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INFORMATION CIRCULAR

SOME DATA ON DUST IN INDUSTRIAL WORK



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BY

D. HARRINGTON

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SOME DATA ON DUST IN INDUSTRIAL WORK^{1/}

By D. Harrington^{2/}

INTRODUCTION

Although the hysteria with regard to silicosis and other occupational diseases seems largely to have passed, and more careful sober consideration is being given this subject, it would be very poor policy for any employer to take the stand that the storm has blown over and that he can safely relax and revert to the status of 5, 10, or more years ago in such matters. The real fact is that occupational-disease compensation is now in its infancy and can be expected to grow by leaps and bounds. At present, while 46 States of the Union^{3/} and the District of Columbia have compensation acts, only the following have some form of occupational-disease legislation: California, Delaware, Connecticut, District of Columbia, Illinois, Indiana, Kentucky, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, North Carolina, North Dakota, Ohio, Pennsylvania, Rhode Island, Washington, West Virginia, and Wisconsin. Silicosis appears to be compensable under those acts in California, Connecticut, District of Columbia, Illinois, Kentucky, Massachusetts, Missouri, New York, North Carolina, North Dakota, Ohio, Pennsylvania, West Virginia, and Wisconsin; possibly it may be interpreted as compensable in others. Occupational-disease legislation (largely relating to silicosis) has been under consideration in some form relatively recently in Arkansas, California, Delaware, Idaho, Maryland, Kansas, Massachusetts, Michigan, Minnesota, Montana, Nebraska, New Jersey, Ohio, Pennsylvania, Tennessee, Utah, and Washington at least. It will be surprising if comparatively broad or inclusive occupational-disease legislation will not be on the statute books of nearly every State in the Union within the next 5 years.

With this situation confronting him, the far-sighted industrialist who has the best interests of his organization at heart will immediately begin to "put his house in order," if he has not already done so, by studying possible occupational-disease hazards to his employees; moreover, he will promptly apply all known remedial measures or will attempt to devise such measures if none of those already devised seem to apply to his establishment.

^{1/} The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7072."
Presented before the Industrial Section, Arizona State Safety Council, Tucson, Ariz., Nov. 1, 1938.

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^{3/} Arkansas and Mississippi are the only States without such acts.

Unquestionably, one of the most important of the surveys that should be made should concern dust occurrence, as State laws on occupational diseases are almost certain to contain provisions applying to dust disease and, moreover, the provisions of any State law are not likely to duplicate or be similar to those of other States.

In trying to make a study of the possible harmfulness of dust to those employed in industry, the investigator naturally will try to ascertain from the experience of others, as embodied in available literature or other sources, the features of dust occurrence that may impair health or cause other harm to workers; here the investigator is very likely to become enmeshed in such a maze of confused and conflicting data that, irrespective of his intrinsic investigative or operating ability or his good intentions, he is likely to have considerable difficulty in ascertaining "what it is all about" and what is to be done about it.

THE EFFECTS OF DUST

While the State laws and regulations on dust apply largely to silica dust with resultant silicosis, insofar as the health hazard is concerned those most familiar with dust occurrence and its possible hazards (though recognizing that breathing large quantities of dust of free silica (SiO_2) is probably the most hazardous health condition likely to be found where dust is involved) know that not even silica dust is harmful to health unless it occurs in very finely divided form and relatively large quantities are breathed rather continuously for a long time. Moreover, many thoughtful, experienced experts on the subject are now veering strongly to the opinion that harm to the health can be anticipated when human beings are required to work in or to breathe high concentrations of any kind of dust rather continuously in their daily work. This idea has been expressed very definitely in recent reports by so many of those who have made dust investigations something of a life study that it seems inevitable this idea must be recognized by the law makers in the future, as it has already been recognized by the courts. Prof. Philip Drinker, of Harvard, as chairman of the Preventive Engineering Committee of the Air Hygiene Foundation, Pittsburgh, Pa., now engaged intensively on investigations on harmfulness of air, very concisely and definitely expressed the modern considered opinion of a group of outstanding dust experts on this idea as follows:

