but that of the average of the older men who had silicosis was slightly higher than for those in the corresponding age group who were essentially negative. Clinical observation shows that the blood pressure of silicotics tends to remain normal or increase only slightly, but in tuberculosis cases it shows a definite tendency to drop. Any persistent marked drop in the blood pressure of silicotics indicates probable tuberculosis infection.

It is generally accepted that the cardinal physical finding in silicosis is diminished chest expansion. Emphasis should be put not upon chest expansion, but rather upon the importance of comparison with a man's earlier chest expansion. Probably, if the vital capacity were taken on a large, unselected series for comparison, the decrease in vital capacity in silicosis would be greater than any chest-expansion measurements, however carefully taken, would indicate.

The slight changes revealed by examination of the heart probably could be attributed to the ages of the silicotics. (12)

Determination of Silicosis by X-ray - The most reliable means of detecting the prevalence of a silicotic condition is by use of the X-ray. However, before the full benefit can be realized from this type of examination, it is highly important that both the technician taking the pictures and the one interpreting them be thoroughly familiar with this work.

According to Pancoast and Pendergrass (1), (17), the ability to interpret roetgenograms (X-rays) of cases of pneumoconiosis properly must be based upon several very important factors which may be enumerated as follows: A knowledge of the anatomy of the chest and many of the physiological problems associated with its anatomical constituents; thorough familiarity with normal roetgenographic and flouroscopic appearances and permissable variations therefrom within the normal limits; knowledge of the histology of the lungs and especially of the lymphatic system; clear perception of the pathology of the condition of pneumoconiosis and of all conditions which may simulate it in roetgenographical appearances; experienced intimacy with the roetgenographic appearances of the condition in question and of those that resemble it, based upon fundamental knowledge of the pathology represented; knowledge of the physical factors involved in the production of the suspected or alleged pneumoconiosis; and the employment of the proper technique to show to full advantage, any or all of the abnormalities present, for technique may fully enlighten, may so modify appearances as to be confusing, or may be quite misleading. (17)

According to the above authorities, the roetgenological phases of this condition may be summarized as follows: (17)

1. The perivascular-peribronchial-lymph node aspect is due to the relaying of phagocyted dust to the pulmonary lymph nodes and their subsequent enlargement and ultimate partial fibrosis to the gradual enlargement of lymphoid deposits along the course of lymph vessels and the subsequent thickening of these vessels and the stasis of contents. This is characterized roetgenographically by increased prominence of the hilum and trunk shadows and linear markings. This appearance is by no means characteristic of pneumoconiosis alone, and even if it does indicate the condition, the phase is absolutely not incapacitating. There is also a barely perceptible appearance of macroscopic nodules.

2. The nodular aspect is due to the gradual enlargement of lymphoid deposits and their coalescence into quite apparent macroscopic nodules symmetrically scattered throughout both lungs. It is conspicuously absent in many industries, especially when the silica intake is rapid.

3. The interstitial type of the condition results from a hilumward and pleuralward block in the lymphatics and the escape of dust phagocytes in large numbers into the interstitial interalveolar tissue and subsequent fibrosis. It appears as a faint homogeneous haze, first on the right side, then on the left. If the silica intake is comparatively slow, it may accompany the perivascular-peribronchial-lymph node aspect, but if more rapid,

it may be associated with the nodular type or may progress without the latter directly into the terminal stage of the condition without any evidence of nodulation. The unprotected or inadequately protected sand-blaster, sand pulverizer, and sandstone abrasive worker or granite cutter have been among those especially prone to present this rapid interstitial aspect.

4. Terminal and incapacitating silicosis is characterized by three general appearances - a terminal diffuse fibrosis of a conglomerate nodular type, one which is quite similar in appearance to a generalized chronic fibroid tuberculosis, and the terminal stage characterized by large fibrous consolidated areas, which closely resemble tuberculous consolidations quite frequently, but which we are now learning to differentiate one from the other. (17)

Importance of Proper Diagnosis. The value of the X-ray or roetgenogram cannot be overestimated in the proper diagnosis of pulmonary fibrosis. Absence of physical symptoms should never be considered as a positive assurance that the condition is not present.

For example Smith (1),(18), points out the striking discrepancies between symptoms and physical signs and pulmonary fibrosis as shown by the X-ray. In a study of rock drillers in the vicinity of New York, 25% of those whose X-rays showed unmistakable silicosis had no symptoms whatever, and in a recent study of granite workers (19) in the same locality, 6 cases of 17 with advanced silicosis had no symptoms. Smith quotes an incident reported by Watkins-Pitchford (20); of a group of 541 miners who had been receiving compensation for silicosis on the basis of physical examination alone, 41% were found not to have it when X-rays were introduced. This authority considers a physical examination somewhat of a luxury where large groups of workers are being examined for silicosis and advances the opinion that where economy of time and expense is desirable, it would seem legitimate to limit the examination to a good roetgenogram supplemented by occupational history.

The examination of the roetgenogram only however, should not be assumed to offer conclusive evidence of the pathological condition and this should be supplemented by the occupational history, and clinical examination of the patient during life. If, after death, a doubt still lingers, a chemical examination for the quantitative determination of silica aids in reaching the correct diagnosis.

Medical Control of Dust Diseases

As yet, medical science has devised no definite cure for pulmonary fibrosis. This can certainly not be attributed to a lack of sincere effort on the part of those men who have unselfishly devoted years of labor to this major industrial problem, but the very nature of the disease seems to offer a problem that baffles its solution. There appears to be no way of re-establishing the normal, healthy structure of the lung once a fibrotic condition has begun to progress.

At the present time considerable research is being done in this country at the U. S. Bureau of Mines, Saranac Lake, and Rochester and it is hoped that these studies will in time shed additional light on the subject of medical control.

It was first believed that the disease was not of a progressive nature and that if the victim were removed from the source of exposure, that the disease could be successfully arrested at that point. The generally accepted opinion among medical authorities now, however, is that a case of silicosis, once begun, continues to develop after the person has been removed from exposure. This contention is substantiated by medical records which show cases of death from silicosis several years after men had discontinued work. This is not meant to infer that once a case of silicosis is initiated, the patient has no choice but to sit back and patiently await ultimate death, because it is entirely possible that he may live to a "ripe old age" and outlast those who never heard of the term "silicosis." However, it is most essential that the condition be recognized before irreparable damage has been done.

The best accepted theories as to what to do for the silicotic patient seem to be to remove him from exposure, allow him to be up and around, and not to send him to a sanitarium, at the same time treating him for cardiac impairment, tuberculosis and bronchitis that are likely to ensue. (1)

There has recently been advanced the theory that certain dusts may serve as curative agents and a few authorities claim some measure of success using this method. The use of such dusts as curative agents as well as preventive will be discussed in detail in another section of this writing. However, it should suffice at this point to say that such a belief is not upheld by the majority of experts because of the lack of definite clinical proof. Its future possibilities should not be overlooked though, for when one is "grasping at straws", every reasonable solution should be considered.

<u>How Medical Control Can Best Be Effected</u> - In order that the full value of medical control can be realized, a program along the following lines is essential:

1. Establishment of an adequately equipped medical department. - The men entrusted with this work should be thoroughly qualified and with some experience, at least, in problems of this nature. In addition there should be provided ample facilities for adequate roetgenographical examinations.

2. Routine examination of all applicants for employment. - This should not only consist of a physical examination but should include that of family history, personal history, and past history of illness. This examination is the most important medical weapon in the control of dust diseases. By this method, certain defects and diseases that would render the employment sought by the applicant hazardous to him, as well as to his fellow workers, can be uncovered. This is not meant to imply that employment in industry should be reserved only for those men who are healthy and physically competent and thus deprive those who are less fortunate in participating in gainful occupations for there remain positions in every plant of reasonable size that can be filled very efficiently by persons with substandard conditions of health. It would not be fair, however, to the employer, fellow workmen, and especially the workman himself if he were allowed to participate in work that would further complicate his condition.

