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Prevention of OCCUPATIONAL DISEASES

Other Than Those That Are Caused by Toxic Dust

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THE USE of volatile chemicals has increased greatly during the past few years. They have become indispensable in the manufacture of paints, in dry-cleaning processes, and as solvents in various industrial processes, to mention but a few of their common uses. In fact, so great has been the demand for volatile solvents both by industry and the general public, that new applications for them are constantly being developed and commercialized. The volatile solvents perform a large and important part of industrial expansion into new fields as new uses for them are discovered.

Partly as the result of the increased use of new chemicals in industry, it is now well recognized that the hazards of certain occupations are important factors in the causation of sickness and even death. Dublin (1)[1] has evaluated the effect of the industrial environment on the well being of a large number of workers in a mortality study among more than three million white, male wage earners. The study covered a three-year period from 1922 to 1924, inclusive, and is compared with a similar study made over a similar period from 1911 to 1913. The groups studied constituted a fairly representative social and economic class and were considered as an urban earning population. Dublin has shown by an analysis of the data obtained, that adult males engaged in industrial pursuits had a higher mortality and a shorter longevity than those in other types of work such as professional, clerical, etc. In the more recent study, it was further shown that the mortality rates for the industrial workers were more than double the rates for the non-hazardous occupations. In terms of life expectancy, the picture presented was impressive. The industrial worker at the age of 20 had an expectancy of 42 years as compared with the normal of 49 years. In other words, the life of the industrial worker in 1924 was shortened by approximately seven years, while the data for 1911 to 1913 showed the decrease in longevity to be even greater. Considering the characteristics of the groups studied, Dublin was led to the conclusion that in the industrial environment, exposure to abnormal conditions such as toxic dusts, vapors, fumes and gases, radiant heat, etc., explains the difference in longevity between industrial and non-industrial workers. Since, furthermore, there are some 900 separate occupations with exposure to occupational-disease hazards (2), the magnitude of the preventive problem should merit considerable attention.

Several methods are at present available for the prevention of occupational diseases due to exposure to substances which are injurious to health. Some of these methods have already been extensively discussed in the literature of industrial hygiene with reference to dust hazards, and, in general, the ideas there formulated have a very general application in other related fields. Briefly, these methods of prevention include: (*a*) sanitary and occupational surveys; (*b*) mechanical and personal methods of controlling a hazard at the point of origin; and (*c*) periodic medical examinations and surveys. Each of these methods is discussed in the paragraphs which follow.

SANITARY AND OCCUPATIONAL SURVEYS

Sanitary Surveys. No estimate of a hazard can be made until the conditions of the worker's environment have been evaluated. In studies made by the Public Health Service (3) it has been customary, as a first step in its field investigations, to make detailed sanitary surveys. These surveys include a study of the various items with which the worker comes in daily contact. The sanitary survey is, in other words, an "inventory" of all the hygienic items which enter into the worker's environment, the manner in which he conducts his work, and the length of time he spends at each task. As a rule, such a study is carried out for each room and for the various occupations in a given plant. This procedure, when completed, gives at once pertinent information as to the types of hazards which are likely to exist and the number of workers which may possibly be affected.

The items which enter into a sanitary survey should include the following:

(1) Physical characteristics of building and room in which the survey is made: construction of building; location and size of room; number of workers; type of illumination; type of ventilation.

(2) Sanitary facilities for workers: refuse cans; cuspidor and sweeping service; washing facilities; type of toilets; drinking-water facilities; eating facilities; type of care and maintenance given to sanitary facilities.

(3) Hazards: safety hazards; dust, vapors, fumes, or gases present; exposure of workers to any sources of radiation or to abnormal temperatures.

(4) Analyses of types of employment: list of various operations and number of workers employed in each; materials handled; absenteeism and labor turnover.

(5) Preventive methods in use: isolation methods; local exhaust and general ventilation; personal respiratory-protection apparatus.

(6) Medical services: type of medical service provided and records kept; periodic medical examinations.

It may be seen from the foregoing list of items that a fairly complete picture of the conditions existing in a plant is recorded. A record of the existence or non-existence of any item at once helps the investigator to form a general conception of the line of study which must be adopted. It further makes available to him a detailed amount of information which is extremely useful. Such a survey may indicate whether or not there is compliance with various state factory or other industrial codes. For example, on the basis of the number of employees found in a given room, it may be determined whether

[1] Numbers in parentheses refer to similarly numbered references at the back of the paper.

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there is ample per capita space, or whether sufficient toilets have been provided.

Occupational Analysis. Following the sanitary inspection of a plant, it is then necessary to study the various occupations. The occupational analysis includes an extensive study of the workers' immediate environment wherever a hazard is found to exist. It also entails a correlative study of the health of the workers. One is supplementary to the other and the omission of either cannot be expected to yield results which can be considered satisfactory. The Public Health Service in all its field investigations has attempted by such a procedure to establish what may be considered the safe conditions under which workers may be exposed indefinitely without injury to health. Two examples of the methods used will aptly illustrate the technique employed in making occupations surveys.

In a study of chromium-plating hazards, Bloomfield and Blum (4) examined 23 men, four of whom were not chromium platers and were selected as controls. Five other workers were not actually engaged in chromium plating, but were engaged at various duties at a distance of about ten feet from the plating tanks. The length of service of the workers was carefully determined from the individual occupational histories and varied from zero to seven years.

Since some of the workers were affected by acid mist, it was important to obtain data on the severity of the exposure. Accordingly, determinations of the amount of chromium mist present in the atmosphere were made. The amounts found varied from less than 1 mg to about 56 mg of chromic-acid mist per 10 cu m of air. The tabulated results showing the period of employment, the degree of exposure, and the findings on physical examination of the workers are given in Table 1. From an analysis of this table, it may be seen that 3 of the 19 persons employed in the plating rooms had perforated septa, 21 per cent had ulcerated septa, 47 per cent had marked inflammation of the mucosa and more than half were subject to frequent nose bleeds. From these data it is possible to discover those occupations which require immediate attention. Together with the occupational analysis, the table further shows that the safe limit of concentration of chromic-acid mist in the air is probably under 1 mg per 10 cu m of air. The occupational analysis thus often establishes the permissible limit of a contaminant for prolonged exposure.

TABLE 1 OCCUPATIONAL HISTORY AND CLINICAL FINDINGS OF WORKERS IN CHROMIUM-PLATING PLANTS

Case No.	Occupation	Months employed in chromium-plating room	Hours per day over tank	Approximate CrO_3 exposure in milligrams per 10 cubic meters	Perforated septum[1]	Ulcerated septum[1]	Inflamed mucosa[1]	Nose bleed	Chrome holes
1	Chromium plater	6 1/2	4	15.0	++	—	++	+	+
2	Chromium plater	20	4	28.0	++	—	+	+	+
3	Foreman plater	7	2	25.0	—	++	++	+	—
4	Foreman plater	8 1/2	3	25.0	—	++	++	+	—
5	Chromium plater	3 1/2	4	56.0	—	++	++	+	+
6	Chromium plater	3/4	7	1.2	—	—	++	+	+
7	Chromium plater	1/4	7	1.2	—	—	++	+	—
8	Chromium plater	7	7	1.2	—	—	++	+	—
9	Chromium plater	3	7	1.2	—	—	++	—	+
10	Chromium plater	36	4	2.0	—	—	++	—	—
11	Chromium plater	5	6	1.2	—	—	+	+	+
12	Chromium plater	3/4	6	1.2	—	—	+	—	—
13[3]	Chromium plater	12	4	28.0	—	—	—	—	—
14	Chromium plater	2/3	2	28.0	—	—	—	—	—
15[4]	Nickel plater	1 1/2	0	([2])	..	+	+	+	—
16	Racker	8	0	([2])	+	—	+	+	—
17	Racker	3/4	0	([2])	—	—	+	—	—
18	Racker	1/4	0	([2])	—	—	+	—	—
19	Wiper	1 1/4	0	([2])	—	—	+	—	—
20[5]	Foreman	0	0	0	—	—	+	—	—
21[5]	Foreman	0	0	0	—	—	+	—	—
22[5]	Clerk	0	0	0	—	—	—	—	—
23[5]	Inspector	0	0	0	—	—	+	—	—

[1] ++ marked; + slight; — negative; [2] Unknown; [3] Used vaseline in nose; [4] Cyanide burns; [5] Work in other departments of factory.

Frequently, it is not possible to correlate engineering and medical data in an occupational analysis. Thus, in a study of the lead hazard in a storage-battery plant (5), the Public Health Service adopted a special method of determining the permissible limit of lead dust. The investigation included a sanitary survey as outlined above and an occupational analysis which included a determination of the lead dust and fumes present in the air, a record of employment and of disabling sickness (mostly compensation cases of plumbism), physical examinations, and blood and urine analysis. The medical examinations, because of the nature of lead poisoning, were necessarily extensive. With each worker, subjective symptoms such as colic, weakness, loss of appetite, constipation, nervousness, etc., were noted. Similarly, the important objective symptoms were recorded, including pallor, jaundice, tremor, reflex and pathological changes in the blood and urine. However, although a large number of engineering and medical data were available, it was found to be inconclusive due to the large labor turnover which the plant had experienced during the course of the study. This had already been indicated by the sanitary survey, and as a result a careful record had been kept of the workers who had reported to the plant clinic for various complaints, characteristic of lead poisoning. From the knowledge of the lead concentration to which these workers had been exposed, it was then possible to estimate approximately that concentration of lead for which a minimum number of workers had found it necessary to visit the clinic. Hence, except for prolonged exposure, it was shown in this manner that the safe limit of exposure of lead dust and fumes was less than 1.5 mg per 10 cu m of air.