There is no satisfactory medical answer at present to this question, but the engineer is making a bad mistake if he lets men breathe heavy dust concentrations of any material. If no other reason for dust control can be found, then one should read transcripts of some of the recent suits at common law in which fantastic damages for alleged silicosis were granted to men who breathed dust containing little or no silica. The courts and compensation boards are not impressed with subtle distinctions between dusts with 10 percent and 40 percent quartz, especially when medical experts are reluctant to make definite statements as to the comparative significance of such differences.

It would be well to realize that men working in dusty trades suffer far more from respiratory troubles of all kinds than do men who work in clean air. The evidence that excessive dustiness of any kind is harmful is beyond argument.

In connection with the problems likely to confront the employer in future compensation obligations with regard to dust; it should be remembered that breathing dust is by no means the only hazard offered by dust in industrial work that may require compensation payment; even here, the harm to the health caused by breathing dust is not necessarily confined to the lungs, as dust of some kinds is known to have a detrimental effect on the nose, throat, and bronchial passages as well as (indirectly) the heart, stomach, and possibly other internal organs. Externally, dust may cause injury to the eyes, ears, and skin; and some dusts on contact with the perspiration are absorbed with definite harm to the health of the victim. Moreover, heavy concentrations of dust in the air materially reduce visibility; in some instances, as in the storms in the Dust Bowl in the Central West, dust in the air reduced visibility to virtually zero in midday with the sun shining brightly. Obviously, in industrial occupations dependent on artificial light or with but limited amounts of natural light available, any decrease in visibility caused by air-dust concentrations (and the decrease in visibility may under some circumstances amount to 75 percent or more) is likely to decrease efficiency materially and also increase accident occurrence, with a resultant increase in compensation commitments. Some dusts (coal, zinc, aluminum, and scores of others, mineral and nonmineral) are explosive, and many are subject to spontaneous combustion with consequent hazards to health, safety, and property. Moreover, many dusts have detrimental effects of various kinds on property as distinguished from persons; machinery, growing vegetation, animals, dwelling houses, and other types of property are damaged by dusts, and compensation of some kind is often exacted from industrial concerns through damage suits or otherwise.

PRECAUTIONS TO BE TAKEN AGAINST DUST

With knowledge of these facts concerning the numerous ways in which dust is likely to be unsafe, unhealthful, or otherwise harmful, it would seem logical for an industrial executive who is trying to protect his employees from harm and his organization from undue avoidable expenditures because of various dust hazards to disregard technicalities and concentrate on reduction of dust in the air at his plant instead of splitting hairs as to the size, kind, quantity, or any of the scores of other uncertainties as to dust. No answer is yet available to some of these questions and in many instances probably never will be.

Prevention of dustiness in the air where human beings must work and elimination of dust or retention in confined places and under complete control emphatically should be an integral part of the operation of any industry in future if operators are to avoid heavy expenditures for compensation and other damages where dust is left uncontrolled and sufferers can assign responsibility for its origin. The progressive industrial executive who has become convinced of his obligation in trying to protect his employees as

well as his company wants to know immediately what constitutes a harmful amount of dust and how to eliminate or reduce it; here, again, the answers are not easy or as specific as might be desired.

From the viewpoint of harm to the respiratory system, it is generally stated (through actual knowledge is by no means certain) that the particles of dust, such as those of free silica, that affect health adversely when they enter the lungs are those less than 10 microns in size; various persons have disagreed as to what the maximum may be - 10 microns or 8 or 6 - and some say that the harm is really done by particles under 2 microns in size. In opposition, it is stated that fibers of asbestos dust as long as 200 microns have been found in the lungs of men and undoubtedly exerted at least some detrimental effect.