3. Selection of workers for employment. - This phase of the program has been substantially covered under (2) and applies to the placing of workers in positions to which they are best suited. Thus a man of sound physique and with a good reserve of respiratory capacity should be selected for the work of a dusty nature in preference to one whose past history indicates susceptibility to respiratory diseases or who now is afflicted with such an ailment. The question of age also enters into this phase of the program and as a general rule persons over the ages of approximately 50, unless their physique is exceptional, should not be confined to occupations where a known dust hazard exists. This is based on the fact that in persons of around this age, there is an increased tendency to a reduction in the expansile power of the chest wall and a proneness to bronchitis and emphysema. Also, there is apt to be an increase in the amount of fibrous tissue as age advances.

4. Periodical physical examinations. - It is highly important that workers engaged in hazardous occupations be examined at regular intervals so that the presence of any new pathological symptoms may be detected. Probably the best means of accomplishing this is by the use of the X-ray but if this method proves impractical, the fluorscope may yield the information for which the physician is searching. Such an examination when compared to the X-ray film taken upon admission for employment should enable the examining physician to detect any serious changes in the employee's condition.

Perhaps the above program may be termed by some as that of an idealist but it is only by the utilization of at least a part of these methods that any progression can be made in medical control.

Principal Dust Factors Influencing Pulmonary Disease

It is now generally believed that the principal factors to be considered in determining whether exposure to dust will produce pulmonary disease are; (1) Nature of dust, (2) particle size, (3) quantity of dust, and (4) the length of exposure.

Nature of Dust. Free silica or quartz has come to be regarded as the outstanding dust factor in the promotion of dust diseases in industry. It has the chemical formula SiO_2 which indicates that is is a combination of the element silicon and oxygen. When it occurs alone or in the free form, it is known as silica or "free silica", and when it appears in combination with other elements, it is called "combined silica".

Silica occurs most frequently in nature in various forms and is roughly regarded as constituting approximately 60% of the earth's crust. For example, quartz and rock crystal are made up of free silica in the pure crystalline form. Other minerals whose essential composition is SiO_2 or free silica but which have been changed in color and appearance by the addition of oxides from other elements are agate, amethyst, bloodstone, cat's eye, flint, onyx, opal, and rose quartz. Many common rocks contain a high percentage of free silica such as sandstone which is composed essentially of quartz with some feldspar, mica, and other materials added; quartzite, a product of sandstone; ganister, a sedimentary rock with a very high percentage (about 98%) of free silica; granite, composed essentially of quartz and feldspar, containing 25 to 35 percent of free silica; and pegmatite, a form of granite. Ordinary sand is almost entirely quartz or free silica. (1)

Combined silica (silicates) occurs in almost every rock species and forms the essential substance of such common materials as clay, mica, feldspar, slate, and asbestos (1).

This element or its compounds possesses many qualities which make it of industrial value such as, hardness, resistance to solution (even in acid), resistance to heat under some conditions, and resistant to temperature changes and for these reasons, as well as others, is used quite widely throughout industry in various sizes, shapes, and forms.

Following are some of the industrial uses of silica: (21)

1. As an abrasive in the manufacture of scouring and polishing soaps and powders.
2. In the manufacture of sandpaper.
3. In sand blast operations.
4. In metal buffing, burnishing, and polishing.
5. For sawing and polishing granite.
6. In the manufacture of whetstones, grindstones, buhrstones, pulpstones, and oilstones.
7. In the manufacture of tooth powders and paste.
8. For wood polishing and finishing.
9. In the manufacture of silica firebrick and other refractories.
10. In foundry-mold wash.
11. As a foundry parting sand.
12. In the manufacture of carborundum.
13. In the manufacture of paint, as an inert extender.
14. In the manufacture of fertilizers and insecticides.
15. As a filler in rubber, and hard rubber pressed and molded goods.
16. In the manufacture of road asphalt surfacing mixtures.
17. In the manufacture of ceramics, such as pottery.
18. In the manufacture of building stone.
19. In the manufacture of ordinary glass.
20. In the manufacture of lenses and optical apparatus.

At this point it seems wise to emphasize the fact that the above is only a brief summary as to where silica may be found in industry in either free or combined forms and does not necessarily mean that a silicosis hazard may be deemed to exist in all of these instances. It should not be lost sight of that there are still four factors that must be considered before a harmful exposure is said to exist, namely, nature or type of dust, particle size, quantity, and length of exposure. Also, it should be mentioned that although free silica is regarded as the most serious of the fibrosis-producing dusts, it is not the only dust capable of producing disease. For instance certain of the silicates such as silicate of magnesium (asbestos) are now recognized as promoting definite pathological conditions in the lung. Sericite or hydrated silicate of aluminum and potassium has already been mentioned as a factor to be given serious consideration. Nor should it be assumed that the silicates or free silica are the only types of dust producing pulmonary disease. Any dust-filled lung should be regarded as an unhealthy lung from which are liable to proceed various diseases, be it fibrosis, tuberculosis, asthma, bronchitis, emphysems, pneumonia, or others. It is merely because silica and the silicates are recognized as producing the more serious damage to the human system, and because its use is encountered so frequently in industry, that it is usually given primary consideration.

Particle Size. The size of the dust particles to be considered in the production of lung diseases has already been discussed previously in the chapter titled "Definition and Classification of Dusts." In order for a dust to damage the lung it must first reach the lung and, as pointed out before, such particles are generally recognized as being from .5 to 10 microns in size, a micron being equal to 1/25,000 of an inch. It is these particles that escape beyond the protective devices of the upper respiratory tract, which must be regarded as dangerous. The particles larger than this are effectively thrown off by the human system and are not regarded as a factor to be considered in the development of pulmonary disease.

It follows, that the smaller the dust particles, the more likelihood of their entrance into the lungs and for this reason those particles ranging from .5 to 2 microns in size are the ones believed to be the most dangerous.

Not only do these particles pass more readily into the lungs, but because of their size, they remain in suspension in the working atmosphere for longer periods of time. For example, it has been estimated that the smaller particles of dust may take as long as from 6 to 8 hours to settle to the working floor. This means that the dust will remain in suspension at the breathing level for possibly several hours after the dust-producing operation is completed.

Another important factor to be respected in connection with these smaller particles when considering their inherent nature is, that such dusts are invisible and unless the employer and employee are warned, they are not aware that a hazard exists. The measurement of such dusts can only be determined by the use of a konimeter or other dust sampling instrument.

Quantity of Dust. It is somewhat difficult to establish definitely just how much dust must be present in the air before a hazard may be said to exist. In considering the disease silicosis, most writers now believe that the liability is directly dependent upon the amount of free silica contained in the dust. As a result of an extensive study of the granite industry, the U. S. Public Health Service has arrived at the opinion that free silica present in the working atmosphere in quantities of approximately 5,000,000 particles per cubic foot and more constitutes a definite health hazard. This, of course, refers to those particles of a size less than 10 microns.

Since the ability of a dust to produce silicosis depends on the quantity of free silica present, it is obvious that the permissible dust amount will vary with different industries. For example, granite contains approximately 35%

free silica and therefore a dust count of 14,000,000 particles or less in the granite working industry should be a reasonably safe limit. On the other hand, where sand blasting is done with quartz sand of about 90% free silica content, the allowable safe dust concentration would be about 5,500,000 particles. It can thus be seen that before establishing a definite threshold limit in any industry, there must first be a thorough knowledge of the material being used and the type of work being done. In many cases the free silica content of a dust can be determined only by chemical analysis. This analysis in many instances is the source of considerably error as there seems to be a long-established convention of reporting the chemical analysis in terms of chemical compounds rather than elements. For instance, in analysing average granite all of the silicon is isolated in the form of silica and its chemical analysis would report it as containing about 70% silica. However, only about 35% of the granite consists of silica while the remainder is made up of silicates, chiefly feldspar and mica. It is for this reason that the term free silica was originated in order to distinguish between the silica that goes to make quartz and the combined silica or silicates. Furthermore certain rocks that show as much as 69% silica on analysis may actually contain no free silica or quartz. Since the danger of silicosis to workers in certain dusty trades is determined chiefly by the amount of silica present in the free form, it is important that this distinction be accurately made.