The foregoing examples show the importance of a carefully conducted occupational analysis. Not all conditions found in practice can be similarly treated, but a few facts stand out and are generally common in most surveys of occupational-disease hazards; these are: (*a*) a detailed list of occupations and the number of workers exposed; (*b*) a careful occupational history of each worker. This is most important as has already been pointed out with regard to dust hazards (6), but it is equally applicable to all types of hazards. The occupational history which is a list of all the previous occupations of the worker and his time spent in each is frequently of great assistance in diagnosing ailments which may not be entirely attributed to his present work; (*c*) physical examinations of all workers with particular emphasis on the characteristic symptoms of the contaminant to which they are exposed. Careful present and past medical histories must also be taken; (*d*) quantitative determinations of the contaminant present in the air; and (*e*) a correlative analysis of the medical and engineering findings with a view to establishing threshold or safe limits of exposure.

Threshold Limits. Thus far the steps necessary to evaluate a given hazard have been outlined. It is clear that the starting point of a preventive program hinges upon the safe limit of air contamination which the worker may breathe continuously without injury to his health. Unfortunately, extensive field studies of the type discussed above have been few and there are still many practical data wanting. However, both in this country and abroad, laboratory experiments have been carried out on animals and humans, and it has been possible to determine approximately the safe limit of exposure to various sub-

TABLE 2 PHYSICAL AND TOXIC PROPERTIES OF COMMON VAPORS AND GASES

Substance	Formula	Ordinary state	Boiling (1) point (deg C)	Spec. gr. of gas or vapor (air = 1)	Inflammable limits (per cent)	Physiological action	Least amount detectable by odor (ppm)	Physiological response to various concentrations (ppm): Kills in very short time	Dangerous for 1/2-1 hr exposure	Maximum concentration for exposure of 1/2-1 hr	Amounts causing slight symptoms after several hours' exposure	Maximum allowable concentration for prolonged exposure
Chlorine	Cl_2	Gas	−34.6	2.486 (1)	Non-inflamm.	Strong irritant	3.5 (2)	900 (3)	14-21 (3)	3.5 (3)	0.35 (3)	<0.35 (3)
Bromine	Br_2	Liquid	58.8	5.5[a]	Non-inflamm.	Strong irritant	No data	at 550 (3)	at 6-9 (3)	at 3.5 (3)	0.3-0.45 (3)	0.15-0.3 (3)
Ozone	O_3	Gas	−112	1.62 (3)	Non-inflamm.	Strong irritant	0.5-1.0 (3)	No data	5 (3)[b]	No data	0.8-1.8 (3)	<0.8
Hydrocyanic acid	HCN	Liquid	25.2	0.93[a]	Non-inflamm.	Irritant Asphyxiant	No data	270 (3)	110-135 (3)	45-54 (3)	18-36 (3)	<18 (3)
Hydrogen chloride	HCl	Gas	−85	1.2678 (1)	Non-inflamm.	Strong irritant	No data	1250-1750	1000-1350 (3)	40-90 (3)	No data	<10 (3)
Hydrogen fluoride	HF	Liq. or gas	19.4	0.69[a]	Non-inflamm.	Strong irritant	No data	660 (3)[b]	50-250 (4)	10 (4)	10 (3)[b]	3 (4)
Sulphur dioxide	SO_2	Gas	−10	2.2638 (1)	Non-inflamm.	Strong irritant	3-5 (5)	535-650 (3)	150-190 (3)	50-100 (3)	25-40 (3)	10 (3)
Nitrogen tetraoxide	NO_2 or N_2O_4	Gas	−21.3	1.6-3.2[a]	Non-inflamm.	Strong irritant	No data	320-530 (3)[c]	117-154 (6)[c]	105-210 (3)[c]	50 (3)[b, c]	39 (6)[c]
Ammonia	NH_3	Gas	−33.4	0.5963 (1)	16-27 (7)	Strong irritant	53 (2)	5000-10,000 (8)	2500-4500 (9)	300-500 (9)	146 (3)	85 (3)
Carbon dioxide	CO_2	Gas	−78.5	1.5290 (1)	Non-inflamm.	Resp. stim.	No data	50,000-67,000 (3)	33,500-44,500 (3)	33,500-39,000 (3)	11,000-16,700 (3)	5,550 (3)
Carbon monoxide	CO	Gas	−192	0.9671 (1)	12.5-74.0 (7)	Asphyxiant	No data	>4000 (8)	1500-2000 (8)	600-700 (8)	500 (10)	100 (8)
Hydrogen sulphide	H_2S	Gas	−59.6	1.190 (1)	4.3-46.0 (7)	Asphyxiant	0.75 (11)	420-600 (3)	360-500 (3)	200-300 (8)	100-150 (8)	85-130 (3)
Arsine	AsH_3	Gas	−55	2.69 (1)	Inflammable	Asphyxiant	No data	250 (3)	15.5 (3)	6.25 (3)	3.1 (3)	<3.1
Phosphene	PH_3	Gas	−85	1.182 (1)	Inflammable	Asphyxiant	1.4-2.8	400-600 (3)	290-430 (3)	100-190 (3)	7 (3)	<7
Phosphorus trichloride	PCl_3	Liquid	79.95	4.7[a]	Non-inflamm.	Strong irritant		652 (12)	50-90 (12)	2-4 (12)	0.7 (3)[b]	0.7 (12)
Phosphorus pentachloride	PCl_5	Solid	Decomp. 160-165	Sublimes	Non-inflamm.	Strong irritant			Analogous to phosphorus trichloride (3), (8)			
Arsenious chloride	$AsCl_3$	Liquid	122	6.3[a]	Non-inflamm.	Strong irritant			Analogous to phosphorus trichloride (3), (8)			
Benzene	C_6H_6	Liquid	80.36	2.73 (13)	1.4-7.0 (7)	Asphyxiant		19,000 (14)	3,000 (15)	3,130-4,700 (14)	1,570-3,130 (14)	100 (16)
Toluene	$C_6H_5{\cdot}CH_3$	Liquid	111	3.20 (13)	1.4-7.0 (7)	Asphyxiant				Analogous to benzene (3), (8)		
Xylene (m-xylene)	$C_6H_4(CH_3)_2$	Liquid	136-141	3.68 (13)	Inflammable	Asphyxiant				Analogous to benzene (3), (8)		
Methanol	CH_3OH	Liquid	66	1.1[a]	7.45-26.5 (17)	Anesthetic		290,000 (3)[b]	No data	No data		
Ethanol	C_2H_5OH	Liquid	78.4	1.6[a]	4-19 (7)	Anesthetic		No data	No data	1380-5000 (19)	No data	No data
Acetone	$CH_3{\cdot}CO{\cdot}CH_3$	Liquid	56.5	2.0[a]	3-11 (7)	Anesthetic		46,000 (3)[b]	75,000 (3)[b]	No data	3370-4220 (3)[b]	No data
Formaldehyde	$H{\cdot}CHO$	Gas	−21	1.0[a]	Non-inflamm.	Irritant		>6500 (20)[b]	No data	No data	200 (20)[b]	No data
Methyl chloride	CH_3Cl	Gas	−23.7	1.784 (1)	8-19 (7)	Anesthetic	No data	150,000-300,000 (21)[b]	20,000-40,000 (21)[b]	7000 (21)[b]	500 (21)[b]	<500
Ethyl chloride	C_2H_5Cl	Gas or liq.	12.2	2.2[a]	4-15 (7)	Anesthetic		150,000-300,000 (21)[b]	60,000-100,000 (21)[b]	40,000 (21)[b]	20,000 (21)[b]	<20,000
Carbon tetrachloride	CCl_4	Liquid	76	5.3[a]	Non-inflamm.	Anesthetic		10,000 (15)	317 (22)	<1000 (22)	No data	<100 (22)
Trichloroethylene	$CHCl{\cdot}CCl_2$	Liquid	87.1	4.5[a]	Non-inflamm.	Anesthetic		7800 (3)[b]	No data	3700 (3)[b]	No data	No data
Carbon disulphide	CS_2	Liquid	46.2	2.6[a]	1.50 (7)	Anesthetic		4,800 (3)	3200-3850 (3)	960-1,600 (3)	320-390 (3)	No data
n-Amyl acetate	$CH_3{\cdot}COO{\cdot}C_5H_{11}$	Liquid	148	4.5[a]	Inflammable	Anesthetic		No data	900 (23)	No data	No data	No data
n-Butyl acetate	$CH_3{\cdot}COO{\cdot}C_4H_9$	Liquid	125	4.0[a]	1.7 (7)	Anesthetic		No data	19,000 (3)[b]	No data	5000 (3)[b]	No data
Nitrobenzene	$C_6H_5{\cdot}NO_2$	Liquid	210	4.2[a]	Inflammable	Narcotic		No data	No data	1.0 (8)	0.2-0.4 (8)	<0.2
Aniline	$C_6H_5{\cdot}NH_2$	Liquid	184.4	3.3[a]	Inflammable	Narcotic		>420 (24)	No data	105-160 (8)	7-26 (8)	<7
m-Toluidine	$CH_3{\cdot}C_6H_4{\cdot}NH_2$	Liquid	203.1	3.7[a]	Inflammable	Narcotic		No data	No data	91-140 (8)	6-23 (8)	<6
Turpentine	$C_{10}H_{16}$	Liquid	200	4.7[a]	Inflammable	Irritant		2900 (25)[b]	540-720 (25)[b]	No data	720-1100 (25)	No data
Phosgene	$COCl_2$	Gas	8.2	3.4[a]	Non-inflamm.	Strong irritant	5.6 (2)	90 (3)	12.5 (3)	No data	1 (2)	<1
Gasoline	C_nH_{2n+2}	Liquid	50-144	......	1.4-6.0 (7)	Anesthetic	No data	30-40 mg/l (3)	25-30 mg/l (3)	10-20 mg/l (3)	5-10 mg/l (3)	10 mg/l (3)

[a] Calculated.
[b] Based on animal tests.
[c] Computed as NO_2

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stances. Such data have, therefore, been tabulated and are presented in Table 2. In this table are given the principal physical characteristics of various gases and vapors and the physiological response on exposure to them. The last column in the table represents the concentration of a gas or vapor which is considered safe (according to information at present available) and which should not be exceeded. Hence, given the problem of exposure to any of the substances given in the table, it devolves upon the engineer to determine methods which will keep the concentration below the given safe limit, that is, the value in the last column of the table.