Since a micron is only about one twenty-five thousandth of an inch, or much smaller than the naked eye can see, it is usually assumed that the larger dust particles that can be seen floating in air and settle out relatively fast do not harm the health. This is certainly a mistake, as the larger particles that float in the air (some of them 100 or more microns in size), if present in considerable quantities, clog the air passages leading to the lungs; some of these passages have agencies that, under ordinary conditions, intercept dust particles before they can reach the lungs, and this clogging allows the smaller and probably most dangerous dust to enter the lungs unimpeded. A common-sense definition of an atmosphere so dusty that dust-prevention action should be taken is that any atmosphere in which dust can be seen by the naked eye is too dusty not only for health but also, at least in many instances, for safety and efficiency. If the visible dust is eliminated, much of the invisible and probably most dangerous dust will have been removed, also, and health and other hazards very likely much minimized or even removed. After the visible dust has been removed it may be necessary, under some conditions or with some types of dust, to investigate more thoroughly the occurrence of invisible dust by means of the impinger, konometer, or other instruments; but unless litigation is effective or threatened such intricate studies are relatively unimportant if the visible dust has been eliminated from the air of working places.

DUST TRAPS AND VENTILATION

Manifestly, if dust is not produced it cannot get into the air or otherwise become harmful, and some relief from dust troubles in industry can be achieved by using construction, practices, processes, or equipment that tend to obviate dust.

In designing and equipping the places in which employees must work, the progressive industrialist would be wise to try to prevent the formation of dust (or to control it if it must be made), and should choose machinery, methods, processes, construction, etc., with dust-prevention or elimination features instead of those that produce or disseminate dust, even though such features may increase the cost of the machine or process. The emphasis now being placed on dust in its various phases and the high costs contingent

upon it make it almost imperative that hereafter more thought be given beforehand to dust prevention than has been given in the past. For example, excessively dusty processes or practices should be discarded for others that produce less dust, or they should be isolated somehow, as housing them tightly in a separate part of the plant or using them when a minimum number of persons is exposed to them or when there is a maximum of time to remove dust as well as other harmful properties or constituents. Such installations or practices should be kept in full, efficient operation constantly, however, if they are to perform the service desired. Moreover, a reasonable amount of common sense should be applied in handling a dust-control practice or system; certainly it is the height of folly to use an elaborate exhaust system to take the dust out of part of an establishment and then exhaust the dust-laden air at such a point as to allow it to be taken again into the same or some other part of the establishment (or of an adjacent one) through doors, windows, fans, or by other means.

If dust must be formed, as is true of many industries, several effective methods are available for preventing its dissemination into the air or into places where it may cause trouble. These include wet methods, such as wet instead of dry drilling, wet instead of dry crushing, wet instead of dry handling, and wetting or washing down floors, walls, and rock faces. In general, water is among the most effective available aids to prevent air dustiness, even though in some instances wet drilling does give off some dust and wet grinding is by no means dustless. Notwithstanding a growing tendency in some quarters to decry the effectiveness of water or wet methods, at present their use is probably our best defense against dust dissemination in mining and tunneling.

The use of dust-exhaust devices such as hoods, traps for drilling, etc., has a definite place in dust control, particularly in surface plants and operations. Under some conditions exhaust systems, when properly installed and kept in repair and operation, not only perform the dust-removing function but also more than pay their way in actual value of the recovered dust. An installation in a surface plant processing one of the metals cost approximately \$7,000 to install, and the dust recovered daily averaged about \$25 in value; moreover, the air of the plant and the surrounding walls and other surfaces were kept virtually free of dust.

