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of prompt and continuous delivery of essential weapons of defense we must not only train new workers and retrain older work-

ers, but we must restrain accidents, which fritter away our supply of skilled hands producing these weapons.

Maximum Allowable Concentrations of Dangerous Industrial Dusts and Gases

By ALICE HAMILTON, M.D.

Medical Consultant to the U. S. Division of Labor Standards, Washington, D. C.

I have been asked to make a brief summary of our present-day knowledge with regard to dangerous degrees of air pollution from gases, vapors, dusts and fumes, and the data which have been secured so far as to the maximum allowable concentration which can be assumed to be within safe limits, below the danger point. A few of the dangerous dusts and vapors have been studied intensively enough to afford us fairly full data on which to establish such standards, but only a few, and even with regard to them our knowledge is not complete, and it would be a great mistake to embody in legal regulations the standards which we are at present tentatively recommending, for it is certain that, as our knowledge increases through investigations in this field, we shall have to change our figures. I believe that the State departments of labor or of health which have adopted standards of allowable concentrations regard them as advisory only, and that is right.

The first attempt at the establishment of a maximum figure of air contamination by an industrial poison was made in England in 1910 by Duckering and Legge, who used the procedure since generally adopted; that is, they determined the amount of lead in the air of a workroom and matched it up with the record of lead poisoning in that room. In this way they were able to state that, if the amount of lead were kept under 0.5 mg. per cubic meter of air, there would be no serious plumbism, no palsy or encephalopathy

and only rarely colic. This amount, you see, was not to be taken as safe, only as free from serious danger. In 1933 our own Public Health Service concluded that the amount of lead dust or fumes in the air should be kept 0.15 mg. per cubic meter for safety. This was on the basis of an investigation of a storage battery plant, and a sickness study of 2,303 men employed there. For "prolonged exposure," the figure must, it seems, be still lower, for some cases were found which had developed even at 1.2 mg.

I believe the next important contribution in this field was made by the Benzol Committee of the National Safety Council, which, as you all remember, established 100 parts per million as the maximum allowable concentration for benzol. That figure still stands, though we have a good deal of evidence that it is too high. You are probably familiar with two remarkable reports on industrial benzol poisoning which appeared in 1939; one from the Massachusetts State Department of Labor on benzol in the manufacture of shoes; the other from the New York State Department, on benzol in rotogravure printing. In both studies cases were discovered that had developed after exposure to concentrations below 100 ppm. As a result, Dr. Francis Hunter of Boston declared that, "It is doubtful whether any concentration of benzene greater than zero is safe over a long period of time."

The American Standards Association has had for some years a committee on this sub-

American Standards Association Committee

Substance	Parts per Million		Length of exposure,	
	100	400	Not over 8 hours daily	
Carbon monoxide	100	400	"	"
Benzol	100	"	8	"
Carbon disulphide	20	"	"	"
Hydrogen sulphide	20	"	"	"

ject, composed of ventilation engineers, chemists and toxicologists. They have set up standards for benzol and carbon monoxide with two gas standards adopted for accompanying insurance men.

restrain accidents, which supply of skilled hands upon.

Dangerous

Washington, D. C.

See. This amount, you see, is as safe, only as free. In 1933 our own Public Health Service concluded that the dust or fumes in the air 5 mg. per cubic meter for the basis of an investigation battery plant, and a 1,303 men employed there. "Exposure," the figure must lower, for some cases were developed even at 1.2 mg.

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Committee of exposure

for 8 hours daily

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Suggested Standards for Illinois and Massachusetts

Substance	Parts per Million		Milligrams per Cubic Meter	
	Illinois	Mass.	Illinois	Mass.
Ammonia	50	100		
Aniline	5	5		
Benzol	75 (and derivatives)	75		
Carbon tetrachloride	100	100		
Chlorine	0.35	1.0		
Chloronaphthalenes			5	1 to 5
Chlorodiphenyls			5	1.0
Chromic acid			1.0	0.1
Gasoline	1000	1000		
Glycols	25			
Hydrochloric acid		10		
Hydrocyanic acid	10	10		
Hydrofluoric acid	3	3		
Lead			1.5	1.5
Mercury			1.5	1.5
Methyl alcohol	100	200		
Nitrogen oxides	10	10		
Nitrobenzol		5		
Ozone		1		
Phosgene		1		
Phosphine		2		
Sulphur dioxide	10	10		
Tetrachlorethane	100	200		
Tetrachlorethylene	100	200		
Trichlorethylene	100	200		
Toluol	75	200		
Turpentine	500	200		
Xylol	100	200		
Zinc oxide	150			15

ject, composed of industrial physicians, ventilation engineers, industrial insurance carriers and toxicologists, who are trying to set up standards for use in industry.

So far we have dealt conclusively only with two gases and two volatile solvents, carbon monoxide and hydrogen sulphide, benzol and carbon disulphide. The limits adopted for the present are shown on the accompanying chart. Benzol stands at 100 ppm., chiefly because of the insistence of our insurance members that this is an ideal that

can be realized practically while a more rigid standard would be rejected, and we should be left with no standard at all. Myself, I am always willing to accept half a loaf rather than no bread, but Manfred Bowditch, of the Massachusetts Bureau of Occupational Hygiene, is unwilling to go higher than 75 ppm., and Yandell Henderson, of Yale, enters an emphatic protest against 100 ppm., saying that if 20 ppm. is feasible for hydrogen sulphide and carbon disulphide, he can see no reason why it is

Tentative Standards Adopted By Public Authorities For Maximum Allowable Concentration Of Silica Containing Dusts			
Authority	Millions of Particles per Cu. Ft. of Air		
	Free Silica Content		
	High	Medium	Low
National Silicosis Conference, 1936. Medical Committee.	5	10 to 20	
Ditto. Engineering Committee.	5	10 to 30	
U. S. Labor Department 1936 Division of Labor Standards	5	15	
New York Department of Labor, 1940	5 Foundry (75% silica) 25 Abrasive Stone (Crane) 100	10	100
Connecticut Department of Public Health, 1936.	5		
California Industrial Accident Commission, 1936.	5		50
Wisconsin Industrial Commission, 1932.	5	15	
Massachusetts Department of Labor & Industries 1940	5	10 (granite)	100 25 Foundry Nuisance Dusts

impossible for benzol. Certainly it is to be hoped that ventilation engineering will progress to the point where a lower figure than 100 ppm. may be reasonably demanded for benzol users.

The standard for carbon monoxide does not need to be defended. This gas has been exhaustively studied by the Public Health Service, by State bodies, by industry and by toxicologists in many universities. Carbon disulphide and hydrogen sulphide are the two dangerous gases which must be dealt with in the manufacture of viscose rayon, and the maximum allowable concentrations given in the chart were established through careful studies made by the American Viscose Corporation, the du Pont Company and the Tubize-Chatillon Company.

When it comes to the other toxic substances I have listed here, we can say only

that the figures given represent our best judgment at the present moment, but we admit that that judgment is often based on something not far from guess work. Take the one on which I happen to be engaged at the present time, tetrachlorethane. We know it is the most dangerous of the chlorinated hydrocarbons used in industry, and we have known since the first world war what its action is on the human body, for it was used by both the Germans and the British in airplane dope, and in both countries gave rise to cases of acute yellow atrophy of the liver; but, in spite of a voluminous literature and an impressive number of clinical cases, we find no instance in which the amount of poison in the air was determined. Therefore, the standard, ten parts per million, is based on Zangger's statement that this solvent belongs with

aniline and group. We the other c CC14, about more. As comes chief pharmacolog non-toxic ag fection whic dustrial poise

To pass o field, silicosis fact, so evide that there is agreement am amount of du tions of free : a workshop. 1 ing from gase: not take fiftce: silicosis may. from the actu affect the dan dust.

Take found: silica, running dangerous gra has for centuri case of stone c of foundry wor of this particu Hatch and Mok tion for the diff and other silici shown the silici chiefly in the lar particle size dec till it may rea microns, only o fifth of the per microns. This is foundry dust cat chipping, jobs w the industry kno foundries are th more chipping is

If our knowles required to produ fying, this is still what constitutes tions. Here the P ing much valuabl mental investigati the industry and c mining, have carri and, in cooperatio

aniline and nitrobenzene in the most toxic group. We have little data with regard to the other chlorinated hydrocarbons, except CCl₄, about which we do know somewhat more. As to the others, our knowledge comes chiefly from the studies made by pharmacologists who sought a relatively non-toxic agent for cases of hookworm infection which is not the same thing as industrial poisoning from fumes.

To pass over to that very controversial field, silicosis, I need hardly emphasize the fact, so evident in the accompanying charts, that there is still much confusion and little agreement among the authorities as to the amount of dust containing varying proportions of free silica that may be permitted in a workshop. This is to be expected. Poisoning from gases and fumes, even if slow, does not take fifteen years to make itself evident; silicosis may. Moreover, other factors, aside from the actual proportion of free silica, affect the dangerous character of a given dust.

Take foundry dust. It may be rich in silica, running as high as the notoriously dangerous granite, yet, while consumption has for centuries been the occupational disease of stone cutters, this has not been true of foundry workers. Recent brilliant studies of this particular dust, notably the one by Hatch and Moke, have provided an explanation for the difference between foundry dust and other silicious dusts, for it has been shown the silica content of the former is chiefly in the large dust particles, and as the particle size decreases, the free silica falls, till it may reach, for particles under 2 microns, only one-fifth or even one twenty-fifth of the percentage in particles over 10 microns. This is, however, not true of the foundry dust caused by sandblasting and by chipping, jobs which everyone familiar with the industry knows to be dangerous. Steel foundries are the worst, probably because more chipping is needed on steel castings.

If our knowledge of the minimum dose required to produce poisoning needs amplifying, this is still truer of our knowledge of what constitutes dangerous dust concentrations. Here the Public Health Service is doing much valuable work. Their two monumental investigations, of the Vermont granite industry and of Pennsylvania anthracite mining, have carried us a long way forward, and, in cooperation with the experts of the

Saranac Laboratory, they have found it possible to establish certain fundamental facts. For instance, the Laboratory is able to state that the percentage of tuberculosis to be expected among workers in an establishment where there is no special dust hazard, is 4.79 per cent. If the rate is higher, there is something wrong; of course, not necessarily dust in the air; perhaps low wages.

Donald Cummings, of Saranac, urges the adoption of two limiting concentrations of free silica; first, the "primary threshold," a concentration of dust in which a healthy man may be employed throughout his working life without a disabling injury; second, the "secondary threshold," a concentration in which a healthy man will "inevitably contract silicosis if regularly employed for several years." General experience shows that the first is at about five million particles less than ten microns in diameter; the second is probably at a level not higher than 100 million.

At the National Silicosis Conference held in Washington in 1938, this formula was suggested for determining the maximum permissible concentration of free silica in the air breathed. Multiply the percentage of free silica by the total small particle dust count by impinger. If the result is under 5 million, the condition may be looked on as permissible. If it is over 5 million, the condition is to be looked on as poor. For example, 10 per cent free silica with an average total dust count of 30 million particles would mean 0.1 times 30 million, or 3 million, good practice; while 30 per cent free silica and 50 million particles would mean 15 million, too much. This formula cannot be applied to a dust with less than 5 per cent silica.

Both New York and Massachusetts have made fairly recent studies of the foundry industry and of work with granite, such as quarrying and stone cutting, tunnel and foundation excavating. New York recommends for dust containing less than 10 per cent free silica, 100 million particles; for 10 to 70 per cent, 10 million; for 70 per cent and over, 5 million. Foundry dust, averaging 20 per cent free silica, should be kept down to 25 per cent; the dust from abrasive blast cleaning, averaging 70 per cent down to 10 million. Massachusetts allows 25 million for foundries, 10 million for granite stone mills, and 5 million for pure silica dust.

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represent our best moment, but we admit is often based on guess work. Take arsenic, for example, which is known to be engaged in strachlorethane. We are dangerous of the chlorinated in industry, and the first world war human body, for it is. Germans and the and in both countries of acute yellow but, in spite of a and an impressive es, we find no instance of poison in the therefore, the standard, based on Zangger's event belongs with

Source of Dust	Percent of Quartz (Free Silica)	Suggested Standard In Million Particles (Below 10 Microns) per Cubic Foot of Air.
Gold Mines, South Africa	86 to 95	3 to 4.5 million.
Metal Mines, Broken Hill, Australia	10 to 17	14 "
Tunneling, Sydney, Australia	90	Under 6 "
Gold Mines, Ontario	5 to 10 (2 Mines) 25 to 35 (- -)	8.5 "
Iron Mines, Canada	50	5 "
Granite Cutting, Barre, Vermont	(Rock, 26.5) Dust, Average 35	9 to 20 "
Metal Mines, Tri-State Area	90	5 "
Potteries, West Virginia	20 to 30	
Anthracite Mines, Pennsylvania	(Rock 43% Coal, 6% Dust 90% Coal, 2-4% quartz) Rock Workers dust average 35	5 to 10 "
Subway and Foundation Drilling, New York City	Less than 1 to 84	10 "

We must not forget that the adoption of any of these standards does not mean that there will be no silicosis among the workers. In the South African gold mines, the free silica in the air was brought down to 3 to 4.6 million particles per cubic foot by 1933, but cases have continued to develop, taking 14 years now, on an average as against an earlier average of 9½ years. In Barre, Vermont, the Public Health Service found cases appearing after only ten years at 6-9 million particles and after 9 years, at 20 million. They have placed the maximum allowable number of particles at 9 to 20 million, which is certainly not extreme.

I need not say anything more about the

great need of careful studies of actual conditions under which damage from poisons and dusts occurs in industry. It is in our country that these studies must be made. The day is past when we could look to Germany as the source of knowledge of industrial toxicology. Now that authoritative position has passed to us. And this particular method of determining safety limits by means of a combination of experts in several fields, chemists, ventilation engineers, and physicians is peculiarly American. No other country has made anything like the contributions to this branch of industrial hygiene that we have. But we need a great deal more.

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Occupational Disease

WEDNESDAY MORNING SESSION

October 9, 1940

The meeting on Occupational Disease, planned as a Panel Discussion, was called to order by the Chairman, Walter S. Paine, Manager, Engineering Department, Aetna Casualty & Surety Company, Hartford, Conn., who presided.

Panel Discussion

CHAIRMAN PAINE: At every meeting that I have attended in this Congress someone has raised the question of industrial disease. This is a subject which has been maligned in some cases and has been a fantasy on the part of others. This, however, should not in any way destroy the realities that are back of the industrial disease problem.

In the discussion of this broad problem, we have asked the medical profession and the law to help us this morning. Each phase of the problem will be discussed on an orderly basis. We have assigned as the first speaker for each of these subjects one of the men on this platform. After he has finished his preamble, we will ask the members on the floor to present any question they may have on the subject.

We have the following subjects to be discussed: "Health Hazards in Spray Painting." Dr. Eugene Walsh, Associate Supervisor of Medical Service, International Harvester Company, Chicago, will open this subject.

"Fatigue and Its Relation to Occupational Disease." This subject will be taken up by Dr. Norbert Enzer, Director of Laboratories, Mount Sinai Hospital, Milwaukee.

"The Toxic Limits of Common Solvents." This subject will be opened up by Dr. Elston L. Belknap, of Milwaukee.

"Lead in Industrial Processes." Dr. Belknap will also handle this subject.

"Skin Affections." This will be handled by Dr. M. J. Reuter, Dermatologist and Syphilologist, of Milwaukee, Wis.

The last, but one of the most important, will be "Should Occupational Diseases Be

Considered as Industrial Injuries?" This will be handled by H. A. Nelson, Director of Workmen's Compensation Department, Wisconsin Industrial Commission of Madison.

We all regret that severe illness keeps Dr. Paul Brehm, Supervisor of Industrial Hygiene Unit of Wisconsin State Board of Health at Madison, from being present.

The panel will be opened on "Health Hazards in Spray Painting." Dr. Walsh.