ENGINEERING METHODS OF PREVENTION

Until recently, the methods of controlling occupational disease hazards met with little attention. Since, however, the use of substances injurious to health has been associated with a subsequent rise in the number of persons affected by continuous exposure to them, the preventive aspects of the problem have seriously engaged the attention of industrial physicians and engineers. The methods which have been developed differ widely due to the varying ways in which processes and operations are conducted. Detailed information, therefore, cannot be given with respect to the design of control apparatus. In general, the control of a hazard by engineering methods can be achieved in several ways, namely: (*a*) by isolation of the hazardous process; (*b*) by exhaust ventilation; (*c*) by means of personal-protection devices, such as respirators and canister-type masks.

Isolation Methods. The object of this method of prevention is to segregate a particular hazard so that a minimum number of workers are exposed. Frequently, a hazardous occupation may affect workers who are not connected with it, but who work close by. An example of such a condition has been given in connection with the five workers in the foregoing chromium study who had ulcerated septa, but who were not engaged in plating operations. Isolation methods have been successfully used in plants where dust hazards exist, such as the modern sand-blast room and the hydraulic shake-out in foundries, which not only tend to localize the hazard within a definite closed area, but also expose few workers who are adequately protected by masks or helmets. Similar developments have also taken place in the spray-painting industries. Thus, spray painting and cabinets have been developed which are automatically operated and require only limited attention by the worker. The same is true of paint-drying rooms and tunnels. Isolation methods are often the simplest and most practical approach in eliminating most occupational-disease hazards. A more extensive use of these methods, however, is often limited because of the complex operations found in many plants which require frequent handling of objects and hence necessitate the exposure of a large number of workers.

Exhaust Ventilation Methods. The use of exhaust methods near the source of a hazard has grown rapidly in recent years. Briefly, the control of any industrial hazard by local exhaust is based on the principle that sufficient air motion must be created by a hood or opening at the source of the hazard to reduce the concentration below the threshold limit. The amount of air motion necessary cannot always be estimated directly but depends upon a careful study of the relation between the amount of air contaminant present and the airflows handled (7). Bloomfield applied this procedure with regard to the degree of ventilation required to keep chromic-acid mist below the threshold limit established by an occupational analysis previously discussed (4). The chromium-plating tanks described in the study utilized lateral exhaust. By varying the air flows handled and making determinations of the chromic-acid mist in the breathing zone of the worker, it was found that the air movement in the plane of the opening, necessary to produce a safe concentration of mist, was approximately 1500 fpm. Some variations were found when the current density in the plating process was increased, since turbulence due to gas formation at the electrodes was increased correspondingly. However, the air movement produced a safe concentration for most conditions encountered.

Since in any case the amount of ventilation required depends on the operations performed and on the shape of the hoods used, it is necessary to study each method of control separately. There are, however, some data on the characteristics of most hoods which are not obstructed in the zone of influence which may prove convenient (8). These characteristics express the conditions of air flow forward of an opening and thus allow some estimate of the performance of a particular hood. For the approximate calculation of the flow at any point along the axis of a hood without any surrounding barrier, the following formula has proved useful (8): $V = 0.1\ Q/(x^2 - 0.1\ A)$, where V is the velocity of the air in fpm at a point along the axis; x is inches from the opening; Q is the volume of air handled in cfm; and A is the area of the opening in square inches. If overhead hoods are used for lighter-than-air vapors or gases, the air velocity at the edge of the tank or basin from which they issue is given by the formula (9): $V = 0.71\ Q/PD$

Here V and Q are as in the former equation, while D is the distance from the hood opening to the edge of the tank in feet and P is the tank perimeter in the same unit. Thus, if the air movement necessary to control a given hazard at a point is known for one hood, the amount of air necessary to be handled by a hood of different size may be approximately determined.

In the case of hoods used in spray-painting operations where solvent vapors are found, it is customary, from the nature of the work, to place the object to be sprayed within the hood, while the operator stands just outside the opening. In such cases, the air flow necessary to secure safe limits of exposure is expressed in feet per minute at the opening. From studies made of the benzol hazard in various industries, it has been found that air flows of from 100 to 200 fpm are required to keep the concentration of benzol below the safe limit of 100 parts per million (10). Here again, however, data on the air movements required to control hazards caused by the use of other substances are lacking, and the investigator must devise special studies and apply the data of Table 2.

While no attempt is made in this paper to discuss the various designs of hoods in use, it is necessary to point out a few important factors in design which must be considered. First, a careful study of the operation to which a hood is to be applied must be made. A hood should be so designed that it offers a minimum amount of hindrance to the operator. Secondly, due consideration must be given to the nature of the substance to be collected. In Table 2, the principal properties of a number of gases and vapors are given. The type of hood design used, therefore, must utilize the fact that if a gas or vapor is heavier than air, it is preferable to use downward or lateral exhaust. This point has been aptly illustrated by Gumaer (11), who has shown that the tendency of a vapor such as benzol is to form into dense layers which sink gradually downward. Lighter-than-air gases or vapors, on the other hand, are best handled with vertical exhaust, taking advantage of their natural tendency to rise. The importance of utilizing the characteristics of a given gas lies not only in the fact that it simplifies the problem of control, but also it prevents any accumulation of gas in such concentrations that they may be accidentally ignited and cause explosions. For this reason there are given in Table 2 the inflammable limits of various gases and vapors when data pertaining to them have been available. Finally, the third factor to be considered is the frequent testing and care of the ventilation apparatus. Exhaust systems should always be operated at their maximum efficiency and periodic checks should be made to see that the concentration of air contaminant is kept below the threshold limit.

Personal Respiratory-Protection Methods. Personal respiratory-protection apparatus are widely used, especially when isolation and mechanical methods cannot be properly designed or when workers are exposed for very brief periods of time. Such apparatus cannot be worn continuously because of the inconvenience incurred in wearing them. Consequently, they form a method of protection when other preventive measures are impracticable. Nevertheless, personal respiratory-protection apparatus form an important part in many preventive programs and a proper knowledge of their uses and limitations is extremely important.

The simplest form of respiratory-protection device is the respirator. Respirators consist of a face piece covering the nose and mouth, with a filter medium to restrain dust or mist on inhalation. A special valve is provided to facilitate expiration. Respirators are used for protection against injurious dusts, such as silica, asbestos, lead, and cadmium oxides. Their effectiveness depends upon the type of filter medium used and the manner in which it fits the wearer. A large number of respirators of various types have been developed. Many of these have been tested and reported upon by the Bureau of Mines (12). This Bureau has recently prepared a schedule of tests for respirators which attempts to standardize the procedure for determining the effectiveness of various respirators (13). Heretofore, much confusion has resulted with reference to the claims made by the various manufacturers on respirator efficiencies.

For the prevention of hazards due to exposure to gases and vapors, canister masks have been developed. These masks are made of special fabrics and cover the face completely. A flexible hose connection extends from the lower portion of the mask to a small canister containing an absorbing medium. Thus, the inhaled air is made to pass through the canister and insures pure air to the wearer. Universal canisters are supplied with a variety of absorbing materials arranged in layers and can be employed against most of the commoner gases and vapors found in industry. Canister masks, however, cannot be used where the gases or vapors are in high concentration. A range of 2 to 5 per cent of a given contaminant appears to be the maximum limit in which a canister-type mask can be used (14).

It is important to remember that canister-type masks cannot be employed in an atmosphere deficient in oxygen. Furthermore, great care should be taken to refill canisters at regular intervals to insure high absorption efficiencies.

Still another type of mask used to protect the worker is the positive-pressure mask. Such masks are supplied with a continuous flow of compressed air from a clean source. This method of protection is finding increasing use in many industries because of the high efficiencies which can be obtained. A chief fault to be found with such masks, however, is the inconvenience experienced by the wearer who is compelled to carry about with him an air-supply hose.

MEDICAL ASPECTS OF PREVENTION

The industrial physician is in a position to estimate the success or failure of a preventive program. He is the first, by virtue of the workers who report to his clinic, to discover the characteristic symptoms of an occupational disease and to call attention to the specific occupations which are dangerous. In this connection, as has been pointed out by the American College of Surgeons (15), the periodic medical examination of workers is of immense value. Only in this way is it possible to secure and maintain the physical fitness of employees and to help increase their longevity. Workers exposed to the hazards of volatile solvents, such as benzol, carbon disulphide, etc., and to such gases as carbon monoxide and hydrogen sulphide, require medical examinations at frequent intervals to insure them against serious chronic ailments. Workers showing symptoms of poisoning should be given other jobs, and should be reexamined at later dates to determine their improvement.

