

DUST

BY

H. S. PATTERSON



SECOND AND EXTENDED EDITION

Issued by
Transvaal Chamber of Mines
1936

MINE
13:4

R.A. LTD.-14518

PRU 738

622.411.5 PAT

LIBRARY

PNEUMOCONIOSIS RESEARCH UNIT OF THE C.S.I.R.

**P.O. Box / Posbus 4788
JOHANNESBURG**

BIBLIOTEEK

PNEUMOKONIOSE NAVORSINGSEENHEID VAN DIE W.N.N.R.

HORNE 52648

DUST

Introduction.

The word "dust" is used with a good many different meanings. Frequently it is taken to imply the kind of gritty particles which are so often blown about in dense clouds on a dry, windy day. The same word is used to describe the hair-like particles which may be seen floating about in the air of a room after, for example, a carpet has been swept, and which settle down to form a layer of dust. Generally speaking, used in its popular sense, dust implies visible particles of solid materials which may be floating in the air or which may have settled to form a deposit.

Unfortunately, the same word "dust" is also used in a different sense. Suppose a beam of sunlight enters a more or less darkened room past the edge of a blind. In the path of the ray of light will be visible numerous small motes, even in a room which would ordinarily be said to be free from dust, and these also are called dust. These motes are of similar type to the dust particles described above, but are very much smaller and, indeed, are only visible as individuals to the naked eye in a strong beam of light. There are in the nose and throat and lungs mechanisms which prevent large dust particles, of the kind which are seen blowing about in dust storms or floating in the air of

Book Case

SHIELD

an ordinary room, from getting into the lungs, and air containing them is generally harmless to breathe, whatever their nature. But the motes which are individually quite invisible to the naked eye except under special conditions, may obtain entry into the body, and if they are composed of certain materials will be dangerous to breathe. It must not of course be supposed that motes are ordinarily harmful if breathed; it is only certain kinds of small particles which are dangerous. It is with these motes or small dust particles that this booklet is mainly concerned, because they are the kind of dust which may cause disease.

Measurement of Dust Particles.

In order to describe the sizes of these dust particles and particularly of the motes or fine dust particles, special units of size are used, as the ordinary units are far too large. An average person with good eyes can see, in a good light, a space of about $\frac{1}{200}$ inch. On the other hand the size of fine dust particles may be $\frac{1}{50000}$ inch or less, so that 250 of these particles placed side by side would go into a length of $\frac{1}{200}$ inch, the smallest space ordinarily visible to the naked eye. To measure the sizes of these small particles a unit called the micron is used, which is $\frac{1}{25000}$ millimetre and equals about $\frac{1}{25000}$ inch.

Thus:

2 microns	=	$\frac{1}{12500}$	inch.
1 micron	=	$\frac{1}{25000}$	inch.
$\frac{1}{2}$ micron	=	$\frac{1}{50000}$	inch.
$\frac{1}{4}$ micron	=	$\frac{1}{100000}$	inch.

Sizes of Particles Absorbed by the Lungs.

Actually the largest dust particles which are ordinarily able to get inside the lungs and which may, if they are formed of a poisonous material, cause disease, have a size of 5 microns = $\frac{1}{5000}$ inch. But particles as large as these are very rarely absorbed, and practically the largest size which is absorbed is 2 microns. Particles smaller than 2 microns are the more easily absorbed the smaller their size, so that if, for example, air containing particles of $\frac{1}{2}$ micron is breathed, many of the particles will get into the lungs. It may be mentioned here that, for many poisonous dusts, the harm done probably depends chiefly on the number of particles of sizes 2 microns and smaller which become lodged in the lungs.

Sizes of Dust Particles.

Hitherto the word dust has been used to describe the particles which, for example, may be blown up from a dusty road, whilst the motes visible in a sunbeam have been called fine dust. Generally speaking, it is usual to confine the use of the word "dust" to coarse particles of sizes, say 5 microns and greater, and to call the finer particles smaller than say 5 microns "smokes." This is owing to the fact that by far the greater number of dusts as ordinarily understood contain typically a number of particles of sizes greater than 5 microns, whilst smokes either from a fire, or burning tobacco, or burning magnesium ribbon, etc., consist

almost entirely of particles smaller than 5 microns, and generally smaller than 1 micron. Thus tobacco smoke consists mainly of particles of $\frac{1}{4}$ micron and smaller, whilst the smoke from an ordinary fire, apart from a few specks of soot, is of a similar size. The white smoke from a magnesium flare used in taking flashlight photographs consists, apart from a few large flakes, of aggregates of particles, the sizes of the aggregates lying mainly between 5 microns and $\frac{1}{4}$ micron. On the other hand the large particles in a dust storm may be as great as 500 microns or more, and these are mixed with a number of smaller particles.