On the other hand, although dust traps may be used with dry drilling in certain types of surface or near-surface rock-excavation work, they have not been found applicable to general rock-drilling practice underground. There are several reasons for this, some of which may be removed eventually. Some types of rock cannot be drilled dry with any degree of effectiveness, and as yet the available types of rock-drilling traps or trapping systems are not workable with wet drilling. If dry drilling can be done, some of the traps now available will ordinarily do a good job of removing the dust from drilling, but this will leave the rock and other surfaces (top, timbers, ledges, sides, and floor in many cases) dry. Subsequent blasting, mucking, timbering, hauling, etc., will then help to throw into the air the dust certain to be created in large quantities by blasting and in smaller quantities by the other processes; the dust thus thrown into the air will settle

on dry surfaces, to be thrown into suspension by any and all activities. Dust traps also are cumbersome, especially when used in the confined places typical of mining and tunneling. As previously indicated, however, dust traps with dry drilling may have a definite place in surface or near-surface operations, where dry drilling can be done, and under some circumstances may have advantages over wet drilling, especially in very cold weather. Some experiments are now under way with use of dust traps in wet drilling, and these may ultimately have a place in some dust-prevention campaigns.

Ventilation is probably the most effective dust-control practice available for many industries, although it ranks second to wet methods in others. Where conditions permit effective ventilation, air-borne dust can be removed or its concentration kept diluted to give almost complete immunity from harm of a respiratory or contact nature occasioned by dust and to minimize dust hazards of almost all kinds, including those connected with spontaneous combustion, though it may enhance hazards of dust explosibility in some instances. The ventilation in some cases should be induced by exhaust methods, but in others forced or blowing systems are more effective, especially in connection with underground work in places where temperature of the air is high, owing to rock, dripping water, or some such other condition as rapid oxidation of surrounding rock, timber, etc.

To obtain really effective ventilation in such work as tunneling and metal mining is usually very difficult, because ordinarily only one opening is driven, instead of having workings in pairs, as in coal mining, where fresh air flows in one opening and return or contaminated air in the other. Conditions caused by the dust problem may force parallel openings to be used in connections with many tunneling and metal-mining operations of the future, and, notwithstanding the violent objection this suggestion will raise, it is logical to believe that in many instances there would be definite savings in dollars and cents as well as in safety by the parallel-opening system, with its numerous advantages as to ventilation, health, and drainage, compared with the many disadvantages and hazards of the present one-opening system. In fact, about the only real advantage of the latter is the fact that its use is customary.

WET METHODS

Dry drilling is without doubt the dustiest occupation in mining, tunneling, and quarrying, and it continues to be used far too much in mine, quarry, and tunnel work in the United States; certainly, if dry drilling is allowed at all, it should be done only with auger twist drills or with simultaneous use of effective dust traps. Wet drilling, as practiced in the United States with water forced or drawn through the drill steel by compressed air, is now "under fire" because it produces relatively large quantities of dust even though the material floating in the air usually is wet. Much of this criticism is imaginary but some of it is legitimate, and the trouble is due largely to the fact that the holes are collared or started dry and, in some instances at least, drilled dry for several inches. The dust caused by this dry starting impregnates the usually stagnant air of the ordinary underground

tunnel or metal-mine working place and leaves it so for much if not most of the working shift after the dry starting has been completed. Sometimes the driller unduly limits the amount of water sent through the drill steel, and while he nominally is drilling wet, the actual practice is closely analogous to dry drilling because the compressed air that flows through the drill steel forces excessive quantities of water-entrained dust bubbles or particles out of the drill hole and into the air of the working place. Sometimes, too, the drill is out of repair and allows far too much compressed air to flow through the drill steel. When reasonable procedure is followed and wet drills of present types are used, the amount of dust from drilling can be controlled; in fact, this is actually being done by numerous alert, conscientious mining and tunneling companies. Some companies in the United States and Canada are now experimenting with rock drills that do not allow compressed air to go through the drill steel but require the water to be forced through the steel by its own pressure; these drills are said to cause less dust than the usual types in which water is sent through the steel by compressed air, but the practicability of the newer type of drill is debatable and its use is still rather uncommon in the United States or Canada.