SUMMARY

This paper points out the decreased longevity of industrial workers in comparison with workers of similar social and economic status. The importance of possible exposure to occupational-disease hazards as a contributing cause in the decreased longevity is stressed, and methods of their prevention with particular reference to substances other than toxic dusts are discussed. These methods include the preliminary plant survey and occupational analysis and engineering and medical methods of prevention. The plant survey consists of a listing of all the hygienic facilities for the purpose of determining those occupations in a plant which require further study. This is followed by an occupational analysis, which is intended to show the severity of the exposure of various occupational groups and to correlate the findings with medical examinations. In this way, it is shown to be possible to determine the safe or threshold limits of exposure. The toxic limits of common industrial gases and vapors are included in table form. With regard to the engineering methods of prevention, there is discussed the comparative features of three methods in present use, namely, isolation, local exhaust, and personal respiratory protection. The value of medical supervision and periodic physical examination as a method of increasing the longevity of workers is shown to form an integral and important part in a preventive program.

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BERTRAM H. JOHNSON
1875 - 1935

The American Foundrymen's Association suffered the loss of one of its most loyal and beloved members and active workers, in the death of Vice President Bertram H. Johnson, who while attending the 1935 Toronto Convention, became ill and passed away in that city on August 20. For many years Mr. Johnson had been active in the work of the A.F.A., serving on committees and representing the Association in its connections with other technical organizations. Elected a director in 1928, he served in this capacity for three years. Then in 1934 he was named Vice President, serving with such distinction that he was elected for a second term at the Toronto Convention.

Mr. Johnson was born at Lynn, Mass., where he received his early education. His technical training was obtained at Massachusetts Institute of Technology. After graduation he became associated with Taylor and Gooding, engineers and machinists of Lynn, and when that firm was merged with the John T. Robinson Co., Hyde Park, Boston, Mr. Johnson accepted the position as superintendent. In 1910, he became connected with the Cresson-Morris Co., of Philadelphia as works manager and remained associated with that company for a period of over 16 years. He then became connected with R. D. Wood Company, first at its Florence Pipe Foundry & Machine Co., Florence, N. J., plant and later in the Philadelphia office as assistant to the President, the position he held at the time of his death.

Mr. Johnson was identified with a group of foundrymen, who in 1928, conceived the idea of establishing a trade association for the gray iron jobbing foundry industry, which resulted in the formation of the Gray Iron Institute. Mr. Johnson was elected first vice president of the Institute and later served for one year as president.

Mr. Johnson was an active member of the Philadelphia Foundrymen's Association during his entire residence in that city. He took an active part in all technical and committee work and was a leader in the reorganization of the Philadelphia Foundrymen's Association as the Metropolitan Philadelphia Chapter of A.F.A.

TRANSACTIONS

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00471

Table of Contents

25. In the preparation of this paper the writer wishes also to acknowledge the kindness of J. Roberts, chief of motive power and car equipment, Canadian National Railways, Montreal, for the permission granted and also the help of Robert Job, consulting chemist, in giving helpful suggestions and some historical data. The photographs kindly supplied by F. H. Williams also are gratefully acknowledged.

DISCUSSION

D. H. [illegible].[1] I have a query in reference to paragraph 16 of Mr. [illegible]'s paper, where it says: "When it is considered that cylinder liners vary in diameter from 20 to 29 in., having a length of 42 in. with a wall thickness of ¾ in. when machined * * * Machinability is very good and a very fine finish is obtained." I would like to know how the total carbon at the top of this liner varies from the bottom, which after all is in direct relation to the strength in the top and the bottom.

H. C. [illegible].[2] I note in paragraph 6 the statement that this investigation was started on the basis of developments in the production of high strength cast irons under the committees on Cast Iron of the A.F.A., supplemented by the A.S.T.M. It is rarely that investigations of that kind it seems to me over an experience of some years have such satisfactory results as have been outlined by the author of this paper. My thought was that perhaps we shouldn't let the matter pass without drawing attention to the excellent work that had been done and the fact that our own publications formed the basis upon which it was built.

Mr. [illegible]. In connection with the question regarding paragraph 16, no work has been done of that nature to determine whether there was a difference in total carbon at the bottom and at the top. The only thing we do to insure soundness in that casting is to cast it about four or five inches longer than the usual length and cut off the head. It is necessary, as you know, for a boring operation to have at least two or three inches for holding such a casting in the jaws of the boring mill and an extra one or two inches is immaterial providing you are getting a good casting.

It is also true that these castings are stock castings and may vary in length for different classes of locomotives, of the same diameter, so that we have not gone into any investigation as to the condition of one end of the casting as compared with the other as long as it is sound. I might say that these castings have given considerably increased life over anything that we ever had before.

[1] Chief Metallurgist, American Radiator Co., Detroit, Mich.
[2] Technical Adviser, Canadian Bronze Co. Ltd., Montreal, P. Q., Canada.

Industrial Health Hazards and Employer Responsibility

By Dr. W. J. McConnell,* New York, N. Y.

The recognition of the importance of giving greater attention, on the part of foundry executives to consideration of the employers' responsibilities in overcoming industrial health hazards which may be connected with foundry operations, prompted the holding of a special session on this subject at the 1935 Toronto convention. This paper by Dr. McConnell, one of two presented at this session, discussing some of the medical aspects, outlines foundry hazards and presents some suggestions for control programs. Discussion of this paper is combined with that of the second paper by D. E. Cummings and may be found beginning on page 180.

A great deal has been heard recently, particularly in the State of New York, about the cost of compensation insurance for the protection against occupational diseases. Various estimates of such costs range from less than 1 to more than 10 per cent of the payroll. Irrespective of what rate will be set in the beginning, eventually the determining factor of cost will depend upon the efficiency of measures used for the protection of workers. Neglect to provide protective measures may prove extremely costly. Control will reduce the cost to an insignificant expense.

Health Maintenance Economically Necessary

With the many demands made upon industry for employee compensation, either through legislative or civil action, following injury to health arising out of, or alleged to arise out of, and during the course of employment, the maintenance of the health of any working force has become, from an economic viewpoint alone, a practical necessity.

During recent years, the responsibility of the employer has steadily broadened, due chiefly to the fact that the capacity for control of health conditions in industry lies almost entirely in his hands, and the employer has found it to be good business to reduce to a minimum the money losses due to sickness among workers. He has done this by providing a program consisting largely of health supervision and education, plant hygiene and safety engineering.

* Assistant Medical Director and Director, Industrial Health Section, Metropolitan Life Insurance Co.

00472

Basis of Health Control

The essential basis of health control in industry is the physical examination. Without knowledge of the physical condition of the individual whose health is to be conserved or bettered, it is difficult, if not futile, to develop the facilities required for his care. It is also true that only by regular medical examinations over a period of years can a reliable opinion be formed regarding the effectiveness of preventive measures used to prevent the occurrence of occupational diseases.

Reasons for Occurrence

The question may be asked, "Why do occupational diseases occur?" Many causes might be cited, chief among which are two.

First, occupational diseases occur because of the employment of poor risks, or the failure to select workers physically and mentally capable of giving reasonably continuous service. In the selection of workers, consideration also must be given to the possibility of the job aggravating existing diseases and defects.

Second, occupational diseases occur because they are actually produced by exposing workmen to concentrations of toxic substances beyond the threshold or toxic limit of those substances, or by the failure to provide and maintain the necessary equipment to protect the workers against harmful exposure.

Foundry Hazards

The health hazards of an industry are determined by a physical survey of representative plants of that industry. Without going into the matter of the methods and standards used in conducting a survey of an industry, the results of that survey should evaluate the various health hazards existing. It should indicate the chief sources of the hazard, the extent and efficiency as well as the faults of equipment intended to protect workers. Wherever physical examinations are made, it is possible to correlate the physical findings with the data collected from the physical survey of the plants. Such studies indicate the foundry industry to have comparatively few health hazards. First might be mentioned the presence of dust of a mixed character. It is true that the harmfulness of a dust varies considerably, depending upon its chemical composition, its concentration, in some instances the par-

ticle size measurements of the dust, the length of exposure, and, perhaps, individual susceptibility.

Foundry dusts, however, do contain some substances which are of a hazardous nature. The majority of the dusts collected in foundries contain varying percentages of free silica, which is responsible for the disease known as "silicosis." [illegible] The inhalation of silica dust produces a fibrosis, from which very few individuals die, but, unfortunately, silica dust in some way or other provides a fertile soil for the development of the tubercle bacillus and a large percentage of silicotics—some quotations are that about 75 per cent—die of tuberculosis.

In studies of the foundry industry, made by the Metropolitan Life Insurance Co., about 50 per cent of the dust counts collected exceeded 10,000,000 particles per cubic foot of air. About 10 per cent of those counts exceeded 100,000,000 particles per cubic foot. It was found that the chief sources of this dust are due to lack of maintenance of equipment. The foundry industry has the facilities for controlling the dust but, unfortunately, this equipment is not maintained at all times.

Dust Sources

There happens to be only three chief sources of dust in the industry, namely, sand conditioning, shake-out operations, and cleaning operations. Facilities are available for controlling the dust in all of these operations.

While the subject of dust is being discussed, there is another substance which is found in foundries where brass is founded; namely, lead. In these foundries, there frequently are sufficient amounts of lead dust to create a hazard of lead poisoning.

Temperature Changes

Foundrymen are frequently subjected to varying temperature conditions, to radiated heat and drafts. The author believes that the high rate of respiratory diseases is due more to the changing temperature conditions than to the dust hazard. He has never been convinced that the foundries have a serious silicosis hazard. While the company with which the author is connected did examine a number of men who had worked a long number of years in the foundry industry and found a certain amount of fibrosis, no advanced cases of silicosis were found. Apparently, the disease progresses slowly among the foundrymen, so that the author feels that with the utilization of the facilities that are already in use in the majority of the foundries—and most important, is the maintenance of the equipment—the dust hazard can be controlled with very little trouble.