Smokes may consist of either liquid or solid particles, whilst dust, as already mentioned, is made up of solid particles. An ordinary fog or mist, on the other hand, consists essentially of liquid particles of the size of very small raindrops.

In this booklet the term fine dust will be used to denote particles of sizes 2 microns and smaller which are produced by the breaking up of rock. These fine dusts are rarely produced naturally in any large quantity.

Plate 1 is a photograph showing particles of road dust which were stirred up into a cloud by a motor-car, whilst Plate 2 is a photograph of the fine dust particles found in the gold mines of the Witwatersrand. In each photograph the dust is magnified 100 times. The numbered black circles in the lower part of the photographs enable the sizes of the particles to be estimated. These

photographs have been included to show the general difference between road and mine dust. The sizes of the finest particles shown are not necessarily correct.

Numbers of Particles in Dust or Smoke Clouds.

It has already been explained that small dust particles can only be seen individually by the naked eye in a bright beam of light, such as a ray of sunlight. The question now arises as to how it is possible to see, for example, tobacco smoke which consists mainly of particles of size $\frac{1}{4}$ micron and smaller. The reason is that the particles in a puff of tobacco smoke are so numerous as to form a practically continuous layer which reflects light just like a cloud in the sky.

The average number of particles in a dust or smoke cloud is generally described by giving the number present in a sample of cloud of 1 cubic centimetre volume, which equals about $\frac{1}{16}$ of a cubic inch. The ordinary smoke drawn into the mouth from a cigarette or a pipe contains perhaps 5 million particles per cubic centimetre, so that in an ordinary puff of a cigarette or a pipe 100 million particles may be drawn into the mouth. It will be readily understood that when air containing this number of particles is blown out of the mouth a practically continuous surface of particles is presented to the light, so that the smoke, though fine, is visible like a cloud.

In dust storms such as may be seen in Johannesburg in the early spring, the visible particles are very large, having sizes up to 500 microns or more, whilst the total number per cubic centimetre of the dust particles blown up is small and is unlikely to exceed a hundred or two. The dust stirred up in walking or driving along a dusty road is of a similar type.

In deserts, such as the Sahara, violent sand storms may arise and the dust may be carried by the wind to great distances. In these storms the total number of particles per cubic centimetre is probably small, whilst the size of the visible particles is again very large. Such storms are occasionally experienced in the Red Sea even as far as 100 miles from land. Some estimate of the intensity of one of these storms may be gathered from the fact that the obscuration by the dust was to great that it was necessary to sound the ship's fog horn over a period of several hours. Plate 3 is a photograph magnified 100 times of the dust collected by Dr. Frank G. A. Roberts during such a storm.

On a still day in a large industrial city, the number of smoke particles per cubic centimetre may be as great as 200,000, and these may merely be visible as a haze. Numbers of this amount or more would not be unlikely in a room in which people had been smoking.

Under ordinary conditions in a town, up to 50,000 smoke particles per cubic centi-

metre would not be exceptional and would not be at all noticeable, indeed the atmosphere would probably be said to be comparatively clear. Of course, in the country, at a distance from a large town, smaller numbers may be found, and over the sea at long distances from land the air may be comparatively free from particles.

Artificially produced fine dusts are as a rule quite invisible, as the number of particles per cubic centimetre is far too small. Of course there may be associated with the fine dust some coarse dust which can be seen, but the presence of coarse dust is no guide whatever to the presence or absence of appreciable amounts of fine dust. Thus coarse dust frequently has very little fine dust mixed with it, whilst large amounts of fine dust may be present without any noticeable amount of coarse dust.

Formation of Dusts.

In nature fine dusts are practically unknown in dangerous quantities. The ordinary processes of dust formation by wind or falling pieces of rocks, etc., do not produce large amounts of fine dusts. This is probably the reason that there is no sufficiently protective mechanism in the human body to prevent the absorption of fine dust.