Without doubt, present-day wet drills can be used so as to keep dustiness of air well within safe limits if employed with care and judgment in collaring wet, using plenty of clean, dirt-free water, keeping the drills in good repair with adequate regulation of the proportion of water and compressed air flowing through the drill steel, preventing the exhaust from the drill from impinging on nearby dusty surfaces of muck piles, floors, walls, or timbers and throwing dust into the air, and planning, insofar as feasible, to reduce drilling of upper holes to a minimum. Upper holes, whether drilled dry or wet, are relatively heavy producers of dust in the air of working places.

GOOD BLASTING PRACTICE

Next to dry drilling, blasting rock in mining, quarrying, and tunneling causes the most finely divided dust to be thrown into the air of working places. Also, blasting with the heavy charges of explosive required in many mining and tunneling operations impregnates the surrounding air as well as the muck piles with considerable quantities of poisonous gases, such as carbon monoxide, possibly oxides of nitrogen, and, in some kinds of rock, hydrogen sulfide and other dangerous sulfurous fumes. Virtually all of these occur in such quantities and percentages under some circumstances as to asphyxiate persons who may breathe them or to cause serious, often permanent, illness. Many of those who have studied the incidence of dust disease believe that breathing even small quantities or percentages of extraneous or harmful gases such as carbon monoxide, oxides of nitrogen, hydrogen sulphide, etc., in the atmosphere inflames or otherwise adversely affects the respiratory organs, especially the lungs, making them much more susceptible to harm from breathing dust particles.

Without doubt, blasting practice of the past must be modified and reformed if employers are to avoid heavy penalties in compensation and other charges due to the inclusion of occupational diseases (one being dust disease)

as cause for compensation payments in the laws of the various States. 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 from blasting should be removed or diluted thoroughly before men return to work after blasting has been done. Ventilation is, of course, an essential agency in cleansing the air after blasting; in addition, the place (walls, floor, roof or top, timbers, etc.) should be wetted thoroughly before blasting, a water blast should be kept in operation during and after blasting, and the region, including the muck pile, thoroughly wetted when the workers return to the face region after blasting. The muck pile should also be kept well-wetted at all times while it is being loaded out, as the water not only tends to settle the dust but also either to absorb or otherwise aid in the dilution or elimination of harmful or poisonous gases from blasting, which usually cling to the blasted material. In general, the larger the quantity of explosive used, the more finely divided is the blasted material, the more heavily is the air impregnated with dust and smoke, and the greater is the quantity of the poisonous gases left at the place; hence, methods should be used that will tend to reduce the quantity of explosives used and the gases and dust produced. In this it will be found that the use of stemming or of some types of blasting plugs now available will confine the explosive more definitely and therefore increase its efficiency and reduce the quantity of explosive used. It will also reduce the amount of poisonous gas evolved and possibly the violence of the blast as well as its tendency to produce dust and disseminate it into the surrounding air. It would be well for users of explosives to investigate types known to give off minimum quantities of harmful gases on detonation and to use them; moreover, elimination of the use of fuse and substitution of electric blasting would help to reduce the poisonous gases from the blasting process. Explosives that have been held in storage too long or stored under unfavorable conditions as to moisture, temperature, etc., are likely to give off large quantities of harmful gases if they detonate at all; hence, the utmost care should be taken in storing explosives and in seeing that they are not held in storage too long before being used.

Appended to this report are some excellent regulations issued recently by the State of New York on "Control of Toxic Gases after Blasting in Mines, Tunnels, and Shafts."

MISCELLANEOUS DUST PREVENTION PROCEDURES

Dust respirators of various types are now available for use in excessively dusty atmospheres. They are cumbersome and inhibit freedom of movement, making them undesirable for constant wear throughout a working shift, though they can be worn readily for several minutes at a time; nevertheless, they do give adequate protection to wearers against inhalation of dust into the respiratory system but essentially no protection against poisonous or asphyxiating gases. Dust respirators should be regarded as useful for emergency purposes only and then for relatively short periods, and adequate dust protection for workers should be of a more fundamental nature; that is, the quantity of dust should be reduced at its source.