Other hazards are of a minor nature. In some instances, there may be an escape of gases around furnaces. These gases may contain carbon monoxide, hydrocyanic acid, sulphur dioxide and a few other gases which are, of course, in moderate concentrations very poisonous; but these are only occasionally found around furnaces due to leakage. Of the indirect health hazards, perhaps the chief is illumination. It was found in the studies to which the author has referred, that the illumination as a rule was poor.

Most Important Hazards

Of all the hazards, perhaps the two most important of the industry are dust—and the author feels that the dust hazard perhaps is more of a legal hazard than a health hazard, and, therefore, very important to control; and second, the varying temperatures, exposure to radiant heat and drafts.

Control Programs

A control program should consist of two phases, the medical and the engineering. The medical phase of the program consists of initial or pre-employment physical examinations and periodical examinations. Unfortunately, only the larger foundries can afford the expense of maintaining their own medical departments. Likewise, an engineering department is generally impracticable for the average foundry. Therefore, it seems that the best plan to consider is a central organization equipped to make the necessary physical examinations and an organization with the personnel capable of conducting physical surveys at the plant. The author has in mind the set-up in Milwaukee, where a central organization provides a physician who interprets all x-ray plates and an engineer who conducts all surveys of the foundries.

Unfortunately, the average physician is not prepared to make the type of examination and interpretation required to diagnose every disease among workers in the foundry industry. The physical examination must include a very careful job analysis, particularly a history of the past occupation. Most important in the

physical examination of applicants who are exposed to dust conditions, is the x-ray examination of the chest. Unfortunately, there are few physicians who have had the experience necessary to properly interpret the findings of the average industrial worker.

There is another advantage in having a central clearing house, in that a uniform method of conducting examinations and a means of comparing the various x-ray findings is available. A central organization likewise is best in conducting a physical survey. Here, again, it is unfortunate that there are not enough engineers trained in this particular type of analysis.

With such a program, which strikes at the two chief causes of occupational disease, the author is convinced that the health hazards of the industry can be controlled and that foundry work will eventually become a safe employment for workmen.

(Discussion of this paper begins on page 180)

Industrial Health Hazards and Employer Responsibility

By Donald E. Cummings,* Saranac Lake, N. Y.

Abstract

Dust has been in existence since man first walked the earth, according to the author, but it was not until the invention of the machine that dust became an industrial hazard. In this paper, the author discusses the action of dust in the lungs and points out that all dusts are not dangerous. Silica dust is one of the dangerous dusts but only when present in certain concentrations of certain particle sizes. The point that complicates the silicosis problem is the fact that in many cases there is also decided evidence of the presence of tuberculosis. He points out that in foundries many men with normal lungs work for years and do not contract silicosis although there may be evidence of fibrosis. The author explains the action of the dust particles inhaled on previous pulmonary injuries and states that workmen who are disabled by occupational fibrosis contracted in the foundry generally are those who exhibit evidence of concurrent pulmonary infection or injury. With regard to the executive's responsibility, he should inform himself on dust hazards, should conduct surveys of his plant and should inaugurate a program of control. In the latter section of the paper, the author groups employes and prospective employes into three general groups and explains which groups are good or fair risks and which should not be employed. He concludes with the recommendation that an educational program, similar to that used in "Safety First" campaigns, be inaugurated to combat the dust hazard.

1. Centuries ago, when man was just emerging as the dominant figure in the welter of life about him, we can visualize a thick-set figure clothed in animal skins setting forth from his cave in the early morning. He carried a rounded stone in his hand as he passed along a trail in search of food, and relied largely upon his keen senses to warn him of approaching game or danger. He inhaled deeply of the air brought to him by the fresh morning breeze, and suddenly tensed as he became aware of the approach of a hare. As the animal fled before him, he hurled the stone but misjudged the distance and missed his prey.

* Field Director, Saranac Laboratory.

Note.—This paper was presented at a session on Industrial Health Hazards and Employer Responsibility at the [illegible] Convention of A.F.A. in Toronto, Canada.

2. In searching for his weapon, he discovered that it had struck a rock and splintered into sharp angular pieces which attracted his attention as useful objects. Later that afternoon, his appetite satisfied, this early man experimented with stone chipping in an effort to produce more perfect weapons or tools. During the process of fashioning a flint spear-head, the early artisan must have inhaled a certain amount of fine flint dust, but there is little to lead us to believe that his health or welfare was seriously affected thereby.

Dust in Atmosphere

3. Before the first tool or machine was devised, the lungs of this early man had already accumulated considerable dust from the apparently clear air about his home. The elementary forces and the activities of living things were constantly producing dusts which were added to the atmosphere in varying quantities. Concurrently, these same forces were operating to rid the air of part of the contamination. Since none of the forces tending to eliminate the dust were perfectly efficient, particulate matter constituted a normal component of the atmosphere enveloping the earth and, because man exercised little or no control over the forces producing dust, he inhaled a portion of it with the first breath of life and continued to do so throughout his existence.

4. Not all of the dust which he inhaled was retained, for a considerable quantity was filtered out and expelled by the air-conditioning apparatus of his upper respiratory tract, which was provided with hairs, moist mucous surfaces, a whipping sea of cilia and the mechanism of cough. Moreover, a further portion of dust was returned to the atmosphere in the exhaled air, but a certain proportion entered the ultimate air sacs of the lungs and was retained there to be disposed of by the interesting processes provided by the pulmonary anatomy.

Behavior of Dust in the Lung

5. If we could have observed the living tissues of this early man under high magnification, we would have noted that wandering cells or phagocytes moved out from the walls of the air sacs and engulfed the particles which had entered the lung, thereby furnishing the dusts a possible means of transportation and more intimate contact with the body fluids but at the same time protecting the pulmonary structures from purely mechanical irritation. Some of the dust containing cells might have appeared to be greatly

00475

stimulated by their ingested particles and would have migrated toward the nearest portal of entry, into the drainage system or lymphatics. Some of these stimulated cells would have come to rest at small catch basins along the drainage system, but the greater portion of them would eventually have lodged in the cesspools or lymph nodes near the root of the lung.

6. At these points there would have been a sufficient concentration of particles to pigment the structures so that the color of the dust could have been discerned with the unaided eye, had the lymph node been exposed to view. Other dust containing cells would have appeared quite differently than those just described, however, for they would have displayed little or no stimulation and would have remained in the air sacs lethargically taking in a new particle from time to time but failing to show any evidence of concern over their burden.

PARTICLE SIZE

7. If the lung of this early man could have been examined with all the microscopic, petrographic, and chemical skill of the present day, many interesting facts about the dust that they contained, would have been disclosed. This dust would have been discovered to have a well defined size distribution with none of the particles larger than 10/25,000-in. (0.0004 in.) in diameter, while 70 per cent of it would have been less than 1 to 2/25,000-in. (0.00004 to 0.00008 in.) in diameter.

TYPES OF DUSTS

8. The particles would have shown a great variety of constituents, some of them being derived from living things, or organic, while others would have been earthy, or inorganic in nature. Part of the organic dust would have been shown to be living bacteria highly stimulating and capable of causing the death of their host cells, while other parts of the organic material would have been composed of animal or vegetable cells. The inorganic components would have consisted largely of small particles of various rocks.

9. Certain of the dusts would have been readily soluble in the body fluids, and would have dissolved in the containing cells, forming either poisonous or innocuous products which in turn either stimulated and killed the host cells or left them unaffected. Other dusts would have been relatively insoluble and would have

remained in the pulmonary framework throughout the life of the tissues containing them. Some of these latter particles would have appeared totally inert, while others would have stimulated the phagocytes and created further change in the tissue.

MACHINERY INTRODUCED

10. Our early man was quite unconcerned about all these interesting phenomena and probably continued to chip flint objects for his tribe until he reached a ripe old age. With the passage of time, better tools were fashioned and a third great force for the production or elimination of dust was introduced in the form of machines.

11. The social group was organized to perform industrial activities and craftsmen appeared who devoted all of their working hours to specific skilled occupations. Frequently, these occupations involved the production of dust and the concentration in the atmosphere about the craftsman was often much greater than that which the artisan of the stone age created, because this modern workman was aided by more efficient tools. It was significant also that the craftsman continued steadily at his work, whereas the early artisan exercised his skill only as his fancy dictated in the hours not consumed by the struggle for the necessities of existence.

12. Certain of these craftsmen soon were observed to have an excessive mortality from one cause or another, and occupational diseases were recognized. About 400 years ago, Georgius Agricola in his famous "De Re Metallica" wrote as follows:

> "When the dust is corrosive, it ulcerates the lungs and produces consumption, hence it is that in the Carpathian Mountains there are women who have married seven husbands, all of whom this dreadful disease has brought to an early grave."

Later, Ramazzini, who wrote the first text-book of industrial medicine, attributed the high mortality from consumption among miners and stone workers to the sharp cutting action of the small bits of stone which these workmen inhaled. Other observers described the unusual appearance of the lungs of men who had worked in dusty trades of various kinds and Zenker coined the work *pneumonoconiosis* to describe the pulmonary changes which follow the prolonged inhalation of any dust or mixture of dusts.

13. Recent investigators have pointed out that excessive exposure to silica appears to constitute the greatest of all industrial

dust health hazards, and the term "silicosis" has been adopted to designate the specific condition which men develop after long exposure to this dust

Effect of Silica Dust

14 In the normal individual, the reaction to inhaled crystalline silica is characterized by the development of a peculiar type of fibrosis or scar which appears in those areas where silica is deposited within the pulmonary structures Silica-containing air enters the lung in turbulent motion and the dust is deposited uniformly throughout the entire organ Since these particles are capable of stimulating phagocytes, they are rapidly transported into the drainage system or lymphatics and the first detectable evidence of characteristic fibrosis appears in the lymph nodes situated at the root of the lung Later, this reaction will manifest itself throughout the entire lymphatic system which encircles the blood vessels and bronchi.