To make fine dust it is in general necessary to make use of a large amount of energy in as small a space as possible, that is, to use concentrated energy. An example

may make this clear. Suppose that a man with smooth-soled shoes were to jump up and down on a smooth, hard stone floor. He would obviously not break up the surface of the floor into dust. But now suppose that he had in the soles of each of his shoes half-a-dozen spikes such as are used by runners. If he jumped up and down in the same way as before, unless the stone were exceptionally hard, he would bore into it a number of small holes and under suitable conditions would produce fine dust.

In nature there are very few processes corresponding to the shoes with spikes. Falling rocks may occasionally land on an edge but most of the energy of falling will generally be taken up by one of the surfaces of the piece of rock, so that the blow instead of being delivered over a small area will on the average tend to be delivered over a large area. Unquestionably some fine dust will be produced by falling rocks, but not a great deal.

In various artificial processes the energy is sufficiently concentrated to produce large amounts of fine dust. For example, when a rock is chiselled, or when a rock drill with a fine edged steel hits a rock many times per second, much fine dust may be produced.

There is one natural source of large amounts of fine dust, but it is very rare. Occasionally there is a violent volcanic outburst such as occurred in the 'eighties at Krakatoa, or more recently in the Andes in

Chili. Owing to the immense force of the explosion, rocks are hurled against each other at speeds far exceeding those ordinarily occurring on the earth, and as a result the finest particles are produced. Some of this very fine dust is blown up into the upper atmosphere by the force of the explosion and there remains suspended, giving rise to brilliantly coloured sunsets.

Ordinary blasting also produces much fine dust, but this is not comparable in fineness with that produced by the immense forces involved in a volcanic outburst. Such dust, however, may be exceedingly dangerous to breathe if formed from certain materials.

Settling of Dusts.

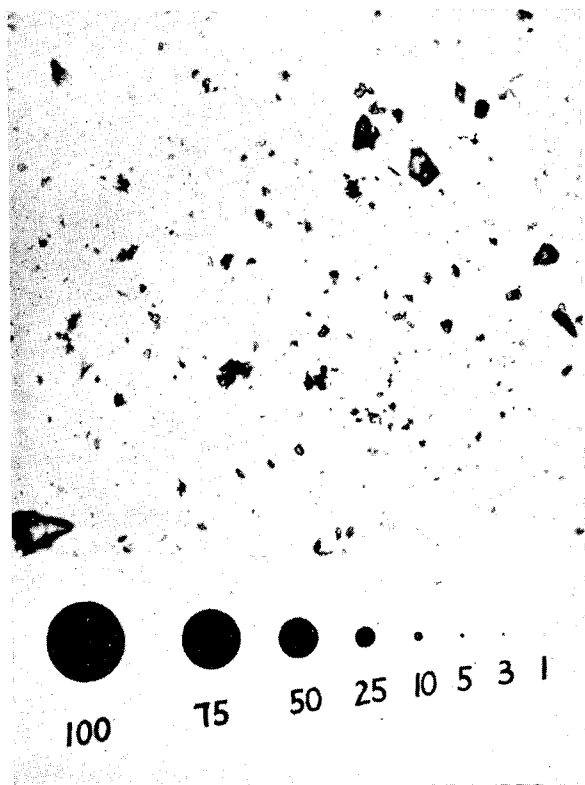
Fine dust settles very slowly. In the following table are given the times taken for silica dusts of various sizes to fall one foot:—

Size in Microns.	Time in Minutes to fall One Foot.
$\frac{1}{4}$	590
$\frac{1}{2}$	187
1	54
2	14.4
5	2.5

From the above table it appears that when once a fine dust has become suspended in air, it will only settle out very slowly. Actually, however, when fine dust has once settled it is very difficult to stir it up again. This is owing to a force called cohesion