Spray Painting

DR. EUGENE WALSH: Painting is a topic that has received considerable attention. There has been an increasing number of hazards imported into the trade. Most of these have received wide attention, particularly in the past few years. It has been incident to the wide use of the spray gun and of the lacquers, particularly. Many of the solvents and products used in the paint industry have known toxicities. Others are in the experimental stage, so far as use and so far as their hazards to health are concerned.

In the old days of brush or dip or flow painting, still widely used, solvents of rather low volatility were employed, and the hazards associated therewith were not as great. However, when we come to the spray gun, particularly in its use in the recently developed lacquers, we come into a host of new solvents.

The quantities used per year in lacquers and solvents in the paint industry in the United States reach astronomical proportions. Many, many tons are used.

In the paints we have the following hazards: first, the pigments. There has been a growing trend definitely away from lead-bearing pigments toward non-lead pigments. Many of the non-lead pigments have their peculiar hazards. Many of them are relatively innocuous and can be used with relative immunity.

So far as the fluid constituents of paints are concerned, in the order of volatility in general, we have, first, the solvents which are, largely, for paints; the paraffins; oils and varnish; varnish with some turpentine or some spirits of various and sundry types. The lower the volatility, of course, if it is a toxic product, the greater the toxicity.

The ordinary paints and lacquers can be considered together because the problem of the solvents, largely, is what we wish to deal with. The solvents used are relatively low boiling products which volatilize readily, such as acetone, ethyl acetate, butyl acetate, amyl acetate, and so forth.

Next, the paint must have a diluent. In the ordinary paints—oils, turpentine or spirits may be used. In the lacquers—alcohol, toluol, xylol, mineral spirits have been used. In the past, benzol was used. We are glad to say that there is a growing trend away from the use of benzol, which has cumulative actions in the human individual, resulting in the low grade chronic toxicities due to a depression of the blood-forming organs. There is a definite trend toward less toxic diluents.

The next essential part of the lacquers includes the driers, such as ethyl lactate or cellulose, monomethyl ethers and various other chemical products of known and unknown toxicities. Also, there must be a flexilizer or a substance giving flow to the plastic. These are relatively high-boiling low-volatility products, triphenylphosphate, castor oil, camphor and others, again of known and unknown toxicity.

The toxicities of the various individual products are often known. It is not the toxicity of the pure product, however, that we are often concerned with. It is the product which is used commercially. It is often the impurities in minute quantities that add to the toxicity. For example, we may say there is, in the case of xylol, some question as to its inherent toxicity. However, since benzol is so frequently a contaminant, we do have some benzol toxicity to be consid-

ered when xylol is used. Also, when we have two substances which are used to make a paint or lacquer fluid, its toxicity, resulting from the combination of the two substances is not usually that of a summation of the individual toxicities of the two. That is, if we have two products (A and B), A of one-plus toxicity, if we wish to use the terminology, and B of one-plus toxicity, we may get a resulting toxicity of three-plus or something of that nature—just to use an arbitrary form.

The methods of control are: First, substitution of non-toxic products such as we mentioned in getting away from lead-bearing pigments in paints. We are fortunate to have alert chemists in the paint industry who are alive to this problem. They are constantly striving and working with the industrial hygienists and the physicians in developing non-toxic products, so far as the pigments and solvents are concerned.

Another factor that has been considered and is of importance today in reducing toxicity is the mechanical development of the spray gun. Many years ago, in its infancy, no precautions were taken. The engineers weren't particularly interested in it. A man would spray with one or another, spreading the toxic substances about. Today, however, with the development of lower pressure spray guns, with the development of engineering methods of control of vapors and fumes and dusts incident to the process, we have less toxicity.

If an individual corporation is alert and serving and controlling the hazards, very little toxicity need be encountered in most processes. This includes, of course, the precautionary methods for the individual when I speak of the industrial hygienist as the engineer's phase of the problem. If an individual is working in a place where engineering methods are not feasible to control the vapors and toxic products, then the individual must have his respiratory protection to prevent inhalation. Most of the solvents which are used have a low action, and their action is by way of absorption through the respiratory tract. Getting away the fumes is the way of control.

I have very briefly outlined some of the major points. Do you choose to pursue the question?

CHAIRMAN PAINE: Discussion will be carried on from the floor and also

the viewpoint of the panel on this subject, namely spray painting?

EDWARD SMITH (Malleable Co., Buffalo, N. Y.) was made about spraying.

DR. WALSH: Spraying is a common procedure. Largely calcium, it is a relatively irritant substance. It is irritating to the eye and may be followed by cough. Not infrequently it is in whitewash which is in them but, washing is a matter that is done in most industries and exposure is relatively infrequent. Hazards are not great.

Likewise, most of the procedures are done in large, open spaces with poor aeration. If it is done in closed rooms, the process is to consume time to have the individual in some manner. Just a simple mechanical dust type respirator would be usable if the exposure is of short length of time.

X-Ray Examination

DR. ROBERT M. BULL (State Medical Assn., St. Paul) there methods by x-ray examination to time or from year to year show progress of bronchial disease of these paint inhalation.

DR. WALSH: There would answer your question. Most roentgenologists, I am at the idea of making bronchiectasis by x-ray. They see in the x-ray are enlarged blood vessels and fibrous tissue. It is true, however, in some paints which I did not mention in the porcelain industry—that is another problem—a silica-bearing paint—characteristic changes of silicosis.

However, for the ordinary paint, it is absorbed, so few progressive changes in the

used. Also, when we which are used to make id, its toxicity, result- ation of the two sub- that of a summation cities of the two. That ducts (A and B). A of we wish to use that if one-plus toxicity, we toxicity of three-plus nature—just to use an

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LAINE: Discussion will the floor and also from

the viewpoint of the panel. May we proceed on this subject, namely health hazards in spray painting?

EDWARD SMITH (Jewell Alloy & Malleable Co., Buffalo, N. Y.): No mention was made about spraying whitewash.

DR. WALSH: Spraying with whitewash is a common procedure. As whitewash is largely calcium, it is a relatively innocuous substance. It is irritating to the respiratory tract and may be followed by a chronic cough. Not infrequently there are contaminants in whitewash which may have toxic products in them but, ordinarily, whitewashing is a matter that is done today, next week, and perhaps a month hence. It isn't done in most industries day after day. The exposure is relatively infrequent and the hazards are not great.

Likewise, most of the whitewashing procedures are done in large, open, airy rooms. That isn't true of some tunnels, of course. If it is done in closed rooms, tunnels and places with poor aeration, it is advisable, if the process is to consume any length of time, to have the individual protected in some manner. Just a simple draft of air or a mechanical dust type respirator probably would be usable if the exposure is to be of any length of time.

X-Ray Examinations

DR. ROBERT M. BURNS (Minnesota State Medical Assn., St. Paul, Minn.): Are there methods by x-ray examination from time to time or from year to year that will show progress of bronchial trouble as a result of these paint inhalations?

DR. WALSH: There are those that would answer your question in the affirmative. Most roentgenologists, however, rather scoff at the idea of making a diagnosis of bronchiectasis by x-ray. The shadows which we see in the x-ray are largely those of the blood vessels and fibrous structures of the lung. It is true, however, if an individual is using some paints which bear silica—and one paint that I did not mention is that used in the porcelain industry, silica-bearing paint—that is another problem. If you are using a silica-bearing paint, you will get the characteristic changes of silicosis.

However, for the ordinary pigment, so little is absorbed, so few of them produce progressive changes in the lung, they rarely

show on the x-ray. Most of them are stopped by the mechanical aids in the nose and upper respiratory tract, that is the hairs, the cilia on the lining of the respiratory tract and, as such, are coughed up, rather than persisting in the respiratory tract.

However, if one is using paints over a long period of time, it is conceivable that a chronic bronchitis might result. However, here one is on thin ice. There are many other factors incident to the causation of chronic bronchitis that are equally as, or more, important than the products used in the paints, either the pigments or the solvents.

MR. CARR (Eastman-Kodak Company): In spray painting in rooms, using lead-free gasoline as a solvent, we have noticed as much as 450 parts per million of aromatics, and we find that many lead-free gasolines now sold contain a large proportion of benzol, xylol and toluol. I wonder if much attention has been given to that fact?

DR. WALSH: That is a problem, it is true. Certain fields of oil, particularly those bearing the naphthionic acid oils do, in their cracking processes, result in benzol in considerable portions, in some instances, in the gasoline. The straight paraffin oils may result in some benzol but not so much. It is a factor to be considered. It depends largely upon the amount of benzol present. In some instances it has been said to run as high as 10 per cent in certain gasolines. That is not usually true.

There is one factor to be considered in gasolines, and that is the difference between benzol, which is the ring-structure and benzene, which is a straight hydrocarbon, and relatively innocuous. It has some toxic properties, but they are transitory, largely.

Benzol has developed a chronic toxicity. This particular subject is receiving attention now, but very little has been produced to indicate that benzol is a definite toxic agent in the gasolines produced. But if the aromatics were up to about 450 parts per million, you certainly are on the borderline of toxicity. I think it should be reduced, if it is at all possible, by ordinary methods. At least the men should be watched very carefully for blood changes, so far as benzol exposure is concerned.

MR. CARR: In that connection, it has been necessary for us to go to a respira-

tory protection of the supplied air type, supplied also with a charcoal canister at the man's waist, so that when he breaks the connection temporarily to go back in the room, he still has the protection of the charcoal canister. The connection, when broken, automatically shuts off both the air supply and also the air connection, so that he cannot breathe the room air.

MR. WALSH: That certainly is a fine arrangement.

DR. ALICE HAMILTON (Division of Labor Standards, U. S. Department of Labor, Washington, D. C.): In the Division of Labor Standards in Washington some two or three years ago, when I was visiting automobile plants, I was told they were making a change in their coatings. I wonder whether that has proved to be true? They told me they were substituting synthetic resins for nitrocellulose and as a solvent were using hydrogenated petroleum products which had very low volatility. It seemed as if that were going to be a revolution in coating in automobile factories. I should like very much to know whether that change has been made.

CHAIRMAN PAINE: Can anyone answer the question of Dr. Hamilton?

DR. WALSH: I would like to say to Dr. Hamilton concerning the substitution of synthetic resins for nitrocellulose products in the automotive industry particularly, most of us receive all of our information concerning the newer development of hazards from no person other than Alice Hamilton. If anyone in the room can answer the question, I am sure that she can. She beautifully reviewed the entire literature in a publication that she produced in 1936 called "Recent Changes in the Painter's Trade" which is Bulletin No. 7 of the U. S. Department of Labor. It is a beautiful presentation, and it is worth while for any of you interested in the paint industry to read it.

Concerning the question at hand, I know of no particular changes at the moment that have been instituted in the industries that I have been acquainted with. I do know that such things are in progress. As Dr. Hamilton suggests, I think that they are changes in the right direction, in many instances.

DR. A. L. BROOKS (Fisher Body Division, General Motors Corp.): We do quite a lot of spray painting. I believe there has been no radical change in the solvents and

diluents used in the lacquers which we are now employing. The process is very much the same.

There has been some change in the length of time required to dry these lacquers, but the constituents are the same as they were.

W. H. KRAUSE (Allis-Chalmers Mfg. Company, West Allis, Wis.): There have been recent changes in regard to the diluents used in paint. Quite a few of the larger oil companies are now producing hydrogenated naphtha. These do contain considerable quantities of benzol and toluol. I wonder if there had been any experiments made with regard to the toxicities?

Benzol Frowned Upon

DR. WALSH: I should have mentioned when we were speaking of toxicities of solvents, that the medical profession frowned upon the use of benzol as a solvent or diluent in any proportion. We just don't like benzol, regardless of its percentage, because it is so easy to get out of hand, and the chronic effects of its poisoning come on so slowly and so innocuously, they creep upon you before you know it. It requires rather close observation wherever there is any benzol or toluol.

So far as the hydrogenated naphthas are concerned, it has been said that the hydrogenation does not change the chemical structure of the naphtha, and it does not increase particularly, its toxicity. If it is in relatively large quantities, 400 to 500 parts per million, then there is the problem of the toxicity inherent to the hydrogenated naphtha itself. But we would much prefer not to see benzol at all.

CHAIRMAN PAINE: Dr. Hamilton, do you wish to say anything else on the subject?

DR. HAMILTON: I think not. My study of the subject is four years old. I thought perhaps very important things had come to light since then. Apparently benzol is still lurking danger which arises in all sorts of unexpected ways, especially as we use more cracked gasoline than we did before. I quite agree that it is something that should be avoided.

We always advise the substitution of toluol, when possible, for benzol, but I don't think any industrial physician would be willing to give a clean bill of health to toluol.

We are beginning to have some suspicion. Dr. G. A. Company believes that we have more than we have thought, as the years go by, accurate knowledge perhaps encourage that probably would be.

MR. GUMMAR would like to offer Commercial toluol, does not contain as much benzol.

CHAIRMAN P. pass on to the next Relation to Occupation will be opened Director of Laboratorial, Milwaukee.

Fatigue and O

DR. NORBERT in the morning I get level of activity a Fatigue is a state transient character. understand it and used but, so far as fatigue is that state work which makes perform what may good output.

It is characterized is characterized investigation by which I will elaborate.

In the strictest sense an occupation which can be direct or circumstance in be labeled as the cause. But as our concept of disease we interpret the variation from health originally used in the must regard an occupation state of ill health used to by circumstance.

Under that definition of disease which, and of affairs, couldn't man is doing. The

We are beginning to look upon it with more suspicion. Dr. Gammon of the du Pont Company believes it is much more harmful than we have thought hitherto. I hope he will, as the years go on, accumulate more accurate knowledge about it so that we may perhaps encourage its disuse, also. I think that probably would be in the right direction.

MR. GUMMAR (Barrett Company): I would like to offer one minor observation. Commercial toluol, as sold in this country, does not contain any measurable amount of benzol.

CHAIRMAN PAINE: We will have to pass on to the next subject: "Fatigue and Its Relation to Occupational Disease." This subject will be opened by Dr. Norbert Enzer, Director of Laboratories, Mount Sinai Hospital, Milwaukee.

Fatigue and Occupational Disease

DR. NORBERT ENZER: At ten-thirty in the morning I generally have a very low level of activity and suffer from fatigue. Fatigue is a state of bodily ill health, of transient character. It is evanescent, as we understand it and as the term is commonly used but, so far as industry is concerned, fatigue is that state of the individual at work which makes it impossible for him to perform what may be considered an average good output.

It is characterized by certain symptoms. It is characterized under ideal conditions of investigation by certain objective findings which I will elaborate in a moment.

In the strictest sense of the term, I suppose an occupational disease is that condition which can be directly traced to some agent or circumstance in employment which can be labeled as the causative factor of the disease. But as our horizon widens and our concept of disease becomes broader, and as we interpret the word "disease" as it was originally used in the Greek sense, a state of variation from health, or dis-ease, then we must regard an occupational disease as any state of ill health which has been contributed to by circumstances of employment.

Under that definition there is hardly a disease which, under some imaginable state of affairs, couldn't be related to what the man is doing. Those are the two extreme

definitions of the term "occupational disease."

Now, any disease will produce fatigue. It is almost synonymous that disease limits the output or the capacity for work of the individual who has been affected. What we must recognize today is that fatigue may also constitute a state of disease. In other words, that we recognize fatigue as a functional disorder which must be treated, which must be recognized and corrected, and its causes eliminated.

The mechanism of fatigue is grounded in a very complex explanation which is not yet clear, and probably won't be clarified until a great deal of investigative work has been done. But in the past few years a considerable amount of investigation has been done, most notably at the Harvard School of Industrial Hygiene under Dr. Dill; and in Europe, up to recent times, a great deal of work has been done, particularly in Germany and latterly in Russia; the object being, in the European investigations, to find out what circumstances of employment contributed to fatigue, to correct those circumstances of employment to prevent fatigue and, hence, to increase the output of the individual in terms of his occupation, without sacrificing any quality of his health.

Now, the thing that we lack at present, so far as its applicability to the practice of industrial medicine is concerned, is a yardstick of fatigue. A number of investigations are going on in that direction, and I think before long something will come of it.