15 As the reaction throughout the lymphatics proceeds, the effectiveness of this drainage mechanism is interfered with and the dust entering the lung is eventually unable to reach the lymphatics and is thereafter deposited by the phagocytes in selected areas throughout the lung substance itself Small, discreet, and uniformly distributed fibrous nodules from 2 to 6 mm. in diameter may eventually develop in large numbers within the lung, presenting in this stage the characteristic picture of advanced silicosis.

X Ray Shows Changes

16 An excellent x-ray film of the normal individual's chest represents a projection of the pulmonary structure cast as shadows of varying density Prominent among these densities, are those cast by the blood vessels, which compose the so-called vascular tree. The fibrous changes initiated by pure silica can be detected in the early stages on a good roentgenogram, by the increased densities shown at the root of the lung where the lymph nodes are situated Further changes throughout the lymphatic system will become evident by an increased prominence of the vascular shadows caused by fibrosis developing in the lymphatics surrounding these structures Finally the roentgenogram will reveal, as small round densities, the uniformly distributed, discreet, fibrous nodules present throughout the lung in advanced silicosis, giving the characteristic "snow storm" appearance described by roentgenologists.

Action of Inert Dusts

17. Inert dusts such as coal, hematite, gypsum, alumina, and limestone, produce no stimulation of the phagocytes and hence tend to remain within these cells for long periods without promoting any further action. When mixtures of silica and these inert dusts are inhaled together, the reaction so characteristic of silica is modified by the inert material which tends to slow down the changes which would result if the silica were present alone These modified reactions are apparent not only to the pathologist, but also to the roentgenologist, and constitute the great bulk of all cases of occupational fibrosis. Experience has demonstrated that individuals with modified silicosis do not suffer from the excessive mortality which characterizes those groups with true silicosis.

Tuberculosis

18. If tubercle bacilli are inhaled, they are handled in much the same manner as dusts. Once in contact with the tissues, however, they are either killed and disposed of or they set up localized foci of infection. The organisms are transported by phagocytes into the lymphatics and the tissues then attempt to wall off these foci of infection by laying down an ever thickening mantle of fibrosis. This reaction is much the same as that which follows the inhalation of silica, except that it is generally localized to one or more portions of the lung and may be visualized and interpreted as tuberculosis with remarkable accuracy in a good x-ray of the chest.

Action of Silica on Tuberculous Lesions

19 Obviously, the lung which has been injured by a pulmonary infection, such as tuberculosis, is far less competent to deal with a dust, such as silica, than is the normal lung. Moreover, it has been proved both clinically and experimentally that the inhalation of pure crystalline silica tends to re-activate a pulmonary tuberculous lesion which would otherwise heal, and frequently renders such infection progressive and fatal. Even if the tuberculous lesion has successfully healed prior to the time when silica is inhaled, a far greater reaction to the dust occurs about the site of the old tuberculous scar than occurs in normal tissue, since the drainage system in that area has already been damaged and since the two processes apparently stimulate the tissues to produce an excessive amount of fibrosis

00477

20. Recent investigations have disclosed that individuals who have simple silicosis, uncomplicated with tuberculosis, are not generally disabled, even though their condition may be quite advanced. A careful physical examination frequently fails to reveal anything abnormal about such individuals, and the changes which have occurred in their lungs can be detected only by the x-ray.

PREVIOUS PULMONARY INJURIES

21. Silicotic workmen who complain of shortness of breath, chest pain, cough or other disabling symptoms are generally found to have either a complicating pulmonary infection, usually tuberculous in nature, or some evidence of a previous pulmonary injury which has left a localized scar. These cases can be discerned on an x-ray film by the characteristic appearance of silicosis to which has been added the densities cast by the localized masses of pulmonary fibrosis which exist about the sites of the infection or previous pulmonary injury. Frequently, such cases fail to show tubercle bacilli in the sputum until shortly before death. In many instances the disease is unusually chronic and only slowly progressive, manifesting itself largely by a progressive shortness of breath. Cases of this type are the prominent feature among the men actually disabled by a modified silicosis hazard.

22. Widespread misconception of the disabling effects of uncomplicated silicosis has arisen from the studies of early investigators who were unable to distinguish cases of silicosis from those complicated with pulmonary tuberculosis or other infections with the equipment or knowledge then available. These earlier investigations revealed silicotics who displayed shortness of breath, chest pain, cough, and other disabling symptoms which were ascribed to silicosis alone, since tubercle bacilli could not be found in the sputum. It should be realized, at the present time, however, that silicosis assumes a serious position as an occupational hazard largely because of its effect on pulmonary infections, predominately tuberculous in character.

DUST HAZARDS IN THE FOUNDRY

23. Though the foundry must always be considered as a dusty industry, the nature of its operations are such as to induce, for the most part, only a modified silicosis. Both mortality studies and clinical examinations of foundry workers fail to disclose the type of hazard associated with a pure silica exposure. Many men

in advanced age groups who have spent their entire working lives in the foundry industry are still capable workmen, suffering from no occupational disability, although most of them will be found to have some degree of pulmonary fibrosis. The workmen who are disabled by an occupational fibrosis contracted in the foundry are generally those who exhibit evidence of concurrent pulmonary infection or other injury. It must be recognized, in spite of these alleviating circumstances, that a certain occupational hazard does exist in all foundries.

THRESHOLD DUST CONCENTRATIONS

24. Any working atmosphere which contains more than a certain threshold concentration of silica will induce the formation of pulmonary fibrosis in workmen exposed to it over long periods of time. Information gathered from field studies made in many parts of the world indicate that a normal man may work for many years in air containing pure crystalline silica dust without impairing his health, providing the concentration does not exceed 5,000,000 particles per cu. ft. of air as determined by the standard method used in the United States.

25. This concentration constitutes a special value for the health hazards created by silica which may be designated as the primary threshold. The value of this threshold will be increased for those industries in which the silica hazard is reduced by the presence of modifying factors. The development rate does not always appear to vary directly with the concentration but increases slowly with the elevation of the dust level up to a certain value where the acceleration becomes very marked.

26. Concentrations of 100,000,000 or more pure silica particles per cu. ft. of air appear to be extremely hazardous and constitute a second special value which may be designated as the secondary threshold. Concentrations of pure silica above this secondary threshold lead to the rapid development of silicosis and men working in these extra hazardous atmospheres have been known to acquire true silicosis in less than two years. Examples of this type can be found among men dry drilling tunnels in quartz rock or sandblasting without protective equipment. Demonstrable silicosis usually develops in workmen exposed to pure silica in concentrations between the primary and secondary thresholds in from 5 to 30 or more years depending up the individual's susceptibility and the degree of the exposure.

27. Experience has shown that diminishing a hazardous dust exposure results in extending the time required for silicosis to develop and that even when it does occur, there is generally little evidence of disability among the workmen who contract it, unless they have a complicating pulmonary infection or other injury. All of the preceding remarks with regard to dust concentration apply only to those individuals without pulmonary abnormalities. The presence of pulmonary infections or other pathological conditions generally alters the normal susceptibility of dust diseases.

28. It appears to be true that the individual with arrested tuberculosis might be subjected to a health hazard in an atmosphere containing less than 5 000 000 particles of pure quartz dust per cu. ft. of air, while he might suffer no ill effects from exposure to fairly high concentration of inert dusts, such as coal, alumina, limestone or hematite. Obviously, the values given cannot be used arbitrarily to measure the degree of any hazard or to form the basis for legislative codes of good practice but they serve as one of the aids in bringing a given dust hazard under control.

Responsibility of Executives

29. What then are the responsibilities of the executives of those industries in which the dust hazard is suspected? In the author's opinion, the first duty imposed upon the operator requires that he secure a thorough knowledge of the nature of the disease itself.

30. Many executives whose interest should be deeply aroused by this subject, unfortunately, assume the attitude that silicosis is just another "racket" and delegate the duty of keeping the organization out of trouble to minor officials. The subordinate officers, having been impressed with the general attitude of the management, are frequently powerless to inaugurate a comprehensive program designed to cope with all of the existing circumstances and delay constructive action by refusing to recognize that their operations are in any way affected.

31. The futility of this procedure is evidenced by the fact that claims eventually arise which compel recognition of the disease and the adoption of a proper policy at a time when conditions are much less favorable for its successful application than would have existed at an earlier date.

32. Some managements apparently regard the silicosis question as a purely legal matter and rely largely on such counsel for determination of policy. This procedure tends to distort the problem by illuminating it largely from a single aspect. Obviously, it is equally inadvisable for a management to depend entirely upon the judgment or suggestions offered by either the medical, engineering or production members of its staff.

Administrative Requirements

33. The most important requisite to good administration of silicosis problems lies rather in an informed management advised and directed by authoritative opinion representing the legal, medical, engineering and production divisions of the industry and assisted by consultation with some organization qualified by long experience with the problem, if necessary.

34. Having divested themselves of preformed conclusions concerning their particular situation, the second responsibility of employers consists in inaugurating a thorough survey of their plant to determine the existence, nature and extent of the dust hazard. A survey of this type may include the physical and x-ray examination of the employees, the taking of occupational records, the determination of the nature and concentration of the dust suspended in the working atmosphere, an analysis of the mortality records in the district, and if possible, post-mortem examinations of old employees dying from any cause.