Length of Exposure. After establishing the fact that an exposure exists, the period of time required to produce silicosis seems to depend upon the individual. Some persons are more physically capable than others in warding off the effects of dust and these workers may continue in dusty operations without any apparent damage for many years.

However, it has been shown that silicosis may develop after relatively short exposure. For example, the United States Public Health Service, in an investigation of the granite industry (1), (22), found that in the group of workers exposed to the heaviest dust the first case of silicosis appeared after approximately 2 years, and by 4 years all in this group seemed to have developed at least an early case of silicosis. In the same group the first case of more developed silicosis appeared after 5 years of service, and by 9 years approximately 90 percent had advanced to this stage. In the group with an average exposure of less than 10 million particles per cubic foot of air, 2 cases of early silicosis had developed after 10 years' exposure and 1 case of moderate silicosis after 6 years.

In a further study (1), (23), as to the effects of exposure to dust in coal mining the Public Health Service found an apparent relation between the occurrence of generalized fibrosis and length of time the workers had been employed in the industry. The percentage rises from 4.8% in the group with less than 5 years' service to 69% in the group with more than 15 years' service; even if attention is confined to workers under 45 years of age, the percentage in the group with more than 15 years' service is 66.7%.

Pancoast and Pendergrass (1), (24) found that the longest period of occupation in a sand-pulverizing plant was 2.5 years at intervals, and the shortest was said to have been only 35 days during a period of a little over 1 year before symptoms of lung affection appeared.

Quaintance and Morris (1), (25), examined 58 pottery workers in an industrial plant manufacturing bathroom ware, using a silica content of approximately 25 percent. After an average exposure of 16 years 8.6% of these workers had advanced fibrosis; 38% had second-stage or moderate fibrosis, and 63.5% had only slight fibrosis.

Chapman (1),(26), reported three cases of acute silicosis, among the first cases in American industry, in which the appearance of respiratory symptoms after 8, 21, and 29 months of exposure to an alkaline dust of high silica content marked a more rapid and severe silicosis than usual. According to Chapman, Russell (27) saw the disease fully developed in a lens grinder who inhaled a pure quartz spray for 8 months. McDonald (1), (28) described the rapidly fatal cases of two young girls who had been employed 2.75 and 4.25 years packing a silica soap powder.

From the foregoing testimony it appears that it would be extremely difficult for one to set a prescribed time limit in which silicosis would develop. The best and most practical method of checking the onset of the disease is by periodic physical examination.

It has been shown what the principal factors influencing dust disease are. It now remains to be seen in what industries the exposure may be found and to what degree a hazard exists.

A Study of Dust Exposure in Industry

It would be impractical to discuss in detail all the sources of exposure to inorganic dusts in industry both because of the many varied operations conducted and because in many cases the existing information and statistics are not complete.

However, it does seem well to devote some space to a few of the more important industries where health hazards are known to exist and concerning which there is considerable medical and scientific data.

The Foundry Industry (1) -- In a survey of 225 foundries conducted by the Special Industrial Disease Commission of Massachusetts (29), there were made 1,614 physical and X-ray examinations. In the foundries studied, excessive dust counts were found in connection with many of the operations. The need for effective control of dust conditions was evidenced by the fact that silicosis was found in 8.8%, and silicosis with tuberculosis in 2.6% of the workers examined.

McConnell and Fehnel (30) in a study of this same industry, found that the death rate from respiratory diseases (including all forms of tuberculosis and influenza) for iron and steel foundry workers was about two and one-third times that for the average of workers in all industries combined. More than a third of all deaths among foundry workers were caused by some form of respiratory disease, whereas but little more than one-fifth of the deaths in all industries combined were due to these causes. One outstanding fact revealed was that the rate of pneumonia, bronchitis, etc., was nearly three times as great for foundry workers than for that of all other workers combined. Among iron and steel molders, founders and casters, where 12 deaths from pneumonia might have been expected, there actually were 38--a ratio of actual to expected deaths of 315%; 24 deaths were recorded for respiratory tuberculosis where 13 might have been expected--a ratio of 179%; the ratio for influenza was 216%, based on 23 actual compared with 11 expected deaths. In an analysis conducted by the Metropolitan Life Insurance Co. it was found the pneumonia was the leading cause of death among foundry workers, a condition not true of any of the other 71 occupations included in the survey. It is not probable that this higher incidence of respiratory diseases was due entirely to the dust inhaled, because foundry workers are also continually exposed to great variations in temperature and humidity which tend to weaken the human resistance, but McConnell and Fehnel emphasize the harmful effects of dust on the lungs of the workers exposed; 67 of 215 X-rays taken were diagnosed as positive for silicosis. Advanced cases of silicosis were not found among those examined, but sufficient evidence of occurence of the disease was presented.

The principal sources of dust exposure in the average foundry are in the application of parting compounds to foundry molds, the conducting of shake-out operations and in the abrasive cleaning of castings.

It is possible to control these dust hazards by the use of the following methods: (1) substitution of non-dust producing or harmless substances, (2) isolation of dusty processes, and (3) local exhaust ventilation applied at the point of dust generation. These methods have all been used with considerable success in many instances.

In considering that the chief source of exposure to foundry molders is from the parting compounds used, this hazard has been considerably reduced by the substitution of non-silicious compounds in place of the almost pure silica which was formerly used. Also with abrasive cleaning, the substitution of metal shot for quartz sand in many plants has resulted in a substantial improvement in health conditions.

With respect to the second preventive method, isolation of the dusty process, this may be used with great advantage wherever excess dust is produced. Unfortunately, although this method offers definite possibilities, it is not generally used. Many plants were designed and built before the comparatively new era of occupational disease recognition and prevention, and little thought was usually given to localizing the dust. However, if isolation is not practiced in some degree, not only is the workman performing the dusty operation exposed, but the other workers throughout the plant as well. A good example of the results from failing to isolate the dusty process is in the shake-out operation, where molders who may be exposed to a dust concentration of 6,000,000 particles per cubic foot under normal conditions are exposed to a concentration of more than 50,000,000 particles when shake-out operations are carried on near-by.

This same condition exists when annealing flasks containing ground slag are emptied in malleable iron foundries, frequently exposing grinders and tumbling barrel attendants at work close by.

One method of reducing the harm from shake-out operations, and one which has found wide use among foundries, is the limiting of this work to periods when a minimum number of men are present in the plant, such as during a night shift. However, although this procedure may result in considerable benefit, it cannot be said to be a completely successful isolation. It is only by carrying on the shake-out operation in separate quarters provided with adequate exhaust ventilation that positive isolation is realized.

The greatest need for isolation is in the process of abrasive cleaning, especially if sand blasting is used. This is the most harmful dust-producing operation in the foundry and should always be carried out in a separate enclosure, tightly sealed from the remainder of the plant.

brass foundries - While brass foundry workers are subject to the same general occupational hazards as ordinary iron and steel foundry workers, there is an increased exposure in this branch of the industry due to the enormous quantities of zinc oxide which is given off during smelting and casting. Statistics assembled by the United States Public Health Service show that a number of brass foundry molders suffer from what is called "brass foundry men's ague", caused from the inhalation of zinc oxide. The symptoms of this ague seem to be a general feeling of illness accompanied by a stiffening of the back and arms. Other symptoms which may be present are dull headaches, metallic taste, irritation of the throat, coughing, burning of the eyes and thirst. These first symptoms may develop into fevers or chills but the effects seem to pass off in a day or so.

The best and one of the cheapest methods of improving these conditions is by providing good exhaust ventilation and a plentiful supply of fresh air, say about one complete air change, in the areas affected, every 7 minutes.

abrasive cleaning - Abrasive cleaning may be accomplished by various methods depending upon the type and size of the castings being cleaned and the quantity. Roughly, these methods are divided as follows: (1) Rooms (2) Barrels (3) Tables (4) Cabinets. (Bloomfield and Dallavalle, 31)

Rooms - Abrasive cleaning rooms are usually constructed of heavy metal plate with dimensions approximately 10 x 10 x 8 feet high. The operator of the abrasive cleaning equipment should be provided with a positive pressure helmet, especially fitted to his person to prevent leakage of dust into the helmet, and provided with approximately 6 cubic feet of fresh air per minute. Considerable care should be exercised that the fresh air supplied to the operator is taken from a source free from any contamination.