Broadly speaking, two main channels of investigation are being carried on. One is a state of fatigue relative to the muscular capacity of the individual. In other words, we relate muscle strength to the load. The other is a form of fatigue which I think is going to be more important as time goes on, and is related to the nervous system. That arises out of the fact that fatigue is produced by agencies which impair the ability of the brain to send impulses to the peripheral muscles so that work may be performed.

Now, monotony of work may be the greatest contributor to fatigue. I use that as an illustration. For example, we found out, in one small investigation, that individuals employed at work which called for dexterity and nimbleness and a high degree of mental alertness fatigued in less than a twenty-

four-hour period. In other words, if a certain standard of measurement was applied in the morning before work began, the same standard applied at the end of the day, we could demonstrate in almost all individuals so tested that they had experienced fatigue, and that that experience was definitely related to the ability of their nervous system to regulate their muscular activity in coordination.

Now, in jobs which call for a stationary position, manipulation of instruments, or monotony of exercise, that kind of fatigue must be recognized by the industrial physician.

The occupational disease, conversely, may produce a fatigue which may not be recognized unless the individuals are subjected to critical examination. For example, we have noted that individuals with a mild type of hypertension, increased blood pressure, have in many instances a lower fatigue threshold than individuals whose blood pressures are normal. Or an enlarged heart, due to valvular disease, a leaky valve, will produce the same phenomenon; or individuals with diabetes or individuals that have a low basal metabolic rate, because of a thyroid gland disturbance, or individuals who are abnormally obese will all show variations in their fatigue thresholds.

The only way that aspect of the subject can properly be investigated is to approach it from the medical point of view first. Examination of the individual becomes the important thing. It is important to apply critical standards of evaluation, then to attempt to correct them by medical program.

The industrial factor of fatigue, which I mentioned first, calls for a recognition that certain kinds of work can produce fatigue, and then to apply methods which will relieve it. I want to illustrate just two:

If we recognize that a certain occupation produces fatigue, we have discovered things which will relieve the fatigue. A man whose job calls for standing at a bench, in more or less one position, doing the same job over and over again, will have fatigue which can be relieved if he can periodically sit down, because his oxygen consumption in the sitting position is greatly reduced over the standing position, and he performs virtually less work within himself. Consequently he has available greater reserves of energy for his performance.

It has been pointed out, and we have been able to show in some small investigations, that if it could be arranged that this job could be done in the sitting position, the output would be increased and the individual would suffer less fatigue.

It has been shown that, in jobs which call for a to-and-fro movement between more or less fixed positions, without much opportunity to rest, if the period is broken hourly or at hour and one-half intervals, and simple freedom of motion allowed to get out of the range of what he was doing, rest is instituted and fatigue is relieved.

We have been able to show that the application of bathing, in certain kinds of industries, will produce a diminution of fatigue and raise the capacity of the individual to resist his industry or his job. Those are some of the features of the occupational aspects of disease, or the industrial aspect of fatigue, rather. With that casual introduction we can go on and attempt to answer some questions.

Tests of Fatigue

CHAIRMAN PAINE: Are there any questions from the floor? This is an interesting subject.

DR. WALSH: I should like to ask a question in relation to various tests of fatigue. The psychologists have all had people putting round pegs in square holes and all that sort of thing, rapidity of processes. That is one method that is not my concept of the way to measure fatigue, but it brings up one point; namely, the relation of fatigue to the mental status of the individual. Again, the psychological yardstick may be applied. What is the relationship of the intelligence quotient of the individual to fatigue? Does the person using his mind in his work fatigue more readily than one doing physical activity in which no mental effort is required?

DR. ENZER: If I may restate the question, I think Dr. Walsh really wants to find out whether individuals of low I.Q. so to speak, experience the same phenomenon of fatigue under the same circumstances as an individual of high I.Q.

DR. WALSH: That is right.

DR. ENZER: I would say he does, though that is not generally recognized.

BEN JOHANEK (Conno: Wakefield, Mich.): Do you think of this is caused through im-

DR. ENZER: We are not that nutrition plays an important part in nervous fatigue because we have certain elements in food that are for the integrity of the central nervous system. But we have been able to show in preliminary experiments and surveys that, in a general way, fatigue is not an extreme instance, is not in acute instances it is. What by that? An individual who has been deprived of food for longer than he is normally accustomed, in other words, meals are separated by too long a time, fatigue will be produced that on ourselves. We took a subject early morning until late at night and were able to show increasing fatigue.

We were also able to show that, as well known, of course—that certain kinds of food which give a temporary relief from fatigue, namely, sugars, carbohydrates, and a lack of sleep have been done on the proteins of food. I sense that I have tried to show that this morning, diet is a factor in fatigue because it becomes a disease state induces fatigue. Diet is a state of fatigue if we have a disturbance in the habits of diet.

Factor of Noise

MISS MARY LOU SCOTT: Seagram & Son, Louisville, like to know the effect of noise on fatigue.

DR. ENZER: Noise is a factor. We demonstrated that objectively in a laboratory. We tested individuals for their reaction rate which, as I said, was our base line. Afterwards, we put their ear with a sound of noise, rhythm and rate, the question was whether we could fatigue the brain and in that way cause another center of the brain, could distract one center from another.

We found that this investigation might light two rather interesting points, would say three, perhaps. One is, constitutionally, individuals

have been investigations at this job position, the individual.

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BEN JOHANEK (Connor Lumber Co., Wakefield, Mich.): Do you not think a lot of this is caused through improper food?

DR. ENZER: We are now recognizing that nutrition plays an important part in nervous fatigue because we know there are certain elements in food that are important for the integrity of the central nervous system. But we have been able to show in some preliminary experiments and from some surveys that, in a general way, food intake, except in an extreme instance, is not important, but in acute instances it is. What do I mean by that? An individual who has been deprived of food for longer than he is normally accustomed, in other words, if his meals are separated by too long a period of time, fatigue will be produced. We showed that on ourselves. We took no food from early morning until late at night and were able to show increasing fatigue.

We were also able to show—and this is well known, of course—that there are certain kinds of food which give some temporary relief from fatigue, most notably the sugars, carbohydrates, and a good deal has been done on the proteins of diet. But in the sense that I have tried to lay the subject this morning, diet is a factor in fatigue because it becomes a disease state, and a disease state induces fatigue. Diet will produce a state of fatigue if we have some acute disturbance in the habits of diet.

Factor of Noise

MISS MARY LOU SCOTT (Jos. E. Seagram & Son, Louisville, Ky.): I would like to know the effect of factory noise in regard to fatigue.

DR. ENZER: Noise is a factor in fatigue. We demonstrated that objectively in a scientific way in a laboratory, in this manner: We tested individuals for the flicker phenomenon rate which, as I said, constitutes our base line. Afterwards, we stimulated their ear with a sound of a regular intensity, rhythm and rate, the object being to see whether we could fatigue one center of the brain and in that way effect fatigue in another center of the brain, or whether we could distract one center from the other.

We found that this investigation brought to light two rather interesting things, or I would say three, perhaps. One is that there are, constitutionally, individuals who are

sensitive to sound, because we could pick out from a group of individuals people whose flicker phenomenon was greatly depressed when their ears were stimulated; which suggests, perhaps, that such individuals work best in a quiet atmosphere. That is a speculation.

Another type of individual constitutionally wasn't affected at all. His flicker phenomenon was exactly the same rate.

The third individual had his flicker phenomenon raised; in other words, he was stimulated by sound. I think casual examination amongst yourselves will probably bring to light illustrations of the individual who can concentrate on reading a book while the radio is going on and understand both of them perfectly satisfactorily.

Now, when we fatigued these individuals by their routine work—in other words, we conducted the same test in the morning and got a certain base line value; then they did their day's work, and we tested them at the end of the day—we found that fatigue accentuated the direction of their natural constitutional tendency. In other words, the individual to whom stimulation of the ear depressed the flicker phenomenon found that depression increased at the end of a day's work.

PAUL M. HARRIS (Western Austin Co., Aurora, Ill.): Does the human system have the ability in any way to build resistance to this monotony, so it doesn't affect fatigue other than the infusion of glucose or the increasing of the oxygenation?

DR. ENZER: That is a phenomenon known as adaptation in a physiological sense and, in the social sense, it is a question of getting used to your job; but the unfortunate part about getting used to your job is you are not the same today as you were five years ago. In other words, the individual today can't get used to the things he was used to five years ago. Age is an important factor in that direction. The longer the individual is at a fatigue-producing job, sooner or later there will come a time when his fatigue becomes manifest.

We have found that our so-called fatigue testing standards showed no important factors, so far as age was concerned; but the older individuals had a lower threshold to the thing that produced the fatigue than the younger individuals. In other words, it is

not entirely true that experience with a job is a guarantee against fatigue.

CHAIRMAN PAINE: In order that you may not be fatigued, I am going to change the subject. I am asking Dr. Belknap to take the two next subjects, 3 and 4: "The Toxic Limits of Common Solvents" and "Lead in Industrial Processes," and dwell on those subjects as one.

Toxic Limits of Solvents

DR. ELSTON L. BELKNAP: Mr. Chairman, I know there may be several distinguished guests but I am sure that we in the medical profession always feel peculiarly honored when Dr. Hamilton is in the audience. If there has been anyone who has been responsible for bringing to the attention of American industry and the medical profession the importance of toxicology in industry, I think it is Dr. Hamilton.

I will emphasize a few of the toxic limits of the common solvents, so-called thresholds. While these limits have been more or less agreed upon by authorities in this field, particularly such as Doctors Drinker, Haggard and Hamilton, there is no threshold that is arbitrarily perfect, and the actual decision of whether or not the solvent has been toxic is the observation of the patient who has been exposed to that solvent, by a physician who must determine whether or not there has been a temporary intoxication and whether or not there has been a residual.

Dr. Walsh has really very ably covered the subject of the hazards of spray painting, and solvents which are the chief hazards of spray painting, but I will mention a few which I have grouped in increasing order of toxicity.

As an example of probably the least toxic solvent—I say least toxic because no solvent is not potentially toxic; in fact, some go so far as to say that all good solvents are toxic—there is gasoline. It has been stated that 1,000 parts per million is a safe limit for continued exposure. The matter of contamination by other substances such as benzol in 5 to 10 per cent in certain gasolines, certainly would alter that safe threshold.

The next group of solvents which are slightly more toxic, are the amyl and butyl acetates and ether which are allowable in 400 parts per million. Some authorities still state that they belong in the 1,000-part-per-

million class. The most recent report classes them as 400.

The third group of 200 parts per million, include the following: Methanol or wood alcohol which, as you know, may have a serious effect on vision and cause blindness; toluol and xylol, tetrachlorethylene, trichlorethylene and turpentine.

The fourth group, which has dropped to 100 parts per million, include carbon tetrachloride and ethylene dichloride.

Then the fifth group of 75 parts per million, benzene and dichlorobenzene; and finally nitrobenzene, which we, fortunately, actually use very rarely as a solvent, is 5 parts per million.

I think it is important to remember that these solvents, if in sufficient concentration, may kill. This is in contradiction to the other subject that I have been given, which is lead, which very rarely kills. These solvents kill, first of all, by simple suffocation if they are used in an enclosed space, such as in a vat. But the sinister element of the solvent, of the toxic solvent, is the fact that it affects the central nervous system because, as you know, these solvents are fat solvents and our nervous system is largely made up of fatty tissue or lipoid tissue, so the nervous system is very easily affected. We have involvement, therefore, of the eye, one of the most highly developed nervous structures. Then we have central nervous system involvement, paralysis, inability to walk. Also, we must realize that some of these solvents actually damage the liver and the kidney, causing an acute Bright's disease. It is thought that some of them may cause cirrhosis of the liver.

Fortunately, one of the best solvents and one of the most dangerous is not included in the list at all now, the tetrachlorethylene group used in the airplane industry in the past. That had the peculiar ability to attack every part in the body, including the heart muscle. That, too, is said to be a contaminant of some of our other solvents. It has been mentioned that possibly the former contamination in trichlorethylene was really the reason why trichlorethylene had originally had a rather bad name.

I think one of the most important things to remember in dealing with the control of a good solvent is that we are dealing with a potentially dangerous substance and not make any effort to conceal that fact from

anyone in the factory. We in the medical profession have always felt put our cards on the table. It is a great deal simpler to to axiom and tell the truth. So for instance, the benzol coming on its barrels, the word "Poison" in a position to know whether or not it did that because they would know they do it.

I think there are many cases that should put the same label on the facts. In this connection I would like to tell of a case that I was asked to examine a young boy, in the middle of his life, working in a shop which suddenly became very sick, had a headache, was dizzy, and had to stop working with a substance which was harmless.

When I first heard of the case, I would want to see the procedure and get my information rather than attempt to talk to the boy by telephone. (The medical profession is learning that it can take responsibility by demanding to know all about the exposure that come into their hands.)

When I went into the shop, this worker was using a large dipper to dip into a large bowl of grease and he then slapped on the machine. On this particular occasion, he evolved the idea of setting the machine, perhaps, blew the material from him, directly opposite material and blew the fumes in his face. He got cooled, and the

I asked the foreman who was handling the material, and he said he didn't know it was stock material, perfect as he knew. I said, "Well, I know what it is." So there was a upsetting of routine. We finally got a flashlight, a barrel of benzol marked "Poison."

Now, no one in that shop was doing. There were a dozen men each doing the same thing, fortunately, had not gotten the idea of the fan.

The curious thing about the shop was that in another

report classes

parts per million, anol or wood, may have a cause blindness; ethylene, tri-

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5 parts per million; and finally, unfortunately, actually, is 5 parts

remember that concentration, addiction to the given, which kills. These simple suffocation, closed space, such element of the is the fact that system because, are fat solvents, largely made up sue, so the nervous system. We have the eye, one of nervous structure, nervous system ability to walk. some of these liver and the light's disease. It them may cause

best solvents and is not included tetrachlorethylene industry in the ability to attack including the heart to be a contaminant solvents. It has the former ylene was really ylene had orig-

important things the control of re dealing with a stance and not that fact from

anyone in the factory. We of the medical profession have always felt that we like to put our cards on the table. We know that it is a great deal simpler to follow the ancient axiom and tell the truth. So that I admire, for instance, the benzol company which puts on its barrels, the word "Poison." I am not in a position to know whether they more or less did that because they were told to, but I know they do it.

I think there are many other companies that should put the same label on their products. In this connection I would like to tell of a case that I was asked to see, where a young boy, in the middle of the summer, working in a shop which made motors, suddenly became very sick, had severe headache, was dizzy, and had to stop work. He was working with a substance which he regarded as harmless.

When I first heard of the case I insisted I would want to see the process and see the plant and get my information firsthand rather than attempt to talk to some foreman by telephone. (The medical profession as a whole is learning that it can only fulfill its responsibility by demanding the right to know all about the exposure of the patients that come into their hands.)

When I went into the shop I found that this worker was using a large paint brush, dipping it into a large bowl of liquid, which he then slapped on the motor to get the grease off. On this particular hot day he evolved the idea of setting a fan, which ordinarily, perhaps, blew the fumes away from him, directly opposite the bowl of material and blew the fumes directly in his face. He got cooled, and then he got sick.

I asked the foreman what was in that material, and he said he didn't know exactly; it was stock material, perfectly safe, as far as he knew. I said, "Well, I would like to know what it is." So there was considerable upsetting of routine. We finally went out into a shed in the yard, completely dark; we finally got a flashlight, and we found a barrel of benzol marked "Poison."

Now, no one in that shop knew what they were doing. There were a dozen other workers each doing the same thing but who, fortunately, had not gotten this brilliant idea of the fan.

The curious thing about this particular shop was that in another department, not

more than thirty feet away, they were doing spray painting, and they were doing it properly. Instead of exhausting the spray overhead and bringing it right back in the worker's nose, they had their suction underneath the objects to be sprayed and took advantage of draft as well as suction. They had good engineering equipment and staff, but they simply didn't know what they were using in this particular instance.