PLATE 1

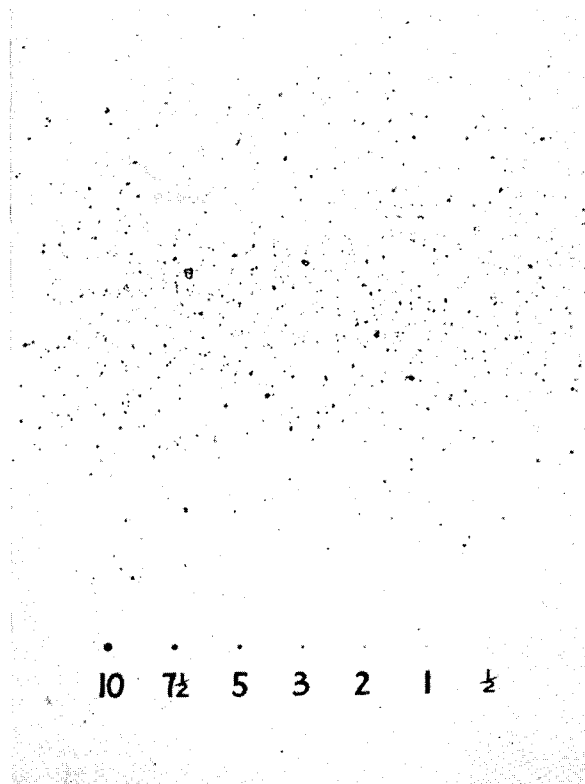
PHOTOGRAPH OF ROAD DUST MAGNIFIED 100 TIMES



The numbered black circles in the lower part of the photograph give the actual size in microns of particles corresponding in average diameter to the discs.

PLATE 2

PHOTOGRAPH OF MINE DUST MAGNIFIED 100 TIMES

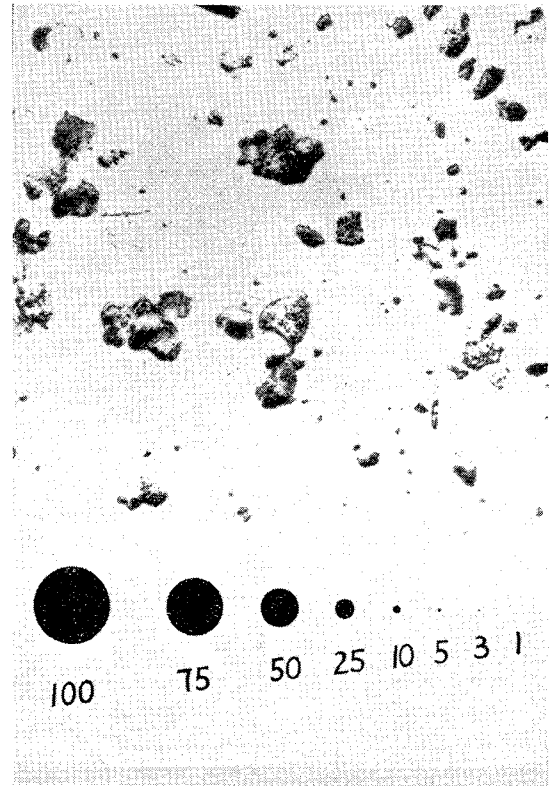


The numbered black circles in the lower part of the photograph give the actual size in microns of particles corresponding in average diameter to the discs.

which is supposed to be due to the existence of minute electrical forces at any surface. If two surfaces are brought very close together, these electrical forces act on each other and tend to make the surfaces stick. Now when a fine dust particle settles it comes very closely into contact with the object on which it lies. For example, if a particle of size 1 micron were to settle, the side on which it was lying would generally be much nearer to the surface on which it had settled than 1 micron, and it is well known that over such distances cohesive forces are effective. Actually the smaller the particles the stronger the cohesive force, so that very fine dust sticks firmly to an object on which it has settled. Of course a particle may occasionally settle on an edge and then it would be more easily removed, but generally speaking, when a fine dust has once settled, it cannot at all readily be stirred up again. This is another reason why fine dust is so uncommon in nature; even if it is formed occasionally, when once it has settled it sticks to the object on which it has settled and is not likely to be stirred up again. Coarse dust, on the other hand, is readily stirred up, because its surface is not sufficiently near the object on which it has settled for cohesive forces to come strongly into play. It must not be supposed that it is impossible to stir up fine dust, but the finer the dust the more difficult it is to do so.

PLATE 3

PHOTOGRAPH OF DUST FROM DESERT STORM MAGNIFIED 100 TIMES



The numbered black circles in the lower part of the photograph give the actual size in microns of particles corresponding in average diameter to the discs.

Removal of Dusts from Air by Coagulation.

It is a common experience that a shower of rain tends to clear the air of dust. This is for two reasons. In the first place the raindrops as they fall tend to hit the large particles of dust, soot, etc., and carry them down, and in the second place the wetting of the ground prevents the coarse dust from rising in the air. The atmosphere is accordingly cleared as it is the coarse dust which as a rule is largely the cause of the lack of clearness. The process of the union of two or more particles whether liquid or solid to form one larger particle is called coagulation.