In addition, exhaust ventilation should be provided for in every case. One of the best accepted ventilation practices for this type of work is to provide air inlet openings toward the top of the enclosure, in back of the operator, with the exhaust openings in the front wall beneath the location of the material to be cleaned. In this manner, the air passes down, over, and away from the operator, across the material to be cleaned and then into the exhaust openings. Thus, the cleaning spray tends to be always carried away from the operator's breathing level and reduces his liability to exposure considerably. Also, this method greatly facilitates the collection of the abrasive material which may be collected and re-used. It is very important that the air supplied through the openings in the top of the room should not be unduly cold or damp as this will subject the workman to a considerable draught and result in an unhealthy working condition. Air of an even, comfortable temperature should be introduced.

The exact amount of ventilation required in abrasive cleaning rooms has not been definitely established, but some of the modern types use from 8 to 12 and sometimes as high as 20 air changes per minute. The accepted level will depend to a large extent on the abrasive being used and the dust concentration present and can best be determined by a study of the particular conditions involved.

Barrels - This method includes two different types of abrasive cleaning. One is by the use of blast cleaning barrels, in which the material to be cleaned is placed in a sealed revolving drum or cylinder. An abrasive blast is then introduced by means of nozzles located in the drum and the revolving motion serves to bring the material under the abrasive spray.

The other type of barrel cleaning is that of the tumbling barrel. With this method, the rough castings are placed in a sealed cylinder along with metal shot or other pieces of suitable material. The revolving motion tends to bring all the materials into intimate contact and the fresh castings are thus cleaned. These barrels have, in the past, been sources of heavy dust concentrations but most of the modern equipment is so constructed that there is little opportunity for the dust to escape. Many old type barrels, however, which are still in use in many foundries, are still sources of much uncontrolled dust.

Tables - This type of abrasive cleaning is accomplished by means of a heavy, substantially constructed, slow revolving table of approximately 7 feet diameter on which the castings to be cleaned are placed. The table is divided into two halves by means of a series of flexible, split rubber curtains. One half of the table is completely enclosed and is provided with several moving nozzles which direct the spray of abrasive on the castings. At the other half of the table stands an operator whose task it is to remove the castings which are cleaned and replace them with fresh ones.

Although this operation is conducive to large quantities of dust, if proper ventilation and isolation of the cleaning half has been provided for, the attendant should not suffer any undue exposure.

Cabinets - When cleaning small castings, the blast cleaning cabinet is sometimes used. Such cabinets are usually of steel plate construction and approximately 5 x 3 x 7 feet in height. With this method, the material to be cleaned is placed inside the cabinet and the operator stands without. A heavy plate glass window is furnished in the front of the cabinet through which the operator may view the work. Handholes, to which are affixed heavy gauntlets, enable the operator to place his hands within the cabinet and direct the materials under the abrasive spray which issues from a fixed nozzle located within. Exhaust ventilation is usually provided for in order to reduce the dust and permit the operator to see the work being done.

Summary of abrasive cleaning - In connection with the various methods outlined for abrasive cleaning, if the castings are first washed with water or oil before introduction into the cleaning devices, the potential source of dust concentration can be greatly minimized.

From the foregoing discussion, it can be seen that it is entirely possible to reduce the amounts of dust arising from this type of operation below a harmful level and insure healthful working conditions. As has been pointed out, this result can be obtained only by the use of adequate equipment. However, even the most expensive equipment obtainable is of little value unless used and maintained properly. For this reason, the workmen concerned should be instructed and cautioned regarding the proper operation and care of these devices.

Summary of the foundry industry - When considering a program designed to promote more healthful working conditions, there is no doubt that this industry should receive major consideration. Not only is the mortality rate from respiratory diseases above that for the general average of other workers but the period of occupational life is shorter.

However, these facts become less depressing, when it is realized that there is a practical solution present to rectify these conditions and that it appears to be now merely a question of time embracing protective measures will be established in those foundries which have not already done so.

Grinding Industry - Again, as in the foundry industry, the statistics for grinding workers show an abnormal amount of fatalities from respiratory diseases when compared with working groups of other working industries.

According to Hoffman (1)(32) the industrial insurance mortality statistics of the Prudential Insurance Company from 1897 to 1914 showed that out of 305 deaths among grinders, 143 or 46.9% were due to pulmonary tuberculosis. In another group of 5,938 grinders, which included cutlers, scissors grinders, axe, plow and other steel grinders but excluded foreman and superintendents, the actual mortality from all causes was 17% in excess of the expected mortality.

The type of dust exposure to which the average workmen of this industry are subjected depends upon the kind of grinding being done and consequently the grinding substance being used. For instance, when grinding is done on relatively soft materials such as cast iron, brass and bronze, a vtrified wheel of silicon carbide is frequently used. When the material to be ground is of a harder substance such as cutlery steel, axe and plow steel and others, the wheel employed is generally composed of Aluminus Oxide (synthetic emery).

If the above types of grinding wheels are used, namely those of silicon carbide and aluminus oxide, the workman will experience little danger from the disease silicosis. This statement is based on the following conclusions: The silicon carbide wheel is composed, almost entirely, of what has been previously defined as "combined silica" and there is very little, if any, of the free silica which contributes to silicosis, given off in the grinding operation. In the case of the Aluminus Oxide wheel, the nature of its constituents precludes the possibility of a silicosis exposure. Thus, with most of the commonly used grinding wheels, the main sources of danger from dust disease lies not in silicosis but from a general pneumoconiosis caused by an excessive inhalation of fine particles of fine, inorganic dusts. This pneumoconiosis, or general disease of the lungs, may be evidenced in various forms such as tuberculosis, pneumonia, bronchitis and other respiratory diseases.

However, in some cases, a stone composed of a large amount of pure quartz or free silica may be employed and when this is true, there is a liable exposure to silicosis. For example, in a German axe grinding plant, Jotten (1)(33), it was noticed that the incidence of silicosis increased after the substitution of Pfalz for Eifel grindstone. Subsequent investigation revealed that the Pfalz stone was 33% higher in silica than the Eifel Stone. This further bears out the theory that the higher the free silica present, the more dangerous the dust.

In the case of the grinding industry, the best possible protection from dust exposure lies in localized exhaust ventilation. This method may be supplemented with some success by the use of wet grinding but the latter should never be considered as offering a complete solution to the problem when used alone. Yet, some believe that since the water succeeds in allaying to a large extent the visible dust that a harmful condition does not exist when water is employed. It should be repeated there that it is not the large particles of dust which are capable of doing harm, but those of such smallness as to render them practically invisible, and upon which the water has little effect. It is from these particles that fly off the wheel tangentially and disperse into the atmosphere that one may expect the chief source of danger.

Although it is always advisable whenever possible to substitute wheels of a less dangerous composition, if the proper design of exhaust ventilation equipment is provided and maintained, this will in itself supply a sufficient amount of protection under all conditions. The installation of such equipment is the only way that full protection can be assured.

Mining Industry - Any mine, be it metal or coal, is a potential source of an enormous amount of dust and unless provisions are made for the control of the dust at the source, and for adequate ventilation, as well as for personal protective equipment, such as masks or respirators whenever possible, there is liable to be present a tremendously serious danger to the health of these workers. Such danger is not only from the free silica dust, which is present in large quantities in the rocks and materials being worked, and which is generally regarded by most authorities as the cause of silicosis, but from the abnormal quantities of other dusts present that cannot fail to be inhaled into the lungs in extremely hazardous amounts unless positive protective measures are taken. In fact, tho amount of free silica present may form only a small percentage of the total dust. Because the dust conditions in mines are known to cause other lung diseases than silicosis, such as miner's consumption, miner's asthma, anthracosis, siderosis and pneumonia, such diseases for the sake simplicity are generally classified under the heading "pneumoconiosis", a term describing all diseases of the lungs due to dust, be they fibrous or non-fibrous. The silicosis-producing silica dust owes its damage to the fact that this dust is soluble in the lung tissues and enters into a chemical combination with, and finally gradually supplants the normal lung structure with a fibrous growth which is known as fibrosis of the lungs. The other dusts usually found in the mine air, with the exclusion of highly poisonous dusts such as lead and arsenic, are generally regarded as being dangerous in that they are insoluble or difficultly soluble in the fluids and tissues of the respiratory organs. Because of this general insolubility, it is difficult for the lungs to throw off this foreign matter, and over a period of prolonged exposure the lungs gradually become filled with various dusts. The effects of this dust inhalation has been previously discussed.