I had another experience with a man who was a so-called neurotic. I think most of you can spot the neurotic, if you have had any shop experience. This man certainly was. He had been to half a dozen doctors. One told him he was going to die, and another one said there was nothing the matter with him.

Again I demanded to see the shop. We found he was spraying an aluminum paint with a harmless solvent, a diluent, with good suction and a good spray gun. However, on further talking with him and confirmation from the foreman, I found he was the one man in the shop who was delegated to clean the spray guns at the end of the working day. He would sit down and squirt material, which he called chloride, in and out of the spray guns, and lean over the vat he was working with. Finally, he noticed he began to get happy and whistle and sing, and he began to look forward to the experience at the end of every day. However, finally he noticed he was getting weak, he was dragging one leg, and his heart was going very fast.

Well, this illustrates one other sample. This was a large corporation. Yes, they were using chloride. Finally, after great difficulty and having to go to the treasurer of the organization and going into the files we found that this was a material which they had bought from a supply house in another city, and they did not know what was in it. We finally found out it was ethylene dichloride.

The course of that individual is interesting, in that we put him in the hospital. It eventually cost that company quite a lot of money. I was in this to find out all I could learn about the action of that particular substance. I put the man in the hospital three or four weeks and did a number of delicate tests on him.

Well, he came through, and interestingly we found that he had an opportunity to de-

velop a cold once or twice. Every time he did, he developed jaundice. Then, of course, we did liver function tests and found reduction of that. We found he had a weakening of the heart muscle. We found a definite loss of the reflex in one ankle-joint, showing a definite involvement of the central nervous system.

We were able to get all the physicians to agree that this man was considerably disabled, that it was due to his occupation. You will understand, I was seeing him not for himself but for the company. I think a good many of them thought I had been a little generous to this malingerer. This man went ahead and got a large settlement. I don't know anything further about the case except that I did hear that the man died and that the death certificate said "cirrhosis of the liver and heart failure." Unfortunately, we didn't have an autopsy to confirm it.

In my opinion, the toxic solvent is one of the most dangerous substances and it may seriously disable and kill.

Lead in Industry

As a preface to the subject of lead in industry I would like to say that I am not specializing entirely in industrial medicine. I am one of that increasing group who feel that industrial medicine is not a specialty in itself but is merely a division of internal medicine or diagnosis, the large field of medicine which in private practice corresponds to or is correlated with the field of general surgery. I am glad that a large proportion of my practice is still private practice. I am also consulting medical director to one of our industrial concerns in Milwaukee, with branches over the country, so that I have an opportunity to see lead and other toxic materials.

When you see a man who has said, "I have lead poisoning," do not forget he may have some other disabilities and diseases, such as acute appendicitis, gallbladder, kidney colic and so forth. In my private practice my interest has been sharpened so that I always make an effort to take a very careful occupational history on a patient, even though he may come to me purely as a heart case, lung case or what-have-you.

In this particular plant in Milwaukee, which began by having and still has, as a large proportion of its work, storage battery

plants, when I came there about ten years ago we were having an incidence of about 24 lead cases per 100 employees per year, which corresponds pretty well with the percentage of 15 to 16 reported by the Public Health Service in work about that time.

In five years, by cooperation with the medical department, the engineering department and management, we dropped that to an incidence of 2 per 100, and for the past five years we have had no cases of lead poisoning at all. We are still handling lead, and we are still handling it in large amounts.

I think that in the storage battery industry, probably, men are exposed potentially, at least, to the greatest concentration of lead for absorption directly into their bodies than in any other industry. I am glad to report that, having followed this particular group of workers of about 80 for this period, at the end of ten years they are certainly just as healthy and, in many respects, I think healthier than the general run of the population. Of course, we have reduced their lead absorption, but at times it will break down the physical resistance and respiratory protection. They occasionally have large doses of lead. Many of these workers were persons who had had lead poisoning or serious lead absorption in the period of observation.

Lead is one of the most widely used so-called poisons in well over 200 industries. I think there is no doubt but in the large industry the hazard is well controlled. First of all, it is recognized and then every effort is given. No expense is spared to study the men and to reduce the continuance of any exposure. However, in the small industry, which is the major portion of industry in this country, lead is continually cropping up, and even silicosis, which got the center of the stage in recent years, certainly in Wisconsin, has now taken a back step, and lead has come back into its own, together with the ever increasing use of solvents.

I would like to stress again the danger here is one of non-recognition, that we have our trouble in the small plant, not in the large plant. I will rapidly run through the types of industry where I have seen lead poisoning occur and in which it is an important factor.

The most important is the storage battery industry. Then the streamlining of our automobiles and trucks where, after welding, of

course, as first smooth it cooled, grinder and finely divide the fact that any lead in. Remember more danger very rarely through the ception of organic and

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course, as many of you know, they were at first smoothed off by lead paste which, after it cooled, was then ground by machine grinder and produced a great amount of finely divided, inhalable dust. This brings up the fact that the most important hazard in any lead industry is the point of inhalation. Remember that lead dust inhaled is much more dangerous than swallowed, and that very rarely are lead compounds absorbed through the skin, perhaps with the one exception of tetrachloride fluid which is an organic and fat soluble substance.

It is rather amusing that many plants, smaller plants, particularly, have had to give up machine grinding of welded joints. Here is a return of modern industry to the horse-and-buggy stage. They are going back to hand filing where, of course, the particles are heavy and are too large to be inhaled. The problem can be licked, however, even by machine grinding, if one uses respirators.

It has always been said that lead poisoning was very common in painting. My experience in ordinary painting nowadays is it is very rare, particularly on inside painting where lead has been substituted by other substances, such as titanium, zinc and so forth, which are harmless. On the outside, however, lead is still used, in many instances, because it is the one substance that will stand the weather.

Here we come again to the question of finely divided, inhalable dust where men burn off old paint in private homes; not in the large installations, of course, or sand, either by machine sanding or by hand sanding. There we have the question of finely divided dust which is inhaled. You must remember that dust when inhaled passes directly into the system and immediately circulates throughout the entire body.

I make a recommendation, therefore, that any worker that has gotten his lead by burning off or sanding, be given a respirator for that purpose, even though he is an outside worker.

In the wrecking of old buildings and old ships, of course, there is the constant presence of lead absorption when the steel has been coated with several coats. It ideally forms a fume which is so fine as to be almost invisible and is absorbed directly into the system. The only way that a worker doing that can really protect himself, in my opinion, is to use an air-line respirator. I

have seen a great many men in one particular type of ship industry, cutting up old ships outdoors in mid-winter, and I have never seen men leaded up so rapidly. Of course, this is an old story. The Navy found this out twenty years ago when they scrapped many of the old ships. Unfortunately, some people in industry, as well as doctors, are not very good on keeping up on their own work, by reading, and experiments have to be made again.

In the smelting of lead or zinc ore and scrap metal, lead poisoning occurs. In pottery making where a glazed mixer is used, one most usually is exposed to lead. In the printing industry we have heard a great deal of lead poisoning.

I had an opportunity recently to make a survey of a group of printers with the Wisconsin Industrial Hygiene Unit. They went into an analysis of the air, and I examined the men. To be sure, our list was not large, some 30 men in fourteen different printing establishments, but it was striking that all of these men were in excellent health and, as far as I could see, there had been no great deal of turnover.

However, there are one or two spots in the printing industry that are danger spots; that is, of course, the man who remelts the old type metal or who saws it, if he uses a machine saw. I think it is interesting, going through our records of printers in the State of Wisconsin, for a great number of years past, we have had only three cases, one of which was really a serious case, and that man was one who remelted—he was the forgotten man, worked down in the basement on a kettle, where nobody paid any attention to him, and there was no protection.

In passing, I will simply name soldering, and that occurs very frequently even in the evaporated milk industry out in the country; tempering of metals, brass foundries, ink making, insecticides. This potentially may occur in leaded steel when it is scrapped. Then I would class as the final one, the risk which says they have no lead hazard. That is the place you should look particularly.

As I said, the important portal of entry is through the nose. If we bear that in mind, the problem of control of lead poisoning is really not difficult. If, of course, your engineers reduce the exposure to 1.5 milligrams, I don't think you will have a case of

lead poisoning. However, as a matter of practical interest, I think it is very difficult to get there in ordinary industry, and I would more or less formulate 3 as a safe level. I think it has also been found by other workers. However, if you get over 3 you certainly have the possibility of serious lead absorption.

I want to emphasize that mere lead absorption does not mean the man has lead poisoning. He may have a lead line, may have lead in the urine, .08 milligrams per liter, but that does not make lead poisoning. That is merely evidence of absorption. He must have, in addition, clinical symptoms of one of the three types of lead absorption.

As a final word in regard to the role of the medical profession in its cooperation in industry, it seems to me that the medical man should first of all be responsible to the highest man in authority in the plant, so that he can go direct to him with any problems that arise, and before any new procedure is used or any new chemical, have a conference with the physician to see whether there is any possible danger, whether there are volatile solvents or lead, so that the danger to the men may be prevented before it happens.

I am not making a plea for absolute substitution for and avoidance of the use of lead. I think industry cannot get along without the use of lead, cannot get along without the use of a number of these solvents; but if industry is forewarned, and if the worker is informed correctly so he will cooperate in the use of protective devices and, finally, the medical profession is allowed to see the patient as often as they see fit, perhaps every two or three weeks, then there need occur no occupational disease in industry.

CHAIRMAN PAINE: Are there any questions on either one of these subjects that you would like to ask?

MR. HUTTER: What is the effect of the smell of kerosene on the worker? Is that a permanent effect or just temporary?

DR. BELKNAP: As far as I know, there is no ill effect from the inhalation of kerosene.

R. S. SKYRM (Employers Liability Assurance Corporation, Boston): Would Dr. Belknap recommend the direct venting of lead pots on linotype machines where the pots are electrically heated and thermo-

statically controlled so the temperature of the lead does not exceed 500 degrees?

DR. BELKNAP: That is a good practical question. As we know, lead melts at a much lower temperature when volatilized. In my experience, lead does not really volatilize until around 1,000 or 1,100 degrees.

In this group of workers that I am following, some years ago, large lead pots, two or three feet in diameter, were unhooded because of certain changes in technical procedure, and the plant never got around to the hood. I disapproved of that and repeatedly said they would have cases of lead poisoning there if they didn't hood. They said they would just as soon as it was practical. It has never been practicable, and I am here to say we have had no lead cases develop to the point of disability, and we have had very little lead absorption result from that. The same men have worked there for ten years, dipping lead out of the pot incidentally, at temperatures ranging usually from 850 to 950 degrees. In this group of linotype workers we found no evidence of lead absorption in some of the shops where they had no suction. I would not say in my own experience that hooding is necessary at 500 degrees.

MR. CARR: I wonder if there is any evidence to indicate the toxic limit for butyl alcohol could be raised above that given? We had experience over some twenty years with the same group of men, working in concentrations from 200 to 400 parts per million, and under careful examination they have shown no indication of trouble.

One other question is whether much work has been done on toxic limits of dioxene?

DR. BELKNAP: I think Dr. Hamilton will have to state if she recalls whether we have toxic limits established for dioxene.

DR. HAMILTON: Dioxene is the trade name for diethylene chloride. No toxic limit has been established for that. We considered it a fairly safe solvent until some very disastrous cases occurred in England from over-exposure, causing five deaths. Since then we have looked upon it with a good deal more suspicion. There has not been enough work done on it to establish any maximum allowable concentrations.

DR. BELKNAP: In regard to butyl alcohol, the butyl radical acetate is much less toxic than ethyl or methyl, particularly. So I would be interested in your point of view.

I think probably in limits.

MR. GUMMAR: Completely the principle of safety standards should be based on toluene, there have been used in the lacquer painting came into air as fine mist, evaporates at a slower rate than the mist, you inhale the mist, you are toxic.

I have employers in State, New Jersey, who for the past six years have reported cases of poisoning; yet Ohio in 1928 had over 69 cases of poisoning in the petroleum line in the petroleum.

As to the experimental data, no experimental data should be such a confusion arises in distinguishing between concentrations, toluene is more toxic than benzol; in a chamber where the concentration is one million, you would get from toluene and with benzene, but the phenomenon from benzene.

CHAIRMAN: I will be "Skin Affected" handled by Dr. M.

Skin

DR. M. J. REU: To what extent is the worker exposed to injurious irritants and the result is not surprising that cases are a major United States problem. Estimates 69 per cent are skin diseases. In 100,000 workers of a year, that one were affected with result of their work, burns, splashes of ordinary pus in abrasions.

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I think probably it could be made at safe
limits.

MR. GUMMAR: I want to endorse com-
pletely the principle of maximum clearances
of safety standards in engineering, but they
should be based on factual data. As regards
toluene, there have been enormous quantities
used in the lacquer industry since spray
painting came into use. It is sprayed into the
air as fine mist, and even though it evap-
orates at a slower rate than benzol, if you
inhale the mist, you get severe effects, if it
is toxic.

I have employers in four states, New York
State, New Jersey, Ohio and Connecticut,
who for the past sixteen years have not had
any reported cases of chronic toluene poison-
ing; yet Ohio in the past sixteen years has
had over 69 cases of poisoning from gaso-
line in the petroleum industry.

As to the experimental results, I can find
no experimental data indicating the toxicity
should be such a low value. Some of the
confusion arises from the failure to dis-
tinguish between chronic and acute poison-
ing. It is a fact that in extremely high con-
centrations, toluene and xylene are more
toxic than benzol; that is, if you go into a
chamber where there are 20,000 parts per
million, you would be unconscious quicker
from toluene and xylene than you would
with benzene, but that is an entirely separate
phenomenon from the slow chronic poison-
ing.

CHAIRMAN PAINE: The next topic
will be "Skin Affections" and that will be
handled by Dr. M. J. Reuter.

Skin Affections

DR. M. J. REUTER: When we consider
to what extent the skin of the worker is
exposed to injuries, the action of chemical
irritants and the various infectious agents, it
is not surprising that occupational skin dis-
eases are a major problem in industry. The
United States Public Health Service esti-
mates 69 per cent of occupational disease
are skin diseases. They carried out a study
in 100,000 workers and found, in the course
of a year, that one per cent of these workers
were affected with some skin disease as a
result of their work. This did not include
burns, splashes of acids and alkalis, and the
ordinary pus infections of scratches or
abrasions.

The problem confronting the physician is
to determine the relationship between the
skin disease and the occupational environ-
ment, to discover the nature of the offending
agent and to adopt measures designed to
cure the condition and prevent its occur-
rence.

There are many predisposing causes of
occupational dermatosis, such as uncleanli-
ness of workrooms, of clothes and of per-
son. Previous skin diseases as, for example,
eczema, are potent factors, because individ-
uals with eczema react seven times more
frequently to external irritants than non-
eczematous individuals. The skin of the
young and old is more susceptible to irrita-
tion and infection than the skin of persons
in middle life. Dry skin is more vulnerable
to irritants than oily skin.

The skin of certain parts of the body is
especially sensitive, for instance, that of the
eyelids and genitalia. Anything which lowers
the normal threshold of resistance of the
skin may act as a predisposing factor in the
production of dermatitis and of infectious
lesions. These factors include bruises, marked
sweating and maceration, prolonged ex-
posure of the skin to water and especially to
alkalis and repeated scrubbing of the skin.
These agents tend to remove the normal
protective coats of the skin, that is the outer
horny layer, and thus expose the sensitive
epidermal cells directly to irritating material.
A point fairly recently emphasized is that
individuals with common athlete's foot are
much more prone to occupational dermatitis
of the hands. Apparently this infection of
the feet acts as a sensitizing factor.

The actual causes of occupational derma-
toses are mechanical, physical and biologic
agents and chemical irritants. Mechanical
agents produce bruises and lacerations, as
well as friction and pressure resulting in
various inflammations and thickenings of
the skin.

The physical agents which may produce
an occupational dermatosis are heat and
cold, either dry or wet, electricity, ultraviolet
rays, either from the sun or artificial, and
x-rays or radium.

The biologic agents are the common bac-
teria, fungi and parasites.