But a shower of water drops is not a good way of taking out fine dust, because the drops of water as they fall push the air out of the way and with it the fine dust. With coarse dust it is different; the drops push the air away, but the dust is sufficiently "massive" not to be shifted with the air, and so gets hit by the drops of rain. Another analogy may make this evident. Suppose a large stone falling through water; it will tend to hit any large object in its path as it passes through the water, but any small objects will be carried away with the water which it pushes out of its path.

A shower of ordinary water drops then is not a satisfactory way of removing fine dust. A shower of very fine droplets, on the other hand, probably would remove fine dust, but such showers are not easy to make artificially.

On the other hand, coarse dust tends to remove fine dust very efficiently, because compared with water drops the particles of even a coarse dust are small and as they settle they do not tend to push the fine dust out of the way, but if the fine particles are in their path they collide, coagulation occurs and the fine dust is carried down. It has already been seen that fine dust settles very slowly of itself, but if a coarse dust is stirred up, the fine dust is removed much more rapidly from the air. Thus suppose fine dust were present in some working place and coarse dust were stirred up by say walking about, the fine dust would tend to be removed from the air.

Removal of Dust from Air by Filters.

When air carrying a dust is passed through a filtering material such as flannel, etc., which is kept dry, a considerable fraction of the dust may be removed. The exact method by which fine dust is caught depends on the size of the dust particles and the particular material used for filtration, but it is not usually due to the particles becoming jammed in the pores of the material, which are as a rule far larger than the particles. Generally speaking, a material of close texture covered with fine hairs such as flannel catches the particles most effectively, as they have to pass through a maze of obstructions, and owing to their frequent changes of direction are likely to hit one of them, when they will certainly stick. For a time a filter tends to become more effective with use, as the

particles caught offer further obstruction to the suspended dust. Later on, however, the resistance to the passage of the air becomes so great that either the volume of the air filtered is too small, or, if the pressure of the air is too high, the filter breaks down owing to the formation of small holes in the material, which let through the dust.

A really good dry flannel filter will catch over 99 per cent. of the fine dust in the air passing through it, whilst any well designed filter made of a suitable material should catch at least 90 per cent. of the fine dust. It is obvious therefore that properly made filters remove fine dust very efficiently.

Removal of Dust from Air by Fans.

A high speed fan forms an effective method of removing dust from air. If air carrying a fine dust is passed through such a fan 30 per cent. or 40 per cent. of the dust is likely to be removed. The action is probably two-fold, firstly the particles are thrown together by the highly turbulent air currents in the fan and coagulate, and secondly they are thrown against the casing, etc., of the fan where they stick.

Diminution of Dust by Ventilation.

If air containing a harmful dust in suspension is diluted by fresh air which is comparatively dust free, the number of particles per cubic centimetre will be reduced and the harmful effect of breathing such air proportionately decreased. This principle of dilu-

tion of dusty air by fresh air has been applied in various ways in the Gold Mines of the Witwatersrand. Thus in some cases fresh air is blown into a working place, in others the dusty air is sucked away, whilst often a combination of the two methods is used. For many working places either of the two first mentioned methods may be quite effective, but for dead ends the best results appear to be obtained by a suitable combination of both methods. It seems likely that much of the marked improvement which has taken place in the dust conditions of these mines may be attributed to the continued increase in the effectiveness of ventilation.

In some circumstances, however, it is difficult sufficiently to dilute the dusty air which is produced in a working place. In such a case it may be preferable to remove some of the fine dust by other means such as filtration.

Prevention of Fine Dust by Water during Drilling.

Theoretically, if some process which would ordinarily result in the formation of fine dust were carried out entirely under water, no dust should escape into the air. In practice, it is found that the formation of fine dust is generally not prevented in this way, for various reasons, of which two or three will now be considered. In the first place, if the drill has a water feed, the water fed to the drill may contain bubbles of air which may be produced in a number of ways. It has been suggested that these bubbles may in some

cases be due to air being sucked into the water pipes by a vortex action in the storage tanks, an action which may be seen when water is allowed to run out of a washing basin through a hole in the bottom. Again, if the water were to become warmed in its passage to the working place, dissolved air might be expelled. These sources of bubbles are quite apart from leaks of compressed air down the drill steel. In the second place, the end of the drill tends to become heated during drilling, and accordingly part of the air dissolved in the water may be driven out in the form of minute bubbles; this may occur even if the drilling takes place entirely under water. In either of these cases, the bubbles will tend to become filled with dust; the coarse dust will settle out to the sides of the bubble and be caught in the water before the bubble gets outside the hole, but most of the fine dust will remain suspended in the bubbles and will escape into the air. Quite apart from the above sources of dust, there is another way in which dust is produced. The air in escaping through the chuck release ports, etc., of a drill, in some cases sprays part of the water which should pass down the jumper, thus producing a fog. If this fog is formed from water containing any appreciable quantity of suspended siliceous material, dangerous dust is produced. In these ways considerable amounts of fine dust may be set free.