It was not by accident that miners were discovered to be affected seriously by diseases of the respiratory organs. As early as 1900 in the South African mines on the Rand, it was forcibly brought to the attention of mine owners that the workers in some parts of the mines were literally "dying off like flies" due to lung infections. A thorough investigation was begun by doctors and engineers covering a period of several years, with the result that not only was it revealed that the staggering mortality rate was due almost entirely to the dust exposure, but measures of effective control and protection were evolved to combat the hazard. Since this period, the effect on the health of underground workers from breathing large quantities of dust has received more attention than that of any other dust-producing industry, and rapid and vastly important strides have been taken by our own United States Bureau of Mines and Public Health Service, as well as others, to make our mines a more healthful place in which to work.

<u>investigations of the mining industry</u> - (1) (Harrington and Davenport) The first investigation of silicosis in the mining industry of the United States was made in 1914-15 by the United States Bureau of Mines, in cooperation with the United States Public Health Service, in the Joplin, Mo., mining district (34). Of 93 men examined, 64 showed plain and definite evidence of pulmonary disease. To gain a more accurate idea of the prevalence of consumption among the miners in the Joplin district, it was decided to examine a large number of men and consequently 720 miners were examined. Of this group, 45.7% had silicosis and tuberculosis, and 5.3% had tuberculosis. Thus, over half of the men were suffering from respiratory disease.

Further investigations by Harrington and Lanza (35) in Butte, Montana, in 1921 revealed that 42.4% of 1,018 miners examined showed definite signs of lung damage due to dust.

An examination in 1921 of 303 gold miners in Nevada disclosed that 80% had silicosis, and a study in California in the same year revealed that 25% of 181 gold miners had silicosis.

According to the United States Public Health Service (23), anthracite miners and their helpers show increased signs of pneumoconiosis as their length of service increases, rising to 16% for persons under 45 years of age after completion of 15 years' work. It was found that the percentage of deaths from respiratory diseases among anthracite miners in Pennsylvania was definitely higher than that of other adult males in the general population. Also, of 95 X-rays of bituminous coal miners, 40 showed generalized fibrosis.

From these statistics and many others prepared by the most reliable sources, there seems to be little doubt that the occupation of mining carries with it a serious menace to health. And yet there are those who continue to scoff and ridicule the idea of the miner's job being dangerous. Such individuals are definitely still living in the "horse and buggy age". In discussing this situation, D. Harrington, Chief of the Health and Safety Branch of the U. S. Bureau of Mines says, "Instead of recognizing the menace due to the diseases of various kinds associated with the breathing of dust and instead of taking advantage of the methods available for combating or preventing them - or at least making a study of the situation with a view to alleviating the harmful conditions and their terrible results - there appears to have been a concerted effort to hide the facts in most instances and to take as few measures as possible toward elimination of the diseases and of the conditions causing them. Miners, especially metal miners, whose health is most directly affected usually refuse to allow themselves to be examined physically previous to or during employment. They frequently oppose the use of wet drills - which probably more than anything else will remedy the dangerous dust condition - and in many instances they destroy or try to make ineffective the water attachments to drills. When water is provided to wet down dust it is generally not used except when the mine boss forces the worker to do it. And metal-mine workers only too frequently destroy or partly destroy ventilation equipment installed for their safety, comfort and health. Mine operators or officials sometimes deny the existence of miners' consumption or other dust disease among employees even when they know or suspect its existence, yet frequently some of the mine bosses themselves are afflicted by such disease. Suggestions as to remedial methods or equipment - such as sprinkling or the use of water in drilling or on muck piles, or the use of fresh-air currents to remove dust - are held to be impracticable or are considered the dream of the theorist, even though these methods or devices are in thoroughly successful use in other mines or in other localities. While sometimes the objection to change is due to disinclination or inablitiy to withstand the probably financial outlay, frequently the main obstacle is the fact that mine officials are of the reactionary type; the old timer with years of experience and more or less limited education usually hates to do anything that he has not been accustomed to doing. He repels the idea that dust in his particular mine is or can be harmful and very often denies the possibility of having enough dust present to be harmful."

The most important step in the regulation and control of this dust hazard lies primarily in education; -- education of the mine owners as to the effects on the health of their workers, of working in mines where protective measures have not been taken, and the consequent tremendous expense that may arise from law suits or high insurance rates as a result of mine-contracted diseases;

education of mine employees to respect the equipment and precautions established for their benefit, and to make use of every available type of protection offered; education of doctors so that they may correctly diagnose the disease, prescribe remedies for its control or cure, issue the proper death certificates and thus give publicity to the prevalence of such disease and its cause.

<u>sources of and control of dust in mines</u>

<u>Metal Mines</u>- Harrington (36) gives the following as the main sources of dust in metal mines and tunnels in order of their importance: (1) dry drilling of holes for blasting - the dry drilling of holes pointed upward, especially those from about 60 degrees to vertical, is in general the worst producer of dust. (2) blasting of dry rock or ore which produces dangerous gases and throws immense quantities of finely divided dust into the air. (3) shoveling or mucking of very fine dry material at the working face, which is usually poorly ventilated. (4) loading cars from chutes. (5) dumping loaded cars into chutes. (6) timbering. Dry crushing and other occupations in metal mines and in metal-mine mills also produce dangerously dusty conditions.

<u>Coal Mines</u> - The United States Bureau of Mines (1) (37) in an investigation conducted in 15 representative coal mines in six coal mining states revealed the following as the chief sources of dust. (1) Jackhammer-drilling produced the greatest concentrations of dust of any of the mine operations, ten times as much as any of the others, and the other dust-producing operations arranged in decreasing order of concentration were electric drilling, undercutting coal by dry methods, auger-drilling by hand, loading coal, undercutting coal with the application of water on cutter bar of mining machines, simultaneous pickming and loading coal, loading rock haulage, and finally, pick-mining. (2) The largest total amount of dust was raised by dry undercutting. (3) Undercutting coal without the use of water on the cutter bar raised the greatest concentration of dust of any of the common mine operations; loading coal ranked next, and haulage, last.

As specific remedial measures for the dust conditions in mining, Harrington (36) suggests the following: (1) mechanical ventilation to force moving currents of fresh pure air to every place where men are working and thus remove or at least dilute the dust and gases in the air breathed by the workers. (2) the use of water in all drilling, in sprinkling ore and rock piles, and in wetting timbers, manways, haulageways, and every place where dust may be found. (Harrington states that next to adequate ventilation, the intelligent and systematic use of water, in his opinion, offers the best present known method of combatting the health hazard from breathing dust) (3) where possible, all the blasting should be done after a shift; if this cannot be done there should be enforcement of strict regulations as to the wetting of the region of blasting both before and after the shots are fired, as to the removal of all explosive fumes by adequate air currents and as to the prevention of entrance into a blasted place until all dust, fumes, etc., have been removed. (4) strict physical examinations of underground workers before employment and at periods of not less than every 6 months during employment, with prompt removal of worker from dangerously dusty work should unfavorable symptoms be found. It may be added that positive air-supply respirators of light construction can be used with considerable success. There are also on the market various types of drilling machinery and dust traps which can be used most effedtively in the control of the dust problem.