For the most part, however, occupational
affections of the skin are the result of con-
tact with irritants of a chemical nature.

case be compensated. The trend is coming on. I believe that industry and society will be gratified when the problem has been solved by whatever methods may be adopted and suited to the different states.

CHAIRMAN PAINE: Are there any questions you want to ask Mr. Nelson before we go into the general discussion?

ADOLF AMRAM (Hamlin & Co., New York City): We passed a compensation law in New York State some two or three years ago. Perhaps you recall that first we passed a most illogical law, the all-inclusive act which acted most disastrously not only to industry itself but to the workmen. You are familiar with the history and the recall of that act. I dare say in a number of states it is absolutely right and proper the compensation act should include silicosis, but it should include silicosis on a schedule basis, as I think is the case in Illinois.

MR. NELSON: All states are not as fortunate as some other states. I think we are showing generally throughout all of the states that the problem can be solved.

Protection for Welders

CHAIRMAN PAINE: We have a few minutes. Anyone in the audience has the privilege of asking this panel of doctors any questions they want to raise on these main subjects.

J. S. GREEN (Edgewater Steel Co., Oakmont, Pa.): I would like to ask to what extent an ordinary welder in a small plant should be protected? Once in a while there will be a hardening material which has poisonous results. Other times there will be flame cutting of paint on a product which will raise some noxious poison. To what extent would a welder or a cutter have to be protected?

CHAIRMAN PAINE: The question is, how are we going to protect, and what is the exposure to welders on new material or on old material that has been painted? I will ask Dr. Walsh to answer that question.

DR. WALSH: Within the past couple of years we have had occasion to go over a group of about 1,000 welders. Of that group some 300 have been welding for ten or more years. They were gone over from the clinical point of view. X-rays of the chest were

taken. Disability due to sickness over the ten-year period was calculated and seen for each individual man. There certainly was no marked difference in sickness rates and in disability rates in the welders as compared to the general run of employees working at their side in the same plant and in the same economic situation.

When you are considering welders who are cutting painted materials, lead-bearing paints, or who are welding in confined spaces, you have a different problem; but for the ordinary welding group, working in a large, airy room, with ordinary precautions and ventilation, their health is just as good as any other group of workers. If they are cutting paint or toxic coatings of any kind or lead-bearing steel, or if they are working in a confined space, then additional respiratory protection is necessary.

So far as the question that was rampant a few years ago, that is the development of so-called fibrosis of the lungs due to welding, we have not found this to be the case. Dr. Enzer and Dr. Sander at Milwaukee have had occasion to examine at postmortem a few of these individuals who have been welding for long periods of time in confined spaces, usually. They did find there was an increase of iron in the lung but no fibrosis causing harm.

Recently, we also have examined another group of welders, that is a variant of the welding trade, scarfers, in the continuous production of steel. These scarfers use a long torch and blow out the defects in the billets rather than chiseling them out. This group also, while it is an infant in the group of welders, apparently have no health hazards of any consequence in their trade. In other words, I think if ordinary precautions, so far as ventilation and so forth are concerned, we need not be concerned other than if we are using lead or chromium or some of the toxic materials.

CHAIRMAN PAINE: Dr. Enzer will speak for a minute on the subject and then Dr. Belknap will follow him right up.

DR. ENZER: I want to seize the opportunity to make some comments relative to the general attitude of this panel discussion. It is most important that in any approach to the problem of industrial health we remember that a statistical analysis of groups is not a true criterion of the health of the individual. In other words, just like the sur-

on who might recovery rate from individual who has per cent constant for the individual contrast there.

Now, when we use solvents, safe limits of an error that the problem, but by analysis and structure to the industry realize that the forms the these problems.

DR. BELKNA: I will say what has a that is when a material that has with lead, he, of require lead absorb about as quickly any other way.

It is very similar to we have whenever he is use such a respiratory series of cases of sorption was pairing some amount of lead.

Also, I had a dozen cases of up tanks in a steel tanks had could not under getting lead. T with a torch 35 absorbed lead a difficult question matter of having the work is for

MR. CARR: we have had work on galvanic nitrous fume coated electrode.

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geon who might boast of a 99½ per cent
recovery rate from a specific operation, the
individual who happened to belong to that
½ per cent constitutes 100 per cent mortal-
ity for the individual. There is a very sharp
contrast there.

Now, when we talk about safe limits of
toxic solvents, safe limits of toxic agents,
safe limits of an industry, we must remem-
ber that the problem is not going to be
solved by a blanket generalization of a
problem, but by a careful and meticulous
analysis and study of the individuals ex-
posed to the industry. I know of no other
way that this can be done except that in-
dustry realize that the profession of medi-
cine forms the keystone to the solution of
these problems.

DR. BELKNAP: I simply wanted to am-
plify what has already been mentioned, and
that is when a welder or cutter works on
material that has been painted or coated
with lead, he, of course, probably will ac-
quire lead absorption in a serious fashion
about as quickly as, if not quicker than, in
any other way.

It is very simple now, with the respira-
tors we have available, for a shop welder,
whenever he is doing that type of work, to
use such a respirator. In my own particular
series of cases one of our cases of lead ab-
sorption was a welder who had been re-
pairing some ovens containing a large
amount of lead.

Also, I had occasion recently to see half
a dozen cases of cutters who were cutting
up tanks in a large chemical plant. These
steel tanks had been lined with lead. They
could not understand why the men were
getting lead. They went through the lead
with a torch 3000 or 4000 degrees and they
absorbed lead exceedingly rapidly. It is not
a difficult question to solve at all but it is a
matter of having perfect confidence in what
the work is for and preparing for it.

MR. CARR: In connection with welding,
we have had instances of zinc chills from
work on galvanized iron. We have also had
nitrogen fume poisoning from the use of
coated electrodes.

I would also like to call attention to a
relatively new development, that of the flame
cleaning of metals before painting, by the
use of a special oxy-acetylene torch. That
includes previously painted metals as well

as those which simply have mill scale on
them.

R. J. WOODHOUSE (Continental Cas-
ualty Company, New York City): I had a
case a short time ago that I was called upon
to investigate. The man worked in a small
printing plant where he was assumed to
have contracted lead poisoning. After mak-
ing impinger tests which proved negative,
an award was given by the commission to
the widow in the amount of \$13,000. The
lead was melted around 650 to 700 degrees
and the experts proved that toxic fumes
were not liberated.

I wonder what yardstick the referees used
to measure those cases, in the face of such
expert testimony.

MR. SKYRM: I would like to know the
relation of hemlock poisoning and poison
ivy to skin disease.

DR. REUTER: Poison ivy, of course, is
the most common plant that causes derma-
titis. Hemlock is occasionally the cause.
Poison ivy is an intense irritant to most
people's skin. It is a question of whether in
itself it is not an irritant to all people's
skin.

We used to think we knew the cause of
poison ivy dermatitis, but more recent work
has tended rather to disprove that we do
know the actual cause of what it is in the
plant that produces dermatitis. Apparently
it is a water-soluble fraction rather than an
oil.

Its relation to occupational disease de-
pends on what the individual is doing. If he
is exposed to it in his occupation, for ex-
ample, as a farmer, WPA worker, lumber-
man or any occupation that keeps an indi-
vidual out-of-doors, and he contacts poison
ivy, it certainly would be an occupational
disease. Poison ivy dermatitis is apt to be
a much more violent dermatitis than that
from hemlock.

CHAIRMAN PAINE: Mr. Gumaer,
will you repeat your question?

P. W. GUMAER: The question was, what
is the basis of the comparatively low maxi-
mum concentration of toluol in the absence
of any reported occupational disease cases,
and are there any experimental data to war-
rant such a low concentration where such
experimental data deals with chronic poison-
ing and not with acute poisoning?

DR. BELKNAP: The question is, whether toluol is really as toxic as I intimated it might be, being permissible in only 200 parts per million. Is that right, Mr. Gumaer?

MR. GUMAER: Yes.

DR. BELKNAP: As far as the official authority of that is concerned, it is taken from the code for safe concentrations of certain toxic substances used in industries, whose authors are Bowditch, Drinker, Haggard and Alice Hamilton which appeared in the June 1940 issue of the Journal of Industrial Hygiene and Toxicology.

I do not know whether there is any practical experimental work backing that up, but inasmuch as toluol and xylol are very closely related to benzol, I assume that the authors felt that it as yet could not be given an entirely safe record, for instance, compared to gasoline.

I will say, among a group of workers who have been working with adequate protection for several years with toluol solvents, I have seen no general reaction.

DR. HAMILTON: May I speak to that for just a moment? That presentation to which Dr. Belknap refers was got out simply because a small group of us felt that we might as well let the public know what was our best guess at the present moment with regard to maximum allowable concentrations of the most commonly used solvents. It is founded very largely on guesswork.

The quantity of 1,000 parts per million for gasoline is guess, and so is 200 parts of toluene. We are hoping that we shall be able to give more accurate figures presently.

The American Standards Association has a committee at work in this field, with a small subcommittee. We have just finished dealing with two gases and two volatile solvents, carbon monoxide and benzol and carbon disulphide and hydrogen sulphide. There we have been able to get pretty accurate figures because we have data to go on.

We are now trying to deal with twelve others which are going to be increasingly important in the munitions industry. We hope to be able to give out more accurate figures then. But it is a very difficult problem. You see the only way we can get any accurate figure is by having a combined inquiry made by the physicians, the chemists and the ventilation engineers, because we have to know how many cases developed in a given workroom at a given concentration, and also at what concentration do no cases come.

We could do that with the four I have mentioned, but it means, as you see, a great deal of careful study in the factory and in the physicians' examining room. Bringing those two together, we can do it with regard to lead; we can do it pretty well with regard to mercury, and we have pretty good data with regard to zinc oxide fumes in galvanizing iron and brass foundries and zinc smelting; but the rest of the substances still are more or less in the realm of guesswork.

CHAIRMAN PAINE: May I, in your behalf and in behalf of the National Safety Council, thank the gentlemen on the platform who have so kindly led us in this discussion? Will you express that thanks by giving them a rising vote?

... The audience arose and applauded.

ADJOURNMENT

Of

The Panel Discussion: accidents was called to man, Julien H. Harve for, The National C New York City, who

CHAIRMAN HARRY to welcome you here t of introduction, I simpl just what the National in mind by the phrase dents." All too frequen sions of this kind ther that we were thinking munity" safety work. thinking of safety we basis, but in another c thinking of a prograr vidual industry or co the problem of acciden employees during the away from work. Thi inception some seven following several sur that a very great pre dents occurred to emp leit the job, as comp occurred while they

I recall one illustrat a well known nation many thousands of en good job of safety we spite that fact, during 37 of their employees at work, but during th their employees had b whistle blew."

We found that situa instances. Proceeding industry is closer to it organizations can be, been able to do a goo vention within the wa ten that it migh through a special pro employees and do son hours of safety beyond In our program thi to take up certain

this ventilating current be interrupted for a period of 24 hours and with the same amount of methane being liberated, there would be 5,760,000 cu. ft. of explosive mixture. Should this be contained in an entry 10 ft. square, the length of the entry would be approximately 11 miles.

Methane detectors are now available which will automatically indicate and record percentages of methane. One type may be located in working sections on cutting and loading machines, in the last breakthrough and along haulage roads. This can be adjusted to give a warning by a signal light or other means at any predetermined methane concentration. For example, at 1 per cent or any specified percentage between .5 per cent and 3 per cent, it will operate special electrical circuits through suitable relays to cut off the power in a section or

give warnings in other parts of the mine or to the outside. Methane recorders for continuously indicating and recording methane in main returns particularly have been perfected recently and are designed to be located in fan houses or other convenient places.

There is no relation between the volume of methane given off in a coal mine and the chemical composition of the coal, as both bituminous and anthracite mines produce methane, and methane has been found in metal and other mines when tunneling through carbonaceous shales. The common occurrence and explosibility of methane are responsible for numerous mine disasters and every precaution should be taken to keep it within safe limits. This can best be done by the use and guidance of methane detectors.

Pulmonary Diseases in the Mining Industry

By DR. R. R. SAYERS

Director, United States Bureau of Mines, Washington, D. C.

Although the attention of those interested in diseases peculiar to mining has been focused recently on one dust disease—silicosis—other respiratory diseases may cause more suffering and economic loss. The increased incidence of these diseases usually is attributed to exposure to abnormal air conditions underground, such as sudden changes from high to low temperatures, excessive dust, and noxious gases. The principal respiratory diseases to which the miner is subject are bronchitis, influenza and pneumonia, pulmonary tuberculosis, anthracosis, and silicosis. Although the mortality statistics in some of the tables included in this paper are old they have been corroborated by later, less complete data.

Bronchitis

Bronchitis is an inflammation of the bronchial tubes due, among other causes, to the inhalation of irritants such as dusts (organic and inorganic). Occupations that entail exposure to atmospheres polluted by irritating gases carry with them the risk of bronchitis. According to Collis,¹ it cannot be distinguished clinically from bronchitis occurring among the general population and its association with the inhalation of dust or gases usually is unrecognized.

During middle life bronchitis causes much recurrent invalidity and incapacity. Mortality records compiled by Collis² indicate that it is of a chronic traumatic origin associated with irritating atmospheric conditions, rather than of an infectious origin.

Statistics for bronchitis for the general population and for workers exposed to dusts in Great Britain³ for 1921-23 show the role played by dusts in the increased incidence of the disease in certain industries. The comparative mortality per thousand (ages 26 to 65) for those in occupations exposed to siliceous dust was 214, for those exposed to nonsiliceous dust 59.5, and for the general population 49.6. (See Table 1.)

In this connection it is interesting to note the mortality statistics per thousand (ages 26 to 65) for coal miners of counties of Wales (in which most of the coal mined is anthracite) compared with those for two other groups in England and Wales.⁴ The figures for coal miners are 112 for all underground workers and 139 for hewers and getters compared with 46 for males in the same social class and 50 for all occupied and retired males. (See Table 2.)

In a study by the United States Public Health Service⁵ 35 cases of chronic bron-

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⁴ Fifteen years ar-

Table 1.—Mortality per 1,000 from Bronchitis in Dusty Occupations and in the General Population, by Age Groups

	Ages at Death					Comparative Mortality Figure
	20—	25—	35—	45—	55—	20—65
Occupations exposed to						
Siliceous dust.....	1.1	1.0	13.7	44.6	153.7	214.0
Nonsiliceous dust.....	0.5	1.7	4.9	12.8	41.8	59.5
General population.....	0.5	1.7	5.4	13.3	28.8	49.6

It was found among 344 employees of two anthracite mining companies examined. In the study conducted by the Bureau of Mines and the Public Health Service at Picher, Okla.,¹ the highest incidence of silicosis or tuberculosis, or both, was found among men who reported having had bronchitis, pleurisy, and asthma.

Table 2.—Comparative Mortality Figures for Bronchitis per 1,000 of Certain Groups in England and Wales

	Bronchitis
Coal miners ¹	112
All underground workers.....	139
Hewers and getters.....	46
Males in same social class.....	50
All occupied and retired males.....	302
Ratio of rate for hewers and getters to rate for same social class.....	

¹ In three counties in Wales.

Table 3.—Influenza-Pneumonia Mortality among Bituminous Coal Miners—October to December 1918

Age Period	Annual Death Rate per 1,000	
	Bituminous Coal Miners	All Industrial White Males
All Ages ¹	50.1	22.3
15-25	29.5	17.5
25-45	62.1	32.6
45-65	44.4	11.7

¹ Fifteen years and over.

Influenza and Pneumonia

Figures of mortality available for 4,700 miners insured in the group department of the Metropolitan Life Insurance Company¹ show that in the last quarter of 1918 during the influenza epidemic 64 of these miners died of influenza or pneumonia. This is equivalent to an annual death rate of 50 per 1,000. Among all occupied males aged 15 years and over, the rate from influenza-pneumonia in the same 3 months was 22 per 1,000 or less than half as high. In the age period 45 to 65 years the rate among bituminous coal miners was about four times as high as among all occupied males in the same age group. (See Table 3.)