35. The actual importance of silicosis as an industrial problem has been greatly over-emphasized for several reasons, chief among which has been the reluctance of administrative officers to investigate and reveal the existing facts in their operations. The mantle of secrecy which has shrouded existing conditions wherever many dust hazards are involved, has served to exaggerate their significance. Coupled with this lack of accurate and complete information, there has been, in the United States, an unwillingness to provide well-framed legislation to regulate the compensation of workmen affected by exposure to dust. This, in turn, has resulted in the filing of numerous claims in civil court which allege that a personal injury has been incurred through the negligence of the employer in permitting men to work in a hazardous atmosphere.

36. The enormous amount of money involved in these civil actions, together with the confusion created by the varied decisions handed down by judicial bodies attempting to deal with this com-

plex question, has given an altogether unwarranted notoriety and importance to this subject. Unfavorable experience with civil actions, has prompted the hasty passage of occupational disease legislation in some of the United States where the facts are still unrevealed, and there is every reason to expect that unreasonable decisions based upon poor medical testimony, misinformation concerning the dust hazard, and a general tendency to attribute all ills to industrial conditions, will tend to discredit these laws and thus further prolong the unusual prominence accorded silicosis.

37. Administrative officers must further recognize that the situation which has been created in the United States, is now of an emergency nature, and that there is neither a sufficient amount of reliable information, nor a large enough number of properly trained and informed authorities in many localities to deal with the silicosis problem. Under the press of emergency, many so-called silicosis experts have appeared over night and technical publications have been flooded with silicosis articles, few of which have added materially to the general understanding of the subject, but many of which have served to confuse and confound everyone interested in evaluating the actual issue.

38. As is true of nearly all diseases known to the science of medicine, certain phenomena associated with dust diseases are not understood or are imperfectly explained by medical authorities. A much more unfortunate difficulty arises out of the fact that many members of the medical profession, whose authority cannot be questioned in their particular field, are erroneously informed on this subject and offer opinions which are accepted as true, to the further bewilderment of all.

39. The same criticism may be offered against engineers, public health officials or attorneys, whose knowledge of silicosis has not arisen out of long and intimate first hand experience. For this reason, it may be advisable to consider consultation with some organization competent to analyse the information available so that a proper policy may be determined.

Advantages of Survey

40. If no hazard is discovered by a thorough survey, both the employer and the employee are protected by the information secured. On the other hand, if a hazard is detected, the original study serves as a guide to the future program of control which should be promptly initiated.

Control Program

41. A control program in a dusty industry whose hazard has been defined, will include the reduction of the dust concentration in the working atmosphere and the application of protective devices, the establishment of certain physical standards for new employees, the selective placement of old employees on the basis of their physical condition and the adoption of an educational program to properly inform all those vitally concerned with the effects of a dust hazard.

42. Thoroughly reliable methods of determining dust concentrations are available and engineers equipped to utilize these procedures can discover the sources and extent of the contamination and devise means of either reducing the hazard to within safe limits or applying adequate protective devices. A constant check of the dust concentration in the atmosphere should be maintained and records should be kept to show the condition of the working atmosphere, the nature of the protective equipment and the total duration of time each workman is required to spend in a hazardous occupation.

43. A pre-employment examination, including an occupational history and excellent stereoscopic chest roentgenograms, should be given to every new employee. In general these examinations will serve to classify men into three main groups composed of (1) those whose chests are apparently normal, (2) those who have an occupational fibrosis without any other pulmonary abnormality, and (3) those who have tuberculosis or other pulmonary abnormalities either with or without occupational fibrosis.

44. In considering the desirability of employing men whose chests are apparently normal, it should be borne in mind that young men, probably up to the age of thirty or thereabout, are not altogether perfect risks for employment in a hazardous dust since they are in an age period during which they may still contract tuberculosis.

Risks Classified

45. In the author's opinion, men who show evidence of simple occupational fibrosis and who are past the age of thirty, as most of them will be, are excellent risks since the author does not believe that uncomplicated silicosis is ordinarily dis-

00480

abling and since these men are past the age period during which they are likely to develop tuberculosis. These men may show some progression of their fibrosis after employment in a dusty industry but they will not tend to develop disability if they have been rigidly examined to exclude those showing any x-ray evidence of tuberculosis or other pulmonary injuries.

46. If this class of persons is to be discriminated against, it will create a most unfortunate social problem, since many skilled craftsmen perfectly capable of a lifetime of useful activity will be thrown out of work to become embittered and the prey of unscrupulous lawyers and doctors who will further complicate the situation by making the workmen claimants and neurotics. It is the author's belief that these men should not be eligible for compensation but if they are made so under the law, then legislation should also be provided to permit them to waive their right to compensation for an occupational disease, so that they may have the privilege which should be accorded to all free men, that of working at the task for which they are best suited. Providing this group is carefully selected to exclude infection and remains under medical supervision while in the dusty industry, their experience should be as favorable as any that the employer could choose.

47. As to the third group of men, an injustice is done to both the employer and the prospective employee by placing any person at work in a hazardous dust who has tuberculosis or other significant pulmonary abnormalities whether or not occupational fibrosis is present.

Placement of Men

48. In the presence of a known dust hazard, old employees should be placed, as far as possible, in those occupations most compatible with their health and welfare on the basis of the physical examinations which they have undergone. Men with normal chests who are past the age of thirty, or those with uncomplicated occupational fibrosis may be employed at any occupation, while young men under thirty should not be exposed to the operations which produce the most harmful dust and should be re-examined fairly frequently.

49. Those cases of inactive tuberculosis, either with or without occupational fibrosis, should be carefully evaluated and every effort made to provide working conditions such that their health will not be impaired or their ability to earn a living wage interfered with. Men in this group should also be re-examined at frequent intervals.

50. Cases of active tuberculosis should not be employed in a dangerous dust either for their own safety or that of their fellow workmen, and should be encouraged to enter a sanatorium or to place themselves under the care of a competent physician.

Educational Plan

51. The occupational disease problem is now much the same as that presented by industrial accidents when the first compensation act was passed. Disabling conditions created or aggravated by exposure to harmful dust can be prevented or controlled but the final success of any plan designed to accomplish these purposes, will depend upon maintaining a broad educational program similar to that adopted in the "Safety First" movement. These policies are not only humanitarian but they are practical, and have been placed in operation in many hazardous industries employing thousands of men. The author sincerely recommends them for consideration.

(Discussion of this paper begins on page 180)

HEALTH HAZARDS AND EMPLOYER RESPONSIBILITY

DISCUSSION

D. M. Avey, President of A.F.A. and Editor of The Foundry, Cleveland, acted as chairman of the meeting at which the papers of Dr. McConnell and Mr. Cummings were presented.

PRESIDENT AVEY: In starting the discussion of these papers by Dr. McConnell and Mr. Cummings, I think the fact that we are meeting on Canadian soil is singularly fortunate, because we have available in Canada considerable experience which will be exceedingly valuable, I feel sure, to those foundrymen from the states. I would like to ask Dr. McGhie, Deputy Minister of Health for the Province of Ontario, to lead the discussion.

DR. McGHIE: On behalf of the Department of Health of the Province of Ontario, I wish to express our appreciation at being invited, as officers of that Department, to listen and take part in the deliberations of your Association.

The Department of Health of the Province of Ontario is charged not only with the provision of adequate treatment for those who are sick but, what to me seems a far more important task, the prevention of illness. As a result, one of the most important divisions of the Department of Health is the Division of Industrial Hygiene, and closely associated with that is our Division of Tuberculosis Prevention.

I am particularly interested myself in this Division of Industrial Hygiene because, to me, it seems to be one entirely of research. Our experts in that Department, headed by the Director, Dr. Cunningham, do not claim to have the last word to give to you on the solving of your problems, but they are anxious to sit in with you to find out what the problems are and to study them as they appear in the various plants. The officers in that work tell me that the readiness with which the managers and directors of the various industrial organizations place at their disposal the facilities for studying the problem in the plant, facilitates the solving of these problems to a very large extent.

Our organization here, working as it does with the Compensation Board, I think comes close to the ideal, and those members of the staff who are here are far better able to explain its ramifications to you than I am.

DR. J. G. CUNNINGHAM[1]: Dr. McConnell and Mr. Cummings have given addresses which, to me, are exceedingly interesting. They are full of material which is very valuable and, really, I believe, leave very little to be discussed as far as the work of our Department is concerned. We are interested, of course, as a section of the Department of Health, primarily in the control of silicosis and other occupational diseases.

In the foundry industry, there is silicosis. Molders, for instance, as far as our experience is concerned, average for the development of silicosis nearly 30 years, which is a long exposure and compares very favorably with 10, 11 or 12 years' exposure necessary to produce the disease in certain occupational groups, and even shorter times in certain other small groups with heavy exposures. I think this should be recognized.

[1] Director, Division of Industrial Hygiene, Dept. of Health, Ontario, Canada.

In certain other occupations in foundries, the occupational exposure is shorter but still around 20 years. However, on the other side, certain cleaning operations, particularly sand blasting, without adequate protection, result in the very rapid development of silicosis.

We recognize these conditions and undertake to deal with them as they exist. It is perfectly possible to do this and without any great disruption in the industry, either from the expense necessary for the use of special equipment or on account of legal complications arising out of claims. The very fact that it takes molders and grinders and some of the others a good many years to develop the disease suggests that even a moderate reduction in the amount of dust exposure would cause the disease to develop only after so many years that it would not be a practical problem. We, however, feel that dust production in foundries should be reduced wherever it is possible to do it. Admittedly, it is difficult to carry on foundry operations with no dust production, but if we can make a substantial reduction in the ordinary processes I am sure that this would have a real influence on the disease produced as a result of these longer exposures. The dangerous short exposures, such as occur in connection with sandblasting, demand a specific program for dealing with the dust.