It is obvious from the above that very special precautions must be taken during

drilling, when the fine dust produced is harmful, if disease is to be avoided, particularly since any fine dust produced may be carried into other working places by air currents.

Methods of Measuring Amounts of Dust.

There are three kinds of apparatus which are often used for measuring the amount of dust in the air: first the sugar tube, second the konimeter, and third the thermal precipitator.

In making a measurement with the sugar tube, a known volume of air is sucked through a tube containing powdered sugar, and the dust which is caught is extracted and weighed. If, as frequently happens, particles of a size of 5 or 10 microns are present in the air, they will be caught by the apparatus together with part of the finer dust. These large particles contribute far more to the weight than similar numbers of fine particles. One particle of size, say 10 microns, weighs as much as 1,000 particles of size 1 micron, or 64,000 particles of size $\frac{1}{4}$ micron. Consequently if a few harmless particles of size, say 10 microns, were caught, they would so greatly outweigh quite large numbers of the fine particles which cause disease that the weight would be no guide to the number of fine particles present.

In the konimeter a small volume of air is sucked at a high average speed through a jet facing which is a glass plate near to the

exit of the jet. Some of the dust in the air which often becomes loaded with moisture strikes the plate and sticks, but much of the fine dust is carried away by the stream of air before striking the plate. The dust deposit obtained, often called the 'spot,' after treatment is examined under the microscope, and the number of particles per cubic centimetre which has been caught is obtained. Unfortunately the instrument is inadequate because so much of the fine dust which may cause disease is not caught.

A new standard instrument called the *thermal precipitator* has recently been brought out by the British Government for use in mines, for finding the number of particles of fine dust. This instrument has been compared with other standard instruments which work in entirely different ways and has been found to be highly accurate. It works on the principle that dust is repelled from a hot surface and deposited on a cold surface. For example, if a hot pipe is running along the side of a room with a light coloured wall, a dark line tends to form on the wall near the hot pipe because dust has been repelled by the hot pipe and deposited on the cold wall. In the actual instrument a thin wire placed between two glass surfaces is heated electrically, and when dusty air is sucked over the hot wire all the dust is deposited on the glass surfaces in the form of two sharp lines. The deposit obtained, after treatment, is examined under the highest powers of the microscope, and

the number and size of the particles which were present in the sample of air are found. As ordinarily used the instrument catches all the particles present in the air between sizes of about 5 microns and $\frac{1}{10}$ micron or less, so that any particles likely to cause disease are obtained. The instrument is strong, compact and easily worked, and may be used for obtaining a sample over a short period in some working place, or may be used to find the average dust conditions over periods of many hours.

Since thermal precipitator samples contain all the dangerous fine dust whilst only a fraction is obtained in konimeter spots, it will be understood that in any given place the number of particles per cubic centimetre caught by the thermal precipitator may be much greater than those found in konimeter spots. There is, however, no constant ratio between the numbers of particles given by the two instruments. This is partly owing to the fact that there is not a constant relationship between the sizes of the particles in a dust. Thus some dusts may consist almost entirely of fine particles whilst others may contain a large fraction of coarser particles. If one of the fine mine dusts is investigated by the two instruments, the number given by the thermal precipitator may be ten or more times as great as that given by the konimeter, since the thermal precipitator catches all the fine dust, much of which is missed by the konimeter. With coarser dusts, how-

ever, the numbers given by the two instruments are much more nearly similar.

It must be emphasized that the much larger numbers which are often obtained with the thermal precipitator do not indicate that the amount of dust in the mines is greater than formerly. Actually the data available on silicosis indicate that the amount of dangerous dust suspended in the air of the gold mines of the Witwatersrand has been greatly reduced and is now probably less than about one-third of that present, say, twenty years ago. The thermal precipitator, however, enables the dangerous dust which still remains in the mines to be located, and so renders it possible to find out what further improvements are necessary.