Influenza and pneumonia, as reported, were responsible, in the years under study, for 31 per cent of the mortality in the group of bituminous coal miners at ages 16 to 70 in Indiana, Missouri, and Wyoming compared with 19 per cent among both farmers and "all other males" at these ages in the same counties. (See Table 4.)

In 1918, the year of the great epidemic, influenza and pneumonia deaths constituted 55 per cent of total mortality exclusive of accidents among the bituminous miners in contrast with 27 per cent among the farmers and 34 per cent among all other males. These percentages were not as high as the figures for Wilkes-Barre. The fact that the soft-coal counties under consideration are largely rural areas may have made some difference.

In the epidemic year 1920, the proportion of deaths from influenza and pneumonia was smaller than in 1918, but, as was found for the anthracite miners, the bituminous group showed a wider difference in the pro-

Table 4.—Percentage of Deaths from Influenza and Pneumonia (After Deducting Accidents) Among Bituminous Coal Miners Compared with Farmers, and With Other Males in the Same Areas of Several Soft-Coal Producing States¹

Male Groups Under Comparison	Ages					
	16-70	16-30	31-40	41-50	51-60	61-70
Bituminous coal miners.....	31.1	49.4	44.7	25.1	19.7	10.4
Farmers.....	18.7	38.4	32.4	19.7	12.4	10.8
All other males.....	18.6	30.0	29.0	16.0	11.3	10.8

¹ The death records for soft-coal miners were obtained from 15 coal-producing counties of Indiana, 1916-20, inclusive, 8 coal counties of Missouri, 1917-21, inclusive, and the 6 principal coal-producing counties of Wyoming, 1919-23, inclusive. The record for farmers and for "all other males" was obtained from the above-mentioned coal-mining counties, and also from 3 agricultural counties of Wyoming, 1919-23.

portion of deaths from this cause compared with "all other males" than in 1918. The percentages in 1920 were 29 for the soft-coal miners and 16 for "all other males." In this epidemic the bituminous miners at ages 40 to 60 suffered heavy excess mortality from influenza-pneumonia, but the differential mortality was not quite so great as at ages 16 to 30.

Among hewers and getters of soft coal in England and Wales, the death rate from influenza and pneumonia, 1921-23, was about 12 per cent greater than among males of comparable social status (social class 3). The difference was found to be 5.8 times the probable error of the difference which is certainly a significant variation.⁷ Thus, an abnormal mortality from influenza and pneumonia is consistently indicated among miners of coal—both anthracite and bituminous—in England as well as in America.

The pneumonia mortality figures in 1921-23 for occupations in Great Britain exposed to siliceous and nonsiliceous dust compared with those for the general population were given by Collis⁸ as 134.3, 76.0, and 85.3, respectively; similar figures for influenza were 47.1, 49.6, and 36.5, respectively. (See Table 5.)

According to Brundage,⁹ an outstanding feature of the statistics of death for hard-coal miners in the United States is their extraordinary mortality from influenza and pneumonia not only during influenza epidemics but at other times as well. In a study by the Public Health Service at Wilkes-Barre, Pa., in 1915-23 and 1906-25¹⁰ it was found that influenza and pneumonia were responsible for 40 per cent of the total deaths compared with 25 per cent among males at ages 15 to 65 who had been en-

gaged in pursuits other than coal mining in Wilkes-Barre and vicinity. The percentage of deaths from influenza and pneumonia for these two groups by ages for the years mentioned was 19.3 for anthracite miners compared with 13.3 for males in other industries. (See Table 6.)

Tuberculosis

In 1925 Collis⁸ said that for coal miners generally the tuberculosis rate apparently is low although miners at the coal face suffer from the disease more than other coal miners underground and workers above ground. Results of more recent investigations seem to contradict the assumption that tuberculosis does not occur among coal miners. An investigation by the Welsh School of Medicine, reported in 1937,¹¹ indicates that this supposed exemption of coal miners from tuberculosis may be due to a mis- or partial diagnosis. This investigation revealed a high incidence of tuberculosis (35 per cent if the "probable" cases are included) among the pneumoconiotics of the South Wales coal fields and supports the theory that coal dust modifies the tuberculosis, leading to failure to recognize the disease or to the mistaken diagnosis of "bronchitis."

Studies by the United States Public Health Service¹² revealed that 6 per cent of hard-coal miners examined had clinical pulmonary tuberculosis. The average prevalence in the adult male population of the United States is about 2 per cent. The prevalence of pulmonary tuberculosis among hard-coal mining employees at ages below 35 was slightly less than that found through studies among male adults in the general population. In the age group 35 to 44, however, the prevalence of tuberculosis was

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Table 5.—Mortality per 1,000 from Pneumonia and Influenza in Dusty Occupations and in the General Population

Occupations exposed to	Pneumonia					
	Ages at Death					Comparative Mortality Figure
	20-	25-	35-	45-	55-	
Siliceous dust	3.3	14.4	30.6	47.2	38.7	134.3
Nonsiliceous dust	4.3	9.6	13.7	28.7	23.9	76.0
General population	4.3	11.5	19.6	24.2	25.7	85.3
Occupations exposed to	Influenza					
Siliceous dust	1.1	7.7	11.3	8.7	18.3	47.1
Nonsiliceous dust	5.4	4.8	13.7	10.6	14.9	49.6
General population	2.0	5.2	7.7	9.7	12.0	36.5

about twice, at ages 45 to 54 about 5 times, and for ages above 55 it was about 10 times the rate found in the general population. The highest prevalence of clinical pulmonary tuberculosis occurred among the rock workers (men who had been employed in rock loading or rock extraction for more than 2 or 3 years). After 20 years' service, of which more than 2 or 3 years were in rock work, 37 per cent presented evidence of pulmonary tuberculosis. In a group of 135 completely disabled former anthracite workers, which did not include any known cases of tuberculosis, 10 per cent proved positive for pulmonary tuberculosis. These findings would appear to corroborate those of the Welsh National School of Medicine that indicate that the supposed exemption from tuberculosis of coal miners is erroneous due to incorrect diagnosis. There is evidence that the above increased incidence of tu-

berculosis is associated with exposure to silica dust.

The incidence of tuberculosis is much higher in metal mines than in coal mines, due no doubt to exposure to dust containing a higher concentration of silica. An investigation in 1914 by the Bureau of Mines in cooperation with the Public Health Service of pulmonary disease among the zinc miners of the Joplin, Mo., district, revealed a high death rate from pulmonary tuberculosis. The mortality rate for tuberculosis for Jasper County was 200.8 per 100,000 for 1911 and 1912 and 229.7 for 1913, according to statistics of the State Board of Health. On the other hand, according to the Jasper County Antituberculosis Society, during the calendar year 1912 there were 720 deaths among miners who had worked 2 years or more underground in Jasper County. Not all

Table 6.—Percentage of Deaths from Influenza and Pneumonia among Anthracite Miners and among Males in Occupations Other Than Mining in Wilkes-Barre and Vicinity

Groups Under Comparison	Ages					
	15-64	15-24	25-34	35-44	45-54	55-64
Anthracite miners.....	39.8	45.2	67.9	42.9	31.8	19.3
Males in other industries.....	25.3	28.7	46.2	31.0	16.8	13.3

Table 8.—Pre-

Outdoor and indoor industries
Coal trade.....
Alcohol trade....
Heat and fumes.
Dust of
1. Animal origin
2. Vegetable and mineral materials..
3. Silica.....

high among those exposed to silica dust but the incidence of these diseases is not always the same under other conditions such as exposure to other dusts, heat and fumes, or working indoors. (See Table 8.)

number of instances probably with physical conditions of rock workers, and considerable exposure to dust in these industries also suggests a greater physical involvement in the control group. Moderate or more severe disease from any cause within the control group was found in regular miners, and in the rock workers.

From 1931 to 1937, 87 per cent of the total deaths in Great Britain due to silicosis occurred among the coal miners of South Wales; two-thirds of the deaths and disease occurred in the Swansea Division; and 89 per cent of the medical certificates granted in the Swansea Division related to anthracite collieries."

[illegible]

Wide differences were found in the extent of physical impairment in the several occupational groups. The highest rate of disability from all causes combined was found in the group of men that had changed more than 5 years before the date of examination from very dusty to relatively nondusty occupations in the industry. In a

The pathology of silicosis in these cases is characterized by the presence of coal dust in the lungs, which is associated with an extensive fibrotic reaction (nodular, with associated regenerative changes, and coal dust).

Dusty Occupations

Table 8.—Prevalence of Bronchitis, Pneumonia and Tuberculosis Under Certain Conditions of Exposure

Exposure		Bronchitis	Pneumonia	Tuberculosis
55-	20-65			
150.6	592.2	low	low	low
29.9	172.4	low	low	high
22.7	163.5	high	high	low
		moderate	high	high
		high	high	low
		low	low	low
		low	low	low
		high	medium	low
		high	high	high

posed to silica dust but diseases is not always conditions such as heat and fumes, or Table 8.)

silicosis

87 per cent of the Britain due to silicosis coal miners of South the deaths and dis Swansea Division; and medical certificates ca Division related to

s the chronic disease breathing air contain the various processes and preparation of trachosilicosis. This is the form of pneumo- mitted miners' asthma in about 23 per cent three anthracite min- by the United State in 1933. About 61 fine anthracosilicosis- ibility, compared with in the control group degrees of disability tely 21 per cent of osis compared with the men serving as

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number of instances the change in occupa- tion probably was made on account of physical condition. Miners at the coal face, rock workers, and men who had had appre- ciable exposure to harmful dusts in other industries also showed evidence of much greater physical impairment than was found in the control group.

Moderate or marked physical impairment from any cause was found in 1.7 per cent of the control group, in 9.9 per cent of the regular miners, and among 12.6 per cent of the rock workers.

There was a marked tendency toward in- crease in the proportion having physical im- pairments with increase in the number of years of employment in anthracite. This tendency is manifested whether one con- sider disability of any kind, disability in which pulmonary infection was contributory, or disability due largely to tuberculosis. In each case the occupational groups arrayed themselves according to extent of physical impairment as follows: (1) Rock workers; (2) regular miners; (3) all others exposed to more than 100 million dust particles per cubic foot of air; and (4) men in haulage- ways except rock workers.

The pathology of anthracosilicosis as ob- served in these cases is essentially a deposi- tion of coal dust in the lungs, accompanied by an extensive fibrosis, both diffuse and nodular, with associated functional and de- generative changes, (silicosis modified by coal dust).

That excess mortality from respiratory diseases as a whole is experienced by Amer- ican hard-coal miners is clear from the studies made by the Public Health Service.

The anthracite miners' proportionate mortal- ity from all respiratory diseases was about 1½ times that of the other adult males in the same region. When proportionate mor- tality was computed for ages 16 to 65 in Wales,* it was found that respiratory dis- eases accounted for 53 per cent of the deaths of anthracite miners compared with 38.2 per cent among males in the same social class. The proportion among hewers and getters of anthracite therefore was 1.4 times that of men of the same social status.

Silicosis

There are various definitions of silicosis but all agree that the cause of the disease is the inhalation of silica or quartz dust." Silicosis is a well-recognized clinical and pathological entity at least as characteristic as that of any cause of death known to epidemiologists." The definition of silicosis, adopted at the International Silicosis Con- ference in 1930 and reaffirmed at the 1939 Conference and generally accepted is:

"Silicosis is a pathological condition of the lungs due to inhalation of silicon diox- ide. It can be produced experimentally in animals."

The first investigation of silicosis in the mining industry in the United States was made in 1914-15 by the Federal Bureau of Mines in cooperation with the United States Public Health Service in the Joplin (Mo.) mining district." As only a few men were examined at that time, it was decided to examine a larger number to gain a more accurate idea of the prevalence of consump- tion among the miners of this district. From

Table 9.—Mortality from Certain Respiratory Diseases of Those Exposed to Siliceous Dust, to Nonsiliceous Dust, and the General Population—by Age Groups¹

Groups	Respiratory Diseases														
	Bronchitis					Influenza					Pneumonia				
	20-25	35-45	45-55	55-65	65-75	20-25	35-45	45-55	55-65	65-75	20-25	35-45	45-55	55-65	65-75
Siliceous dust.....	1.1	1.0	13.7	44.6	153.7	214.0	1.1	7.7	11.3	8.7	18.3	47.1	3.3	14.4	30.6
Nonsiliceous dust.....															
General population.....	0.5	1.7	5.4	13.3	28.8	49.6	2.0	5.2	7.7	9.7	12.0	36.5	4.3	11.5	19.6

¹ Made up from tables 1, 5 and 7.

May 15 to December 31, 1915, 720 miners were examined: 45.7 per cent had silicosis and tuberculosis and 5.3 per cent had tuberculosis.¹⁴ A later report (1917) of this same investigation by Lanza and Childs¹⁵ included the results of the first detailed X-ray studies of silicosis made in the United States.

Investigations of mining conditions by Harrington and Lanza¹⁶ in Butte, Mont., in 1921, revealed that 42.4 per cent of 1,018 miners examined showed definite signs of lung damage due to dust.

From July 1, 1927, to June 30, 1932, the Metropolitan Life Insurance Co., the Tri-State Zinc & Lead Ore Producers Association, and the Federal Bureau of Mines operated a cooperative clinic at Picher, Okla., to demonstrate to industry a workable method for diagnosis of silicosis, to educate workers in preventive measures, and to serve as a model to industries presenting a dust hazard. Of 27,553 individuals examined during this period 5,366 had silicosis, 742 silicosis plus tuberculosis, and 320 uncomplicated tuberculosis.

The chief cause of disability in silicosis is tubercle infection. The silicotic lung appears to be a more favorable medium for the growth of the tubercle bacillus than the normal lung, not because it is fibrotic, nor because its lymphatic drainage is interfered with, but because it contains silica.¹⁷ Apparently silica dust possesses this characteristic of increasing the liability to pulmonary tuberculosis. That this is true is indicated by the statistics quoted in this paper which indicate also that silica dust increases the liability to other respiratory diseases. (See Table 9.)

The results of virtually all studies are in agreement regarding the high mortality rates from tuberculosis for industries in which large numbers of men are exposed to a silica hazard. These rates are so high that they leave no room for doubt of the cause-and-effect relationship between the hazard and the high mortality.¹⁸

Joint studies made by the Actuarial Society of America and the Association of Life Insurance Medical Directors¹⁹ revealed that there were 65 deaths where 6 were expected (about 11 times the expected number) from tuberculosis in 1925-1936 among a group of underground miners, most of

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The cause of disability in silicosis is the silicotic lung which appears to be a favorable medium for the tubercle bacillus than the normal lung because it is fibrotic, nor is the drainage interfered with because it contains silica.²² Asbestos possesses this characteristic of the liability to pulmonary tuberculosis. It is true as indicated in this paper which is quoted in this paper which is that silica dust increases the incidence of respiratory diseases. (See

Table 10.) In virtually all studies are in line with the high mortality rates for industries in which men are exposed to dust. These rates are so high that there is no doubt of the causal relationship between the hazard and the mortality.²³

made by the Actuarial Society and the Association of Medical Directors²⁴ revealed 65 deaths where 6 were expected times the expected number of deaths in 1925-1936 among underground miners, most of

whom were employed in metal mines. Tuberculosis deaths were fourteen times the expected among copper miners, nine times the expected among gold and silver miners, and eight and a half times the expected among iron miners. In an earlier study²⁵ covering the years 1915-1926, there were 18 times as many deaths as expected among lead and zinc miners.

An analysis by the field division of the Saranac Laboratory²⁶ of the roentgenograms of 5,000 white miners exposed to the inhalation of harmful concentration of silica dust shows that the incidence of pulmonary tuberculosis lesions increases as the degree of reaction to dust progresses. In this group of miners tuberculous lesions were found in approximately one-fourth of those with first stage silicosis, one-half of those in the second stage, and 65 per cent of those in the third stage.²⁷

Prevention of Dust Diseases in Mining

The data given in this paper point to dust as the greatest contributor to the excessive mortality from pulmonary diseases experienced in the mining industry and to silica dust as the immediate cause of the disease silicosis. Therefore, the principal method of preventing these diseases is to eliminate as far as possible or reduce to harmless concentration the dust in the breathing zone of the workers. Experience has shown that the properties of a dust that determine its capacity to produce injurious effects are its composition, the quantity suspended in the atmosphere breathed by the worker, and its particle size.