Granite Industry - Because granite contains about 35% free silica and because during the working of this stone large quantities of dusts are given off, the occupation of a granite worker is considered to offer a serious exposure to dust disease. In summarizing his report of dust pneumoconiosis in the granite industry, Hoffman (2) states that even with granite workers enjoying above average conditions of sanitation and housing and with generally superior physiques than the average of other workers, the mortality rate of this group is decidedly above the average normal to industrial occupations.

The chief occupational disease experienced by these workers is silicosis or silicosis with tuberculosis, and the degree of exposure depends directly upon the amount of dust inhaled. Thus the principal cases of disease according to Hoffman (2) are mostly among the men employed in granite-stone cutting, it being especially severe among men using pneumatic tools. Other occupations such as polishing, tool sharpening, bed-setting, etc., do not show a marked excess, if any, in the mortality from tuberculosis. In Massachusetts it was found that the death rate from pulmonary tuberculosis among granite cutters was five times the normal experience in the population at large. Although silicosis and tuberculosis are the main causes of sickness and death among this group, other respiratory infections such as bronchitis, pneumonia and asthma are also of common occurrence.

control of dust disease in the granite industry - Medical control in this industry is of great importanee in the selection of qualified workers best suited for dusty tasks and for periodical check-ups by physical examination. However, the most successful and only sure method of relief, as in the other dust-producing industries, is by engineering control. Again, exhaust ventilation is the best solution obtainable. There are some types of granite cutting equipment which are designed to remove the dust at the point of cutting by use of a hood integral with the machine and surrounding the cutting tool to which is attached a pneumatic air tube, drawing away and depositing most of the generated dusts into a dust collector. Where these types of machines prove too costly, a system of general exhaust ventilation, if designed intelligently, may solve the dust problem. Respirators, too, offer a degree of protection although these used in the absence of any other equipment will not remedy the condition. Also, as with other industries using a mechanical system of exhaust ventilation, it is important that such equipment be maintained in efficient working order at all times.

Cement Industry - It is generally conceded by most authorities that cement workers as a whole experience more freedom from silicosis and tuberculosis than those of other industries who are exposed to dusts of a high silica content. In fact there are many who believe that the cement worker enjoys increased immunity from tuberculosis due to the nature of the dust he breathes into his lungs. The chemical analysis of cement shows it as containing about 62% lime or calcium hydroxide and 22% silica. However, most of this silica is in the "combined" form and there is actually present only about 6.5% in the crusher houses, raw mill, and stone house, and only about 1% in the finished. The remainder of the cement is composed of about 7.5% alumina, 1.5% sulphur trioxide, and 2.5% each of iron oxide and magnesia. The chemical composition is not fixed, however, and the percentages of the constituents may vary during different stages in its manufacture.

The apparent immunity from silicosis and tuberculosis may be partially explained by the presence of a large amount of calcium which is regarded as one of the least harmful of the inorganic dusts. There is also some evidence to support the theory that calcium dust actually retards the action of tuberculosis and therefore acts as a curative agent. This curative effect will be discussed later.

However, regardless of the evidence advanced by some that cement workers do not suffer the same degree of exposure from respiratory diseases as other workers in dangerously dusty occupations, it does not appear true that these men experience no occupational disease hazard due to the dust inhaled.

In an investigation conducted by the United States Public Health Service (38) of the cement industry, it was found that among cement workers there were twice as many absentees from work, for two days or more, because of respiratory diseases, than there were among the workers of 11 factories in other industries. In comparing the health of cement workers with those of a rubber company, those men in the cement industry were found to have almost three times as many absences due to colds, bronchitis, influenza and grippe as the rubber workers. Also diseases of the eyes and ears, of the pharynx and tonsils each occurred three times as often.

There was found to be a tendency toward self-elimination from the industry of those workers who were more susceptible to respiratory disease and who showed the harmful effects of the dust, as the respiratory incidence among men who quit work during the period of study was 68% higher than those who remained in the industry. Among those who did remain, the rate for respiratory diseases was low during the first few years, but after eight years' employment there was a tendency for the rate to increase. This fact is considered to indicate that as the seasoned workers were really a selected group, this increase in the respiratory rate occurred in spite of an inherent ability to resist disease. This trend seemed to be the same for men under and those over 45 years of age.

About one-third of the employees, as represented by the years of life under observation, had one or more respiratory defects or chronic respiratory diseases and these diseases were found to be most frequent among those workers exposed to large quantities of dust. X-rays of the chests of 37 employees who had been employed in the industry more than three years showed that 15 had pneumoconiosis, 3 of these workers also having tuberculosis, while of the remaining 22, 8 gave evidence of arrested tuberculosis, 4 were negative for either disease and 10 were considered doubtful. It seems of important significance that 8 showed signs of arrested tuberculosis. This offers a certain amount of support to the claim that cement dust has a retarding action on this disease. In the majority of other industries, such an infection instead of being arrested would be aggravated.

In conclusion, while there is reason to believe that the cement industry is one of the least hazardous of all dusty industries, there is still present a sufficient detriment to health from dust as to make positive control measures necessary. As in other cases, this control is best effected by mechanical exhaust ventilation.

Abrasive Industry - (Manufacture of artificial abrasive wheels) In recent years, the increased manufacture and use of artificial abrasive wheels has practically eliminated the natural sandstone wheel which is known to produce a silicosis hazard, although this latter type wheel is still used to some extent in the manufacture of cutlery and axes. The artificial abrasive wheels most commonly used are those of silicon carbide and although these substances are composed of hard, tough cutting crystals which cannot help but have a harmful effect when inhaled into the lungs, they are not instrumental in causing silicosis.

In a study of the dust hazard in the abrasive industry (39) made by Winslow, Greenburg and Greenburg over a period of 14 years in the largest single abrasive and grinding wheel factory in the world, it was found that out of approximately 500 employees examined, only one had definite signs of early silicosis. This worker was not employed where there was abrasive dust, but in the clay plant, where an analysis of the clay showed it contained about 9% of pure or free silica in the form of feldspar. Although pictures of the lungs of workers exposed to artificial abrasive showed no signs of pneumoconiosis, there was evidence that the lungs of some of the men were working hard to keep themselves free of dust. In comparison of the death rate from tuberculosis of the workers in the plant with that of the surrounding community, it was found that the rate for abrasive workers was only slightly higher than those outside the industry, their death rate being 6½% from tuberculosis as against 5% for the community. These writers conclude that in those abrasive factories employing efficient means of dust removal, such as the mechanical exhaust blowers used in the factory investigated, there is little danger of pneumoconiosis.

Pottery Industry - The British Home Office (40), in an investigation of compensation problems in the pottery industry discovered an excessive mortality rate among potters. The rate for mill workers, slip-makers, and potters was found to be 64% above the average and that of earthenware, china-kiln and oven men, 83% more than average. The deaths from respiratory tuberculosis in these workers was exceptionally high, especially after the age of 35, which would seem to mean that the prevalence of this disease increased with the length of occupation, and therefore was due directly to the type of work done. In addition, there were found several cases of silicosis. The investigating committee concluded that "a considerable proportion, if not all, of the deaths from respiratory tuberculosis in excess of those occurring in the general population must be accounted for by injury to the lungs resulting from the inhalation of dust."

The occupations in this industry which appear to offer the greatest exposure to the dust hazard are those in which the raw materials are handled, such as in flint milling, the manipulation of the composite body of the ware, the placing of flint or sand used in firing biscuit ware and the removal of the sand adhering to the ware, and occupations involving exposure to other dusts, as in mold and sagger making and glaze dipping.

Preventive or Curative Dusts - There is a wide divergency of opinion concerning whether or not certain dusts exert not only a protective influence, but possess in addition certain curative qualities when inhaled into the lungs.

For several years many authorities have considered such dusts as coal, shale, hematite, limestone, cement and clay as being not only harmless in themselves but of great benefit when inhaled along with other more harmful dusts. While there is considerable evidence that these dusts are less harmful than others, most investigators are of the opinion that any minute dust inhaled in sufficient quantities will produce harm in some degree. However, it cannot be denied that there is some logical reasoning behind the theory that certain dusts serve as protective or curative agents, and it would result in lifting a tremendous burden off industry if it could be definitely proved that such was the case.