What might be designated good housekeeping has a definite place in dust-prevention activities. Dusty materials should be stored in dust-tight containers or bins. Dusty processes, including the handling of dusty material, should be conducted, as far as feasible, in dust-tight compartments or structures tightness of which should be maintained. Ledges or surfaces on which dust may lodge and accumulate, to be easily thrown into the air by some shock or movement, should be changed, as far as feasible, to prevent opportunity for such accumulation; if this cannot be done, such surfaces should be cleaned periodically by vacuum process, by washing down, or by sweeping (the latter is a relatively poor method and should be used if possible only when a minimum number of other workers is present). Floors should be kept as dust-free as practicable, and the use of water or washing methods is recommended where they can be used. Air for the use of workers certainly should not come from dusty sources.

One of the most important features in connection with prevention of harm to the health from dust is the physical examination; unfortunately, this is clouded by so much controversy that its effectiveness is largely nullified, though it should be one of the principal cogs in the machinery operating to minimize harm to the health from dust in industry. Without doubt, every person employed in an industry where considerable dust may be present in the air should have a rigid physical examination by a competent doctor before employment; if the examination reveals respiratory trouble, especially if tuberculosis is involved, the person should not be employed. Moreover, at intervals not exceeding 12 months (possibly 6 months) every person in an industry wherein much dust is present in the air should have a rigid physical examination; if disease is shown to be developing, the victim should be transferred to nondusty employment, if such is available. Handling physical examinations in a manner fair to the worker as well as to the employer is a problem that should be worked out, and it must be admitted that up to date this has not been done at all adequately.

CONCLUSION

Prevention of dust disease is chiefly an employer responsibility and he should not hesitate to shoulder it with a view not only to safeguarding the health of persons under his supervision but also to relieving his firm from the heavy financial burden likely to be assessed by compensation or legal authorities should any considerable number of employees become afflicted with dust disease. When one realizes how little is known about the cause or cure or even the alleviation of this disease, it seems sensible to do anything practicable to reduce the amount of dust in the air of working places. This does not mean that the employee should not help himself, as it is manifestly as much to the employee's interest to avoid dust or any other occupational disease as to avoid having accidents. However, information on occupational disease (including dust disease) is not readily available in a form understandable to the worker; the employer should therefore conduct an educational campaign to inform his foremen about matters pertaining to occupational diseases and have them transmit the information to the workers. The latter will then be able to cooperate more wholeheartedly in trying to eradicate these dread diseases from industry or at least control them more effectively than has been done in the past.

NEW YORK STATE DEPARTMENT OF LABOR
STATE OFFICE BUILDING
NEW YORK CITY

RECOMMENDATIONS OF COMMITTEE
TO THE
INDUSTRIAL COMMISSIONER
RELATIVE TO
CONTROL OF TOXIC GASES AFTER BLASTING IN
MINES, TUNNELS, AND SHAFTS

- (a) Each case containing explosives for underground use shall be clearly marked in 1/4 inch or larger type with the designation "Fume Class 1", "Fume Class 2", or "Fume Class 3", to indicate the amount of poisonous gases produced. The amount of poisonous gases produced shall be the total volume of carbon monoxide plus hydrogen sulfide emitted in the Bichel Gauge by a 1-1/4 x 8 inch cartridge of such explosive as determined by tests according to the standard procedure of the U. S. Bureau of Mines, in which tests the gases emitted shall not contain more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state. The amount of poisonous gases produced per 1-1/4 x 8 inch cartridge shall be less than 0.16 cu. ft. for "Fume Class 1", from 0.16 to 0.33 cu. ft. for "Fume Class 2", and from 0.33 to 0.67 cu. ft. for "Fume Class 3." Explosives in cartridges smaller than 1-1/4 x 8 inches shall comply with the limits specified for the Fume Class of the 1-1/4 x 8 inch cartridge of that explosive.

NOTE: The Standard test procedure of the U. S. Bureau of Mines referred to in Paragraphs (a) and (c) of these orders, is recorded on pages 91 to 94 of U. S. Bureau of Mines Bulletin 346 entitled "Physical Testing of Explosives."