Although any dust may be harmful to breathe under certain conditions, as indicated by the data presented here that show a higher incidence of pulmonary diseases in nonsiliceous dusty industries than in the general population, physiological studies reveal that, in mining the harmfulness of a dust is proportional to its content of free silica or quartz, in particles small enough to enter the finer spaces of the lungs, and in high enough concentration to overcome the normal defenses of the respiratory system.

The prevention of dust diseases is the function of the physician and the engineer, working together to determine the extent of the dust hazard in industry and methods for its control.

The first step is to determine what dusts are harmful and in what concentrations. The procedure is somewhat as follows: It is observed that respiratory diseases appear more frequently or with greater severity among workers in certain industries or in connection with certain operations within an industry. The physician attempts to determine the extent of the injury to the health of those exposed and the cause. If the cause appears to be exposure to excessive dust, the engineer samples the air to determine the kind, amount, and size of the dust present. The physician and the engineer can correlate the results of their investigations to determine allowable concentrations of dust, exposure to which is not likely to cause harmful physiological reactions. The engineer is then in a position to devise measures for the reduction of the dust to a harmless concentration. The aim, of course, should be to eliminate the dust entirely or to reduce the dust to a concentration that will not cause disability during the working lifetime.

Allowable Concentrations of Dust in Mining

Investigations conducted over a period of years show that exposure to certain concentrations of harmful dusts for a certain time causes varying degrees of respiratory disability but that below these concentrations disabling pulmonary diseases do not occur within a working lifetime. The classical example of this is the experience in South Africa with the reduction in mortality from silicosis that has followed the reduction in air dustiness in the mines of that country.

The reduction in the incidence of silicosis in the South African mines attests the effectiveness of the control measures employed and the practicability of using a definite dust concentration as a guide in setting allowable limits of air dustiness in the prevention of pneumoconiosis in dusty industries. The production rate of silicosis in the scheduled mines of South Africa²⁸ in 1932-33 was 9.59 per 1,000 compared with 21.95 in 1914-15. (See Table 10.)

The incidence rates for silicosis uncomplicated by active tuberculosis among South African miners in 1936-1937 was between 8 and 9 per 1,000 per annum.²⁹ The liability among the whole body of miners to contract the disease in 1936-37 was less by 65

Table 10.—Average Number of Miners Examined Annually and Production Rates for Silicosis in Each Triennial Period Since 1917-18

Period	Average Number of Miners Examined Annually	Production Rate of Silicosis per 1,000	Period	Average Number of Miners Examined Annually	Production Rate of Silicosis per 1,000
1917-20	14,070	21.95	1926-29	14,624	21.11
1920-23	13,260	19.16	1929-32	16,774	13.87
1923-26	12,523	33.28	1932-35	20,139	9.59

per cent than it was in 1920-23. Among the "new Rand miners" who entered the industry by way of initial examination since 1916 and who have been exposed solely to the progressively improving occupation conditions that have obtained since that date, the liability to contract silicosis was less by 87 per cent than the similar liability among all miners working for an equal period in 1920-23. These "new Rand miners" constituted 77 per cent of all working miners examined. The group of pre-1916 miners, who in 1935-36 constituted less than 17 per cent of the total number of working miners contributed nearly 78 per cent of the new cases of silicosis.

In the study by the Public Health Service¹⁰ of anthracosilicosis among hard coal miners silicosis was not found in a control group of mining employees whose dust exposure averaged less than 5 million particles per cubic foot of air.

The prevalence of anthracosilicosis among the entire group of employees was found to be about 23 per cent.

Among all except rock workers, less than 2 per cent of the men developed anthracosilicosis when the duration of employment was less than 15 years, regardless of the amount of dust in the air.

Among men exposed 15 to 24 years to dust containing less than 5 per cent free silica, 14 per cent of those who had worked where the average dust count was 100 to 199 million particles per cubic foot, 29 per cent of those exposed to 200 to 299 million particles, and 58 per cent of the men who had worked for this period in more than 300 million particles per cubic foot, developed anthracosilicosis.

Among men employed for more than 25 years in dust containing less than 5 per cent free silica, the proportion of persons found with anthracosilicosis under different concentrations of dust was as follows: 5 to 99 million particles, 7 per cent; 100 to 199 million particles, 54 per cent; 200 to 299 million particles, 71 per cent; 300 or more million particles per cubic foot, 89 per cent.

With the exception of miners, their helpers, and rock workers, about 25 per cent of all the men employed underground developed anthracosilicosis after a working period of more than 25 years. This group was exposed to dust having a quartz content of about 13 per cent.

The prevalence of anthracosilicosis among persons who had been exposed for more than 2 or 3 years to dust of which about 35 per cent was free silica, varied from 10 per cent among those who had worked in concentrations of less than 200 million particles per cubic foot for less than 15 years, to 92 per cent among those who had been employed for more than 25 years in dust concentrations exceeding 300 million particles per cubic foot, more than 2 or 3 years of which time was spent in rock work.

Age per se appeared to play a minor role in the development of anthracosilicosis.

Analysis of the data for the purpose of determining safe limits of dust exposure indicated that employment in an atmosphere containing less than 50 million dust particles per cubic foot would produce a negligible number of cases of anthracosilicosis when the quartz content of the dust was less than 5 per cent. In the gangways where the silica content of the dust was about 13 per cent, a safe limit appeared to be 10 to 15 million

Table 11.
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Table 11.—Pneumoconiosis Cases Occurring Among 798 Workers Exposed to Mixed Dust, Classified by Average Dust Concentration, Length of Employment, and Number of Workers Exposed

Average Dust Concentration (Million Particles per Cubic Foot)	Years in Industry				
	0-4.9	5-9.9	10-14.9	15-19.9	20 and Over
0-9:					
Number of pneumoconiosis cases.....	0	0	0	0	0
Number of workers exposed.....	81	56	29	13	8
Percent with pneumoconiosis.....	0%	0%	0%	0%	0%
10-24:					
Number of pneumoconiosis cases.....	0	0	0	2	4
Number of workers exposed.....	123	94	66	29	23
Percent with pneumoconiosis.....	0%	0%	0%	6.9%	17.4%
25-49:					
Number of pneumoconiosis cases.....	0	0	3	3	6
Number of workers exposed.....	43	45	31	11	18
Percent with pneumoconiosis.....	0%	0%	9.7%	27.3%	33.3%
50 and over:					
Number of pneumoconiosis cases.....	0	4	5	4	4
Number of workers exposed.....	45	44	25	8	6
Percent with pneumoconiosis.....	0%	9.1%	20.0%	50.0%	66.7%

Production Rates

Production
Rate of
Silicosis
per
1,000

21.11
13.87
9.59

more than 25
than 5 per cent
persons found
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particles per cubic foot. The limit of toleration for rock workers was set tentatively at 5 to 10 million particles per cubic foot of air. Similar results were obtained by the Public Health Service in an investigation of pneumoconiosis among mica and permatite workers. (See Table 11.)

The relation of the average dust concentration and duration of exposure to the percentage of workers found to have pneumoconiosis was as follows: Of those who had worked in an average concentration of 50 million particles of dust per cubic foot of air, 9 per cent had pneumoconiosis in 5 years, 20 per cent in 10 years, 50 per cent in 15 years, and 66 per cent in 20 years. Of those who worked in an average concentration of 25 million particles 10 per cent had pneumoconiosis in 10 years, 27 per cent in 15 years, and 33 per cent in 20 years. Of those who had worked in an average concentration of 10 million particles of dust, 7 per cent had pneumoconiosis in 15 years and 17 per cent in 20 years. (See Fig. 1.)

The data obtained in other studies of dusty trades, anthracite mining, asbestos textile manufacture, and the pottery industry have been treated in a similar fashion and have yielded similar, although usually less regular, results. The position of the threshold

value below which no cases were found and the magnitude of the trends between per cent affected and both time and intensity of exposure varies in different sets of data, depending, to a large extent, on the chemical nature of the dust to which workers were exposed and possibly on the regularity of employment.

It is tempting to seek to summarize the data of table 12 and figure 1 into a simple mathematical relation such as the following: With each twofold increase in average dust concentration above 10 million particles per cubic foot, the probability of finding cases of silicosis (in men exposed for comparable lengths of time) is approximately doubled. Application of the standard methods of curve fitting would yield more refined descriptions of these data. Nevertheless, it does not seem to be advisable to set up any mathematical treatment because, of all the men who entered the industry, only the survivors have been studied. There is no adequate way of finding out whether or not men who dropped out of the industry were in a better or worse state of health as far as silicosis is concerned than men who remained in the industry, and thus there is no way of introducing a correction for this element of selection into a mathematical

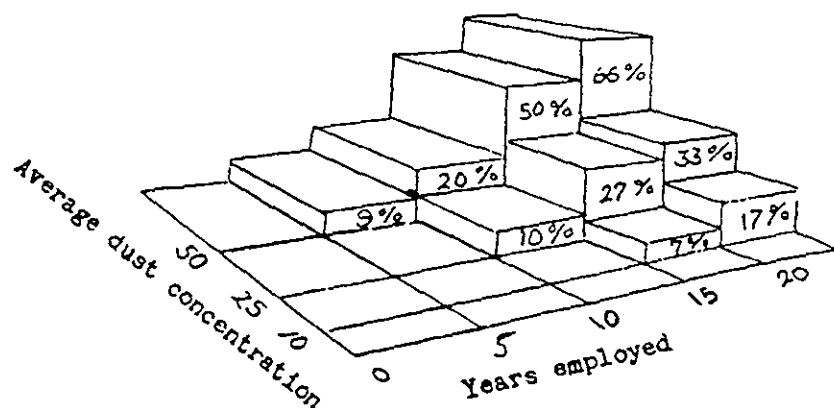


Figure 1.—Relation of average dust concentration and duration of dust exposure to the percentage of workers found to have pneumoconiosis. Based on data presented in Table 11.

treatment. It seems to be preferable to present the facts as simply as possible, together with the precautions to be kept in mind in studying them, and to emphasize that the principal use of these data is to show the degree of improvement in health to be expected in the future if dust formation and dust dispersal are brought under control in these and in similar industries.

Methods of Dust Control

After the physician and engineer have learned by observation and experimentation what kinds of dust are harmful and in what concentrations, it is the function of the engineer to evaluate the hazard in a particular industry, plant, or mine and devise measures for its elimination. The first step is to become thoroughly familiar with the industry being studied to determine the dusty occupations, the number of persons in each, and the various activities and time devoted to each activity in any one occupation.²¹

The amount of harmful dust created by various activities can be determined by taking samples of the atmosphere in their vicinity and counting and identifying the dust particles. Sampling of air is also a means of checking the efficiency of any control measures that may be adopted.

Several devices are available for collecting and counting dust samples. The im-

pinger, however, is the instrument used most frequently in the United States. The Bureau of Mines and the Public Health Service have issued publications describing the method of sampling dust by the impinger (as well as by other methods) and procedures for counting and identifying the particles.^{22, 23}

Dust sampling is complicated by the fact that air dustiness fluctuates rapidly from moment to moment. A single dust count represents only the amount of dust in the atmosphere at the time and place of sampling and gives no indication of the average exposure of the worker over a period of years, especially if he has not worked continuously at one job. The ultimate lung injury that he may suffer will depend upon the integrated effect of the dust over a long period.²⁴ A proper measure of dust exposure requires a picture of the variations in dustiness. The best procedure is to determine the dustiness during different stages of an operation and, with the aid of a time study, break down the worker's day according to the time spent in each step; from these data the average dust exposure of the worker can be calculated.

Drilling.—Experience in South Africa²⁵ with new methods of sampling have revealed that more dust is produced by rock drills

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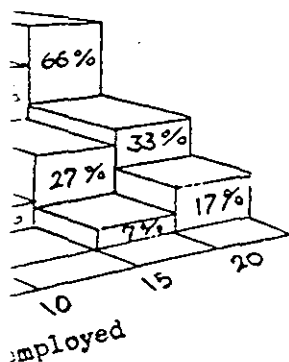
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Table 12.—Period Worked at Face by First-Stage Silicotics

Job	Average Number of Years	Number of Men	Job	Average Number of Years	Number of Men
Shovelers' helpers (bruno men).....	6.8	8	Machinemen (drillers)...	11.4	348
Shovelers.....	8.4	428	Powdermen.....	11.5	24
Drillers' helpers (dummies).....	8.4	79	Shovel bosses.....	15.8	21
Trackmen.....	9.8	52	Ground bosses.....	19.0	54
Roof trimmers.....	11.3	26			



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—Experience in South Africa
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than had been suspected, the difference con-
sisting entirely of dust too fine to be de-
tected by the older methods. The importance
of control of drilling dust as a measure of
the prevention of silicosis is demonstrated
by the fact that the incidence of silicosis has
remained consistently and considerably
higher among machine drillers than among
those who have never worked machines, and
the excess incidence among machine drillers
has been in direct proportion to the amount
of time spent upon rock drilling.

Until relatively recently drilling of holes
for blasting was a negligible producer of
dust or air dustiness in coal mines especially
other than anthracite mines. The hand-
operated auger drill produces very little fine
dust, but with the extension of mechanized
mining power drills are becoming more and
more essential and some of them are heavy
producers of finely divided dust; this is
especially true of reciprocating drills of the
jackhammer type drilling dry and using
compressed air in the clearing of holes either
in coal or in roof or floor material.

Blasting.—The exceptionally heavy inci-
dence of silicosis among rock drill miners in
the early period of the gold-mining industry
in South Africa²⁵ was due to the exposure
of the rock-drill miner not only to drilling
dust but to high concentrations of dust from
blasting, and frequently to the inhalation of
varying amounts of the irritant fumes pro-
duced by blasting, owing to the methods of
blasting then in use. Blasting produces large
quantities of very fine dust, the finest frac-
tions of which tend to remain suspended in
the mine air for a long time, unless removed
by ventilation.

Shoveling or Mucking.—In the Picher,
Okla., study²⁶ it was difficult to show the
relationship of the duties of the men to

silicosis because of frequent change of oc-
cupation. All examined were divided into
two groups—those exposed to large amounts
of dust (those employed at the face) and
those exposed to relatively small amounts
(those away from the face). In the order of
exposure to the dust hazard, the men at the
face included shovelers' helpers, shovelers,
drill helpers, machinemen, trackmen, roof
trimmers, powdermen, shovel bosses, and
ground bosses. According to analysis of the
occupations of face workers the hazard was
greater for shovelers' helpers and shovelers
than for machinemen if length of time re-
quired to produce first-stage silicosis is a
criterion. It is noted from table 13 that the
average number of years worked by shovel-
ers' helpers and shovelers was 6.8 and 8.4
years, respectively, while that for machine-
men was 11.4 years.

Loading and Hauling.—Under some con-
ditions hand loading of coal throws into the
air of the working place considerable quan-
tities of dust, but the amount is about one-
tenth that caused by some types of mechan-
ical loading. The greatly increased occur-
rence of dust from mechanical loading is
due not only to the stirring of the dust into
the air by the loading machines themselves
but also to the greater rapidity of breaking
down and taking coal from the face regions
which increases other dust-producing pro-
cesses, especially blasting, cutting, and haul-
ing.²⁷

Poorly constructed or poorly maintained
pit cars or over-topping of coal in cars al-
lows fall off or fine material to sift through
to the tracks to be ground under the wheels
of rolling equipment or the hoofs of mules
and then to be thrown into the air by speed-
ing cars or shuffling mules or men.²⁸

(5) dusts. In coal mines the order of importance would probably be (1) movement, (2) gases, (3) dusts, (4) relative humidity, and (5) temperature.⁴¹

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out any of the high
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when the operating thr-
owing position, and tra-
jectory of the hole being drilled.
Escaping is affected by
through the drill steel;
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creases. Mining offic-
concluded that such air
probably facilitating re-
moval of the cuttings from the
drillable for entrapping fine
material into the air during
drilling they have devoted
designing drills that pre-
vent practical air leakage thr-
ough and have established reg-
ulations for such drills. Canada
has worked along this line,
and state that such drills are
able to reduce about one-fourth
of the corresponding
"dustless-head" features.