Most authorities supporting this theory base their conclusions on the belief that the initial reaction of the lung is greater for "inert" dusts than "dangerous" dusts, and that the former are eliminated more rapidly. It is thought that when such inert dusts as coal or shale are mixed with the more dangerous dusts, such as those containing free silica or those which are difficultly soluble, the phagocytic action of the lung is stimulated and as a result much more of the dangerous dusts are removed than if they were present in the lung alone. The principal dust of this nature, or at least the one that has received the most attention, is coal dust. This dust has even been used in the clinical treatment of pulmonary disease and in some cases has proved moderately successful. However, as yet such a treatment does not seem to be sufficiently arresting to enable it to be classed as a definite or even partial cure.

What may prove to be a vitally important discovery in the control of silicosis is the use of finely powdered aluminum hydroxide. Since it is believed that free silica is dangerous because of its tendency to dissolve in the lung tissues and form fibrosis, some authorities believe that if there could be found some way to prevent these particles from dissolving, a solution of this problem might be reached. After many exhaustive experiments it was revealed that when aluminum hydroxide was present with the silica dust in a test tube, the silica would not enter into solution. From this and further tests, the conclusion was reached that the aluminum dust formed a coating over the silica particles and prevented them from entering into chemical solution with the lung cells. It is now thought that by spraying this powdered aluminum hydroxide in small quantities (as little as 1% seems to prevent solution) in locations where the men are exposed to silica dust, this hazard will be relieved or at least considerably lessened. As yet it seems to early to accept this method as any positive cure, as a great deal of the work done so far has been in the laboratory with animals, and such laboratory conclusions are sometimes not found applicable when tried in the field and on human beings. However, the evidence already assembled indicates that it is worthy of serious consideration and it is sincerely hoped that this may prove a positive solution for the prevention of silicosis.

In conclusion it should be said, that although certain authorities are of the opinion that the action of some of the "inert dusts" is definitely favorable towards both the retarding and curing of silicosis and tuberculosis, and although there are records of successful treatment of these diseases with such dusts, it appears at the present somewhat early to accept definitely that such treatment offers a final solution to this occupational problem.

Personal Protective Equipment for Workers

Respirators - Although the use of respirators should be encouraged among all workmen, it should never be assumed that such devices furnish the solution to the dust problem. The most efficient respirator is usually that type which contains the most filtering material, and consequently offers the greatest resistance to normal, comfortable breathing. For this reason it is oftimes difficult and in some cases practically impossible to induce the workmen to wear such apparatus.

As a result of the increased difficulty in breathing caused by the use of respirators, the workmen's energy is more rapidly expended and it becomes necessary to stop for periodic and frequent rest periods. Also, this equipment is uncomfortable to wear, especially after it has been moistened by exhaled humid air, and as a result skin rashes are of common occurrence among the workers. In addition they frequently do not fit properly and the dusts succeed in passing directly to the nose through openings between the mask and face.

Whenever dust respirators are used, each man should be provided with an individual mask which is sterilized periodically, and also with a supply of extra filters which should be changed regularly.

In some classes of work where it is very difficult to localize the dust, respirators offer the only practical solution for workmen protection, but whenever possible they should be supplemented by some form of exhaust ventilation.

Positive Pressure Respirators - A more expensive but more efficient type of respirator is one to which is supplied a positive flow of fresh clean air. One such type consists of a mask-fitting respirator to which is attached a small flexible air-hose. The other end of the air-hose is attached to a miniature air compressor which is strapped on the waist. The compressor draws in air through a filter in its intake side, where it is cleansed and then forces the dust-free air through the tube to the respirator. In this manner the workman is assured of a positive supply of filtered air without any accompanying difficulty in breathing. Another similar method is for the workman to wear the mask to which is attached the air-hose, but instead of the other end of the hose being connected to the compressor at the waist, it can be connected to an air-pipe running through the plant which is designed for that purpose. The workman can then perform his work with less encumberance.

Positive Pressure Helmets - In the dust-producing industries, this type of protective apparatus is used mostly for abrasive cleaning or sand-blasting work. They are usually constructed of heavy substantial material and built to completely enclose the head of the operator. Air is supplied to the helmet through a flexible hose which is connected at the other end to an air compressor. Between the compressor and helmet there is usually an air-filter to remove any entrained dust and also a water separator to remove excess moisture from the air. These helmets have a very high efficiency, but have the disadvantage of being heavy and cumbersome.

Dust Measuring Instruments

In order to determine when an occupational hazard due to dust exists, it is necessary to have some means of measuring the amount of harmful dust in the air. The method employed should be as simple and yet as efficient as possible and the results obtained should be able to be calculated quickly and with a high degree of accuracy.

The konimeter - One of the best known instruments used for dust measurement is the Zeiss konimeter. It is compact, light in weight, requires little skill to operate, is rapid in operation, and can be used for a large number of tests without re-setting. In addition, the microscope which forms an integral part of its construction enables the operator to readily count the dust particles in the air-sample taken. There are several different types of Zeiss konimeters on the market. The primary function of the knoimeter is to introduce into the machine a sample of air of a definite volume. Its secondary function is to provide a means of rapidly and accurately counting the particles of dust contained in the known volume. This is accomplished as follows: A small cylinder containing a piston with an adjustable stroke is the means by which the sample is introduced. The piston can be set in either of two positions, one for a displacement volume of 5 cubic centimeters, and the other for 10 cubic centimeters. The 5c.c. setting is used for a very dusty atmosphere and the 10c.c. for those less dusty. In setting for a test the pistion is pulled back against the action of a spring to whichever volume setting is to be used, and held there by a trip catch. When the test is taken the trip catch is released and the tension on the spring causes the piston to move rapidly in the cylinder, creating a suction. The suction side of the cylinder is connected to the atmosphere through a fine mesh screen whose purpose is to allow only those particles of dust approximately 10 microns or smaller to enter the instrument.... either 5 c.c. or 10 c.c. of air being drawn in depending upon the setting of the machine. After the sample is introduced, the compressive action of the cylinder impinges the sample on a glass disc which has been coated with a thin layer of vaseline so that the particles will adhere readily. This disc contains spaces for 30 different tests and a new setting is made by revolving it so that a clean space appears over the impringment opening. The number of dust particles in the sample are now counted by means of the microscope, the end of which can be brought directly over the particles to be counted by further revolving of the glass disc.

Besides the konimeter there are also many other efficient means of measuring the quantity of dust in the air. The chief methods employed by these other types for sampling are: Condensation, filtration, washing, sedimentation, electrostatic, resistance, and impingement. Some of these methods possess an advantage over the konimeter in that larger quantities of dust can be counted and a somewhat higher counting accuracy is obtained. However, for all-around effectiveness and efficiency, the konimeter is recognized as being one of the best of the dust-measuring instruments.

SUMMARY OF SOURCES, EFFECTS AND MEDICAL CONTROL OF INDUSTRIAL DUSTS

We have now seen where some of the principal sources of harmful, inorganic dusts are found in industry, what their possible effects on the lives and health of our workmen may be, and how medical science can effectively reduce the occurrence and danger of disease resulting from the inhalation of these dusts.

There has also been presented statistics on mortality and disability resulting from dust inhalation in various industries. However, a great many of these statistics have been arrived at some years ago before occupational diseases were given the benefit of the concern and control they receive today. In this connection the reader would perhaps obtain a more accurate picture of the situation as it exists at the present time if the figures given in many of the instances cited were considered as representing those of exceptionally bad conditions, and not entirely true of these industries as a whole.

While it is correct that many individual plants and factories have made practically no progress of any kind since the first initiation of occupational disease legislation in this country, there are many others who have taken at least some, if not all, of the corrective measures possible, and for this reason it would not be exactly fair to assume that such statistics are still entirely true for all the individual members of such industries. However, these vital figures do serve as a means of gauging what results may be expected if little or no form of occupational disease control is practiced.

BIBLIOGRAPHY

1. D. Harrington, Chief Health and Safety Branch, U. S. Bureau of Mines, and Sara J. Davenport, Principal Translator, U. S. Bureau of Mines, from U. S. Bureau of Mines' Information Circulars 6838, 6840, 6848.