- (b) No explosive other than those in "Fume Class 1" shall be used underground in any operation, except that if conditions in any operation warrant, the Commissioner may, at his discretion, grant permission for use of explosives in "Fume Class 2" or "Fume Class 3" when proper application has been made by an operator for such use.
- (c) No explosive shall be used underground in any operation if the gases emitted in the Bichel Gauge, in tests, according to the standard procedure of the U. S. Bureau of Mines, contain more oxygen than is sufficient to burn the combustible gases to their maximum oxidizable state.

- (d) No explosive which is packed in cartridges of less than one inch diameter shall be used underground in any operation.
- (e) No explosive shall be used underground in any operation except in its original wrapper only, i. e., no explosive shall be used with its wrapper removed and no additional paper shall be wrapped around the explosive charge.
- (f) No explosive which has obviously deteriorated due to improper storage, or to any other cause, shall be used underground in any operation.
- (g) Permissible explosives used in underground operations having inflammable gas shall conform to all requirements of the United States Bureau of Mines as to permissibility and are therefore excluded from the requirements of Paragraphs (a) and (b) of this order.
- (h) No person shall enter a hazardous area created by a blast involving 25 pounds or more of explosives in any underground operation until at least 15 minutes have elapsed after such blast.
- (i) No person shall enter with the intention of remaining, or shall remain, in a section containing gases produced by a blast in any underground operation unless the ventilation meets the requirements herein prescribed. The ventilation must be maintained so that in the breathing zone of the section the concentration of carbon monoxide, as determined by a carbon monoxide detector approved by the Department of Labor, does not exceed 0.030 percent by volume at the time of entrance into such section, and does not exceed 0.015 percent at the end of one hour after entrance, and 0.010 percent at the end of two or more hours thereafter; provided, however, that this regulation is not intended to prevent entering into, passing through, or remaining in localized sections for a period not exceeding five minutes in concentrations of carbon monoxide of 0.060 percent to 0.100 percent or for a period not exceeding fifteen minutes in concentrations of carbon monoxide of 0.030 percent to 0.060 percent.

When the concentration of carbon monoxide and the conditions of exposure to this gas in a section exceed the limitations stated in the foregoing paragraph, adequate respiratory protection shall be provided for and shall be used by any person entering said section.

A contractor or operator shall designate a capable man whose duties it shall be (1) to make such tests and examinations as are necessary to establish conditions with respect to ventilation and poisonous gas concentrations in sections containing such gases from blast from explosives; (2) to direct and control the entrance into and periods of exposure of all persons within such sections; and (3) to keep a dated record of all such tests and examinations which record shall be available for examination by inspectors of the Department of Labor at all times.

- (j) In addition to the foregoing in any shaft or tunnel of a construction project the minimum amount of fresh air introduced into the shaft or tunnel heading shall be the larger of the two following alternatives: (1) 100 cubic feet per minute per man occupying the section within 200 feet of the blasted face; and (2) 5 cubic feet per minute per cartridge of explosive used in blasting that face.

In all blasts involving delay electric blasting caps in shafts or tunnels, each shot hole must be adequately stemmed with non-combustible material or the explosives confined in some other manner approved by the Industrial Commissioner.

No internal combustion engine shall be used in any shaft or tunnel of a construction project except as same has been approved by the Department of Labor.

A contractor doing work involving shafts or tunnels, the total contract value of which work is \$250,000 or more, shall employ a licensed professional engineer whose duty shall be: (1) to make such tests and examinations as are necessary to establish conditions with respect to ventilation and poisonous gas concentrations in sections containing such gases from blasts from explosives; (2) to direct and control the entrance into and periods of exposure of all persons within such sections; and (3) to keep a dated record of all such tests and examinations on a form provided for the purpose by the Department of Labor, to certify same, and mail same monthly to the Department of Labor.