Ventilation probably is the most effective dust-control measure although under some conditions it ranks second to wet methods. Where ventilation can be applied effectively, dust can be removed from the air or its concentration can be so diluted as to render it almost harmless.²⁹

The results of this series of tests show that generators can reduce dust resulting from drilling by increasing the water flow through the water tubes of larger diameter. Tests also have been made by the Bureau of Mines on spraying water along the steel compared with the ordinary drilling practice. The tests show that spraying water along the outside of the drill pipe should not take the place of spraying water in the drilling. However, if a device can be developed by which the device may be used at any inclination, it is a valuable accessory to the collar and drilling. Tests show that the amount of dust thrown into the air is reduced in place in drilling the fire

The principal measures for controlling dust in mining operations are ventilation, wet methods, proper blasting practice, the use of personal respiratory protection, and physical examination.

In tests by the Bureau of Mines² the dust concentration in the air during actual drilling decreased as the water flow through the drill increased. The water flows for stopers was 0 to 3 gallons per minute, and that for drifters from 0 to 1.02 gallons per minute. The rate of decrease for stoper drills was greater for water flows from 0 to 1.3 gallons per minute than for higher water flows. The rate of decrease for drifter drills was similar to that for stoper drills at corresponding water flows and rather constant for water flows* of 0 to 1.02 gallons per minute.

Wet drilling standards in New York State for classes of rock. The rate in Class II rock (more than 10 per cent free silica), which include the best ventilation, are quoted:

In most pneumatic rock drills air passes

1. "Wet drilling" shafts
ous application of water

the order of im-
be (1) movement,
relative humidity,

nt of air from the
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drills air pass-

through the drill steel with the water. Ord-
arily some of the high-pressure air sup-
plied to the drill for its operation escapes
into the back end of the drill steel, even
when the operating throttle is not in the
blowing position, and travels up to the face
of the hole being drilled. The amount of air
escaping is affected by the water flow
through the drill steel; as the water flow
through the drill steel increases the air flow
decreases. Mining officials in South Africa
concluded that such air leakage, although
probably facilitating removal by the water
of the cuttings from the hole, was respon-
sible for entrapping fine dust and blowing
it into the air during drilling." Conse-
quently they have devoted much attention to
designing drills that permit the minimum
practical air leakage through the drill steel
and have established regulations on the use
of such drills. Canada is also doing much
work along this line, and recent reports
state that such drills are practical and pro-
duce about one-fourth the dust concentra-
tion of corresponding drills without the
"dustless-head" features."

The results of this study show that op-
erators can reduce dust concentrations re-
sulting from drilling by increasing the
water flow through the drill steel, either by
increasing water pressure or by the use of
water tubes of larger inside diameter.

Tests also have been conducted by the
Bureau of Mines" on the effectiveness of
spraying water along the outside of the drill
steel compared with that of standard wet-
drilling practice. The tests show that spray-
ing water along the outside of the drill steel
should not take the place of regular wet
drilling. However, if a method is developed
by which the device may be used on holes
of any inclination, it might prove to be a
valuable accessory to regular wet drilling in
collaring and drilling the first 2 feet of a
hole. Tests show that the greatest amount
of dust is thrown into the air of a working
face in drilling the first 2 feet of a hole."

Wet drilling standards have been adopted
in New York State for drilling in various
classes of rock. The requirements for drill-
ing in Class II rock (rock containing more
than 10 per cent free silica) in confined
areas, which include the use of mechanical
ventilation, are quoted below."

1. "Wet drilling shall mean the continu-
ous application of water through the central

hole in the hollow drill steel to the bottom
of the drill hole. The central hole in the
steel shall not be less than $\frac{1}{8}$ " diameter.

2. "The water flow shall be maintained
continuously whenever the drill is in opera-
tion, including the period of collaring or
starting the drill hole. The valve in the
water line shall be of such design that it has
only two fixed positions, namely, closed and
completely open. Six months after date of
approval, all wet drills shall be equipped
with a combination air throttle and water
valve of such design that the required rate
of water flow through the drill steel will be
insured whenever the air throttle is in the
operating positions, half speed as well as
full speed.

3. "The water shall be clean and bacteria
free and shall be delivered to the drills under
pressure from an adequate source of supply.
Portable water tanks for individual drills
shall not be used unless approved by the In-
dustrial Commissioner.

"Wet drilling in Class II rock in confined
areas shall be used with mechanical ventila-
tion, or in confined areas under decking by
natural ventilation, if approved by the Indus-
trial Commissioner and subject to the fol-
lowing provisions:

1. "The rock surfaces for a distance of
30 feet from the heading or other drilling
area shall be maintained in a damp condi-
tion.

2. "Hand-held drills (maximum piston
bore, 3") minimum rate of water flow
through drill steel, 0.75 gallon per minute;
maximum rate of air flow through drill
steel at full speed, 2.0 cubic feet per min-
ute; maximum rate of air flow through the
drill steel at half-speed operation, 1.0 cubic
foot per minute; minimum rate of general
ventilation in the drilling area, 500 cubic
feet per minute per drill and shall be in-
creased if found upon tests by the Industrial
Commissioner that the dust concentration is
not in accordance with the requirements of
the Code.

3. "Drifter-mounted and wagon-mounted
drills (maximum piston bore, 4") minimum
rate of general ventilation per drill in the
drilling area, as shown in the table 'Limita-
tions in Air and Water Flow Through
Steel.'

4. "In the case of positive-pressure ven-
tilation, the air must be well distributed
over the drilling and must not create drafts

at the various drilling positions, in a manner satisfactory to the Industrial Commissioner. The intake for the ventilating system must be located at a point free from contamination with dust or provided with an efficient filter.

5. "In the case of exhaust ventilation, the location of the intake pipe or pipes must be such as to insure the removal of air from the entire drilling area in a manner satisfactory to the Industrial Commissioner.

6. "The required ventilation may be obtained by means of a recirculating air-cleaning apparatus provided the dust concentration in the air at the breathing zone of the drill operators is maintained at a level below that required in Rule 33-2.3 and the apparatus is otherwise acceptable to the Industrial Commissioner.

7. "The above rates of ventilation shall be increased whenever necessary to reduce dust concentration to the amount permitted by Rule 33-2.3."

Proper blasting practice.—Methods of controlling dust and fumes in mines by proper blasting practice have been determined by members of the Bureau of Mines staff by observation and experiment.^{25, 26} If at all feasible, blasting should be done at the end of the working shift or on an off shift, and the dust- and gas-laden air should be removed or thoroughly diluted before the men return to work. Ventilation is an essential agency in cleansing the air where blasting has been done. Results of investigations by the Bureau of Mines²⁶ show settling rate of dust after blasting under the following conditions:

1. The atmosphere was bratticed off for 3 hours while the dust samples were being taken. In this period, under these conditions, the dust concentration dropped from approximately 5,000 million particles per cubic foot to 50 million particles per cubic foot.

2. The atmosphere was bratticed off until 26 minutes after blasting when the brattice was raised and natural ventilation (which was virtually negligible except for eddy currents) was allowed to dilute the dust-laden air. It required 2 hours and 20 minutes after blasting for the dust concentration to drop from approximately 5,000 million particles per cubic foot to 50 million particles per cubic foot, and 2 hours and 50 minutes to drop to 15 million particles per cubic foot.

3. The atmosphere was bratticed off until 37 minutes after blasting, when the brattice was raised and 10-inch canvas tubing installed to about 50 feet from the face. At 46 minutes after blasting, about 1,000 cubic feet of air per minute was forced into the face. It required 66 minutes after blasting for the dust concentration to drop to 50 million particles per cubic foot, and 70 minutes to drop to 15 million particles per cubic foot.

The accompanying table shows the time, in minutes, required for the dust concentration to drop from 825,000,000 particles per cubic foot to 50 million and to 15 million particles per cubic foot under the three different conditions:

Ventilating Condition	Time, in minutes, to drop from 825,000,000 particles per cubic foot to—	
No ventilation.....	121	181
Natural ventilation....	105	135
Mechanical ventilation	20	24

In addition, the place (walls, floor, roof or top, and timbers) should be wetted thoroughly before blasting is done, and a water blast should be used during and after the blasting. The region should be wetted thoroughly when the men return to the face region after blasting, and the muck pile should be kept well wetted at all times while it is loaded out, as the water not only lays the dust but also either absorbs or otherwise aids in diluting or eliminating harmful or poisonous gases that follow blasting and that usually cling to the blasted material.

Tests²⁶ on the effectiveness of a spray of water mist in reducing the concentration of dust in the air after blasting and during mucking of the blasted material were conducted in three headings in medium hard to hard rock. The use of the spray apparently made it possible to reduce the concentration of dust generated and thrown into the air during blasting more than 99 per cent from the amount present when the spray was not used. Dust dissemination during mucking of material sprayed several hours before mucking was begun was much less than during shoveling of material thoroughly sprinkled just before and during mucking; and, of course, the dust present after use of either the spray or the sprinkling method is

far less than if the mucking had been done dry.

In general, the larger the quantity of explosive used, the more finely divided the blasted material, the more heavily the air will be impregnated with dust and smoke, and the greater will be the quantity of poisonous gases left at the place; hence, methods should be used that will tend to reduce the quantity of explosives used and of gases and dust produced. In this connection it will be found that the use of stemming or of some types of blasting plugs now available will confine more definitely the explosive, hence, increase its efficiency and reduce the quantity of explosive used and also reduce the amount of poisonous gas produced and possibly reduce the violence of the blast and its tendency to raise dust and disseminate it into the surrounding air. It would be well for users of explosives to investigate types of explosives that are known to give off minimum quantities of harmful gases on detonation and to use them; also, the discontinuance of the use of fuse and the substitution of electric blasting would aid in reducing the amount of poisonous gases from blasting. Explosives that have been held in storage too long or that have been stored under unfavorable conditions as to moisture, temperature, etc., are likely to give off maximum quantities of harmful gases, if they detonate at all; hence, utmost care should be taken in the storing of explosives to see that they are not held too long before being used.

Personal respirator protection.—This method of control of air dustiness is unsatisfactory in underground mining except for temporary use in emergencies. Although dust respirators give adequate protection against dust, they afford the wearer essentially no protection against toxic or asphyxiating gases, and are too cumbersome and uncomfortable for constant wear.

The Bureau of Mines has established a schedule of minimum requirements for mechanical respirators, one type of which is for protection against dust generated by disintegration as in drilling and blasting. About 30 respirators have been approved under this schedule.

Physical examination.—Although strictly speaking physical examination is not a dust-control measure, it is an important means of determining the efficacy of the methods em-

ployed to reduce the dust hazard. If workers exposed to dust are examined periodically increased incidence of respiratory disease can be discovered and measures taken to reduce the amount of dust in the air or remove any affected workers to a less hazardous environment.

In South Africa all white applicants for underground work are examined and certified to be physically fit and free of any disease of the respiratory organs and then re-examined every 6 months to determine and report all cases of simple silicosis, tuberculosis with silicosis, and simple tuberculosis that may have developed. In this way comparable records can be obtained for measuring the degree of pneumoconiosis and the extent of impairment of working capacity among employees from year to year. Comparable records will not be obtained unless periodic examinations are conducted in a standardized way, preferably by a permanent medical board composed of physicians specially trained and having adequate experience in the diagnosis of pulmonary diseases.

Summary

1. The principal pulmonary diseases to which the miner is subject are bronchitis, influenza and pneumonia, pulmonary tuberculosis, anthracosilicosis, and silicosis.

2. Statistics indicate that much higher morbidity and death rates from pulmonary diseases are experienced in dusty than in nondusty industries, especially where silica dust is used or produced.

3. Investigations by the Public Health Service reveal that hard-coal miners suffer a high mortality rate from influenza and pneumonia not only during influenza epidemics but at other times as well. In 1915-25 and 1906-25 influenza and pneumonia were responsible for 40 per cent of the total deaths among hard-coal miners compared with 25 per cent among males at ages 15 to 65 who were engaged in pursuits other than coal mining. Six per cent of hard-coal miners had pulmonary tuberculosis compared with 2 per cent in the adult male population of the United States. The rate for metal miners is still higher.

4. Anthracosilicosis was found in about 23 per cent of 2,711 employees of three anthracite mining companies studied by the United States Public Health Service in 1933.

About 63 per cent of those having anthracosis showed evidence of disability, compared with less than 10 per cent in the control group. Moderate and marked degrees of disability handicapped approximately 21 per cent of those with anthracosis compared with less than 2 per cent of the men serving as controls.

5. The occupational groups in anthracite mining, arrayed by the Public Health Service according to extent of physical impairment, are (1) rock workers, (2) regular miners, (3) all others exposed to more than 100 million dust particles per cubic foot of air, and (4) men in haulageways except rock workers.

6. The principal pulmonary disease in metal mines is silicosis and the chief menace in silicosis is tubercle infection. Apparently silica dust alone increases the liability to pulmonary tuberculosis.

Joint studies made by the Actuarial Society of America and the Association of Life Insurance Medical Directors²⁰ revealed that there were 65 deaths where 6 were expected (about 11 times the expected number) from tuberculosis in 1925-1936 among a group of underground miners, most of whom were employed in metal mines. Tuberculosis deaths were fourteen times the expected among copper miners, nine times the expected among gold and silver miners, and eight and a half times the expected among iron miners. In an earlier study²¹ covering the years 1915-1926, there were 18 times as many deaths as expected among lead and zinc miners.

7. As dust is the greatest contributor to the excessive mortality from pulmonary diseases in the mining industry, the principal method of preventing these diseases is to eliminate as far as possible or reduce to harmless concentrations the dust in the breathing zone of the worker.

8. The aim should be to eliminate the dust entirely from the air breathed. Where this is not always feasible it may be possible to reduce the dust to a concentration that will not cause disability during a working lifetime.

9. Analysis of data collected by the Public Health Service to determine safe limits of dust exposure indicate that employment in an atmosphere containing less than 50 million dust particles per cubic foot produces a negligible number of cases of sili-

cosis when the quartz content of the dust is less than 5 per cent; when the silica content is about 13 per cent 10 to 15 millie particles appears to be a safe limit.

10. The amount of harmful dust created by various activities in mining can be determined by sampling the atmosphere in their vicinity and counting and identifying the dust particles. Sampling of air is also a means of checking the efficiency of dust control measures.

11. The impinger is the dust-sampling instrument used most frequently in the United States.

12. The dustiest operations in mining are dry drilling, blasting of dry rock or ore, shoveling or mucking, loading and haulage, and machine coal cutting.

13. The principal measures for controlling the ill effects of dust in mining operations are ventilation, wet methods, proper blasting practice, the use of personal respiratory protection, and physical examination of workers.

14. The efficiency of these measures in the reduction of the incidence of dust diseases is attested by the experience in the mines of South Africa where among the whole body of miners the liability to contract silicosis in 1936-37 was less by 65 per cent than it was in 1920-33. Among the "new Rand miners" who entered the industry by way of initial examination since 1916 and who have been exposed solely to the progressively improving occupational conditions that have obtained since that date, the liability to contract silicosis was less by 87 per cent than the similar liability among all miners working for an equal period in 1920-23. These "new Rand miners" constituted 77 per cent of all working miners examined.

Conclusion

The mortality and morbidity from pulmonary diseases are excessive in the mining industry as a result of exposure to large amounts of dust in the air breathed. Therefore, control of the dust hazard is necessary to prevent these diseases. No single measure of control is applicable to all dusty operations and processes, therefore, all the means of prevention must be practiced to insure success in the solution of the problem.

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