2. Frederick L. Hoffman, LL.D., The Problem of Dust Phthisis in the Granite Stone Industry, Bulletin No. 293, U.S. Department of Labor, Bureau of Labor Statistics.

3. Alice Hamilton, A.M., M.D. Assistant Professor of Industrial Medicine, Harvard Medical School, Boston, Mass.; Formerly Special Investigator of Poisonous Industries for the U. S. Bureau of Labor Statistics, from "Industrial Poisons in the United States".

4. J. J. Bloomfield, Sanitary Engineer, U.S. Public Health Service, and J. M. Dallavalle, Assistant Sanitary Engineer, U.S. Public Health Service, from Public Health Bulletin, No. 217, "The Determination and Control of Industrial Dust."

5. Louis I. Dublin, Ph.D., Third Vice President and Statistician and Robert J. Vane, Supervisor of Occupational Ratings, Metropolitan Life Insurance Co., from Bulletin of the United States Bureau of Labor Statistics No. 582, "Occupation Hazards and Diagnostic Signs."

6. The Largest Abridgment of Webster's New International Dictionary of the English Language.

7. BADHAM, CHARLES Notes on a Fine Type of Fibrous Pneumonoconiosis Produced by Silicates and Other Minerals. Rept. of Director General of Public Health New South Wales, for Year Ended Dec. 31, 1927, Studies in Ind. Hygiene No. 13. *

8. JONES, W. R. Silicotic Lungs; The Minerals They Contain. Jour. Hygiene, vol. 33, 1933. Quoted from Min. Mag., vol. 49, 1933, pp. 67-68. *

9. CANADIAN MINING JOURNAL. Liquids in Quartz. Vol. 55, 1934, p. 406. *

10. GOODRICH, HOWARD B. Silicosis. Jour. Missouri State Med. Soc., vol. 31, 1934, pp. 193-8. *

11. PROSKE, H. O. and SAYERS, R. R. Pulmonary Infection in Pneumoconiosis; I. A. Bacteriologic and Experimental Study. U.S. Public Health Reports, vol. 49, 1934, 839-58. *

12. SAYERS, R. R.; MERIWETHER, F. V.; LANZA, A. J. Silicosis and Tuberculosis Among Miners of the Tri-State District of Oklahoma, Kansas, and Missouri. I. For the Year Ended June 30, 1928. Tech. Paper 545, Bureau of Mines, 1933. 30 pp. *

13. SAYERS, R. R. The Clinical Manifestations of Silicosis. Journal Am. Med. Assoc., vol. 101, 1933, pp. 380-3. *

14. PANCOAST, H. K. and PENDERGRASS, E. P. The Roentgenological Aspects of Pneumoconiosis and Its Medico-Legal Importance. Jour. Ind. Hygiene, vol. 15, 1933, pp. 117-35. *

15. SILICOSIS (MEDICAL ARRANGEMENTS) COMMITTEE. Report of the Departmental Committee Appointed by the Secretary of State to Advise as to the Medical Arrangments Which Could be Made for the Diagnosis of Silicosis. Home Office, London, 1929, 19 pp. *

16. IRVINE, L. G. The Clinical Pathology of Silicosis. Same as ref. 15, pp. 249-69. *

17. PANCOAST, H. K. and PENDERGRASS, E. P. Pneumoconiosis; The Importance of Accuracy in Roentgenological Interpretation. New England Jour. Med., vol. 209, 1933, pp. 425-37. *

18. SMITH, ADELAIDE R. Silicosis Among Rock Drillers, Blasters, and Excavators in New York City, Based on a Study of 208 Examinations. Jour Ind. Hygiene, vol. 11, pp. 37-81. *

19. ______. The Unreliability of the Physical Examination in the Diagnosis of Silicosis. Ind. Med., vol. 3, 1934, p. 277. *

20. WATKINS-PITCHFORD, W. The Silicosis of the South African Gold Mines and Changes Produced in it by Legislative and Administrative Efforts, Jour. Ind. Hygiene, vol. 9, 1927, pp. 109-139. *

21. SMITH, ADELAIDE R. Review of Silicosis. New York State Dept. of Labor, Ind. Bull., vol. 12, 1933, pp. 32-33. *

22. RUSSELL, A. E.; BRITTEN, R. H.; THOMPSON, L. R.; and BLOOMFIELD, J. J. The Health of Workers in Dusty Trades: II. Exposure to Siliceous Dust (Granite Industry). U. S. Public Health Bull. 187, 1929, 206 pp. *

23. OFFICE OF INDUSTRIAL HYGIENE AND SANITATION. The Health of Workers in the Dusty Trades; III. Exposure to Dust in Coal Mining. U. S. Public Health Bull. 208, 1933, pp. 7-19. *

24. PANCOAST, HENRY K. and PENDERGRASS, EUGENE P. A Review of Pneumoconiosis; Further Roentgenological and Pathological Studies. Am. Jour. Roentgen. Radium Therapy, vol. 26, 1931, pp. 556-614. *

25. QUAINTANCE, P. A. and MORRIS, F. J. Pneumonoconiosis. California and West. Med., vol. 40, 1934, pp. 337-340. Abs. in Ind. Med., vol. 3, 1934, pp. 349-350. *

26. CHAPMAN, E. M. Acute Silicosis. Jour. Am. Med. Assoc., Vol. 98, 1932, pp. 1439-1440. *

27. RUSSELL, A. E. Personal communication to Chapman (ref. 26) *

28. MACDONALD, G.; PIGGOT, A. P.; and GLIDER, F. W. Two Cases of Acute Silicosis. Lancet, vol. 2, 1930, p. 846. Quoted by Chapman (ref. 26) *

29. COMMONWEALTH OF MASSACHUSETTS. Report to the General Court of the Special Disease Commission. 1934, 215 pp. *

30. McCONNELL, W. J. and FEHNEL, J. WM. Health Hazards in the Foundry Industry. Jour. Ind. Hygiene, vol. 16, 1934, pp. 227-251. *

31. J. J. Bloomfield, Sanitary Engineer, U. S. Public Health Service and J. M. Dallavalle, Assistant Sanitary Engineer, U. S. Public Health Service, from Public Health Bulletin No. 217, "The Determination and Control of Industrial Dust."

32. HOFFMAN, F. L. Mortality from Respiratory Diseases in Dusty Trades. U. S. Bureau of Labor Statistics Bulletin 231, 458 pp. *

33. JÖTTEN, K. W. Significance of the Abrasive on the Occurrence of Silicosis and Silico-Tuberculosis in an Ax-Grinding Plant. Zentralb. Gewerbehyg. u. Unfallverh., vol. 10, 1933, pp. 173-176. Jour. Ind. Hygiene, vol. 16, 1934, pp. 33-34 (abs.) *

34. LANZA, A. J. and HIGGINS, EDWIN. Pulmonary Disease Among Miners of the Joplin District, Missouri, and Its Relation to Rock Dust in the Mines. Tech. Paper 105, Bureau of Mines, 1915, 47 pp. *

35. HARRINGTON, DANIEL, and LANZA, A. J. Miners' Consumption in the Mines of Butte, Montana. Tech. Paper 260, Bureau of Mines, 1921, 19pp. *

36. HARRINGTON, D., Chief, Health and Safety Branch, U. S. Bureau of Mines. Information Circular #6867.

37. FORBES, J. J. and EMERY, A. H. Sources of Dust in Coal Mines, Report of Investigations 2793, Bureau of Mines, 1927, 17 pp. *

38. UNITED STATES PUBLIC HEALTH SERVICE. Bulletin 176, "Cement Workers" (published in U. S. Department of Labor Bulletin - Bureau of Labor Statistics #491.)

39. UNITED STATES DEPT. OF LABOR, Bureau of Labor Statistics, Bulletin #439.

40. UNITED STATES DEPT. OF LABOR, Bureau of Labor Statistics, Bulletin #491.

* Indicates that these references have been taken in whole from United States Bureau of Mines, Information Circulars 6835, 6840, 6848.