Now, a word with reference to tuberculosis. As has already been indicated, tuberculosis is the main problem in relation to dust inhalation. It has been stated that silicosis on its own account, except in certain exposures and they are few, would not be the serious problem were it not for the development of tuberculosis. It should be recognized first of all that tuberculosis occurs in foundry workers the same as in every other section of the community, quite apart from dust exposure, and, indeed, that fact is recognized in workmen's compensation legislation in Ontario.

On the other hand, there is an impression abroad that silicotics with tuberculosis do not spread the disease in the way that ordinary individuals without silicosis and with tuberculosis spread it. Studies, even locally, do not support that idea and when we come to the control of tuberculosis, which has already been indicated as the main problem, we must recognize the value of physical examination. It becomes so much more important when one realizes that individuals exposed to silica are more susceptible to tuberculosis, so that one man with tuberculosis in the plant, whether it arises partly as a result of dust inhalation or not, is a menace to all the rest of those exposed to dust in that plant. Therefore, one of the main functions of the physical examination to which reference has already been made, is to see that that individual is not allowed to continue under those conditions.

Physical examination gives us information with which to start a man on employment; it assists us to control the tuberculosis problem as these men are examined from time to time; and finally it enables us to arrive at some sort of rational method of handling or dealing with the individual who perhaps has silicosis but has not tuberculosis, such as would be spread from one to another, because, as Mr. Cummings says, it does seem to us very important that a reasonable disposition should be made of those individuals who are found to be affected but who are still able to do their work.

G. W. CANNON*: I have listened with keen interest to these able papers and the discussion, for as a foundryman, I am intensely interested in the rapid engineering advance being accomplished in the problem of dust control and disposal. I have been in the foundry industry all my life and in the years gone by we never heard of any foundry workers dying from the effects of dust. They did not seem to die from any cause, — they just dried up and blew away,— we were a pretty healthy bunch of mechanics as a class.

The modern production methods now used in our industry have, however, changed the conditions under which our employees must labor. Speed in production has brought about a concentration of effort in such operations as pressure blasting, whether it be pneumatic propulsion or mechanical projection. Speed at the shakeout has also greatly increased the generation of dust, heat and noise and it is in this hot, dust-laden atmosphere of these and other similar operations that it is necessary our workmen perform their labor; a condition which did not maintain in foundry practice in the years preceding the introduction of continuous and high speed equipment.

The problem of dust control and disposal is one in which we (I am speaking as a member of a firm employing 2,000 men) feel is a tremendous responsibility and one which cannot be thrust aside with indifference. In fact and to the contrary, we feel it must be met and conquered as soon as possible and that, with the aid of the best knowledge that can be procured through scientific research carefully analyzed and engineered by technical men skilled in this particular line of endeavor.

It is my opinion, however, that the successful solution of the problem cannot be achieved by the individual foundry and I suggest that within our own Association there be fostered an organization of men trained in this highly technical subject who would be compensated properly for the time and attention that must be devoted to the effort necessary to bring about a dustless foundry plant; such a setup would pay big dividends. I appreciate, as must all of us engaged in the foundry business, that satisfactory results in conquering the existing dust conditions and associated evils which militate against healthful conditions in which to work will involve large expenditures of time and money. It is not improbable that the larger foundry organizations can undertake this work independently with success, but the smaller foundries also have the same conditions to correct. The large and small units of the industry are interlocked in competition and expensive equipment installation has its reflection in competition. Successful correction measures in one plant will be of benefit in another so I would urge that our Association get into action in an orderly way, through proper organization processes to assist us in creating the best possible working conditions for the employees of the foundry division of American and Canadian industry.

*Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich.

In our plant we are only at the beginning of a program of betterments and we have a long way to go. We are undertaking the correction of the greatest evils first. Suitable designs for our mold shakeouts and core knockouts, one of our worst dust and heat producing sources, are being considered and it will involve the rebuilding of the molding units to gain the desired results; the cost will doubtless be high but we will have to stand the pressure.

In the Cleaning Department, we are confronted with an equally serious problem, that of taking the operators out of the blasting rooms. This will require the building of special fully automatic machines to handle, not just one design of a cylinder block or head, but a large variety of sizes and shapes. In this particular department we have progressed to the stage of selecting the most desirable design. The disposal equipment handling the disintegrated abrasive from grinders and the dust from our few remaining tumbling mills is also being revamped. We feel keenly that our responsibility in the betterment of working conditions is by no means finished if we are successful in the elimination of the dust-health menace. We are constantly engaged in battling with a problem that goes hand-in-hand with it,- the education of the men to take care of their own health.

Years ago the majority of our employees were foreigners. They dressed well from a health standpoint at least, they fed well on good food from the old-fashioned dinner pail prepared by the old-fashioned wife who took good care of them. Today the young men in the foundry are high school boys. They are tenderfeet; not strong enough of body to withstand the abuses that the old-timers were used to. In this campaign, our director of personnel is posting a new placard each week, advising them how to dress and what to eat as the seasons change and in general how to care for themselves. The work of the personnel supervisor does not end with the posting of placards; he sees that the messages which they carry are read and absorbed. We have even gone so far as to provide woolen undershirts, the good, old-fashioned, perspiration-absorbing kind that many of us here present wore and found comfortable in the years gone by.

Successful operation means that conditions must be bettered from every standpoint in order that we may give our employees better places in which to work. Better working conditions will induce a better and higher grade product, better products create greater profit.

PRESIDENT AXLY: That discussion is very pertinent, and it is one of the purposes, of course, underlying this general assembly, that we have here tonight. The whole problem is too large for the individual, and it is a rather large one for the entire industry. These matters are going to have to have the best consideration and the best brains of the best leaders we have in the industry.

JAMES MURPHY*: We all know that dust is the principal cause of silicosis and long before I ever heard of the word "silicosis," I took measures for the elimination of the extreme amount of dust that was in the foundry that I was operating at that time. That was back in 1907.

*Hamilton, Ohio

The workers themselves have a faculty for creating a lot of dust that good management could avoid. In the cleaning of castings, it is far easier for them to stick an air hose into the casting and blow the dust all over the place than it is to dig it out by some other means. To eliminate that dust, I adopted a method of cleaning castings by means of a water blast. Castings that had formerly taken six or seven days for two men to clean, we cleaned in 35 minutes by this water jet. This method can be used in a great many foundries for the elimination of dust, particularly on large castings. Certain parts of the foundry, such as the shakeout, of course, cannot be reached that way, but they can be reached through dust arresters.

I believe that the State of Wisconsin has recently adopted some regulations for the use of water sprays. The sprayer can be used to keep down dust in a very good way, being a much better method for spraying gangways and keeping them moist than by taking a pail and sprinkling water over them, which may make them too wet. The use of sprayers for gangways is getting to be quite common. The principal thing is to keep the foundry damp.

MEMBER: We were faced with the same dust problem. Our foundry is a brass foundry. We started by washing the whole foundry from the ceiling down to the floor, taking all the dust off the beams, making a general clean-up. We had had our cleaning room on one side of the foundry but not separated from it. We moved that and closed it and separated it entirely from the foundry, with a partition, with swinging doors between, and the doors are always closed when the room is not in actual use.

We do a little barrel sandblasting. To overcome a big dust trouble there, we built a room outside of our foundry so that the operator has to go through two doors to get into the sandblast room. The valves that control the air are on the inside, so that at no time is anybody in the sandblast room while it is in operation. Beside the exhaust fan on the sandblast, we put an exhaust fan on the room, so that any dust that comes from the sandblast—and it does come from all of them, no matter how good they are—is pulled out of the room, or at least a good portion of it is.

We have cement floors and we sweep our floors at least three times a week and we sprinkle them all down before they are swept. The one problem that we do not think we have solved satisfactorily is our shakeout, because we do not have a conveyor and the shakeout is done between the molders. We are seriously considering putting in a conveyor, not so much for protection, but from the fact that we believe we could bring our shakeout operations into one room and have two to three men only around that operation.

A. B. ROOT, JR.[4]: It may be that the members will be interested in our experience in Massachusetts. Reference has been made to the necessity of keeping in contact with your state legislature and I suggest that it might be perhaps equally as important to keep in touch with your Commissioners of Insurance.

[4] Hunt Spiller Mfg. Co., Boston

A little over a year ago, the insurance companies through their rating bureau requested the Commissioner of Insurance in Massachusetts to approve an occupational assessment rate of $4.00 per hundred dollars of payroll, in addition to the manual rate for industrial accidents. That request was made without any contact with the foundries or with the foundry organization that was known to exist there and had it not been for the fact that our Insurance Commissioner was very well acquainted with one of the foundry executives it might very easily have gone through. Fortunately the Insurance Commissioner called one of us up and said, "Do you know anything about it and will you come over and see if you think this is a reasonable request on the part of the companies?" As a result of the negotiations which started from that beginning, the rate, instead of being $4.00, was made $2.00.

And bear in mind that the rating bureau, and, through them the insurance carriers, had no statistics from their experience on which to base any request for an increase in rate. They were doing it simply to provide a back-log on which to fall in case they had cases of silicosis to settle in the future.

As a result of that, our Association appointed a committee to confer with the rating bureau on what might be done, first to reduce that below the $2.00 rate and, if it could be done, on what basis it might be done. We suggested to the rating bureau a rating plan of credits by which the carrying out of certain dust prevention features would entitle the foundries to credits on that $2.00, and the plan which they submitted to us was the most terrible thing you ever saw, such suggestions, for instance, as ventilating a portable sand cutter moving up and down the shop. They were the most impracticable suggestions, I believe, that were ever put out. I think there is where our danger lies, through the insurance companies requesting increases in rates through the Commissions.

I would like to ask a question as to how the foundry interests of the country can best coordinate their efforts for the protection of their own interest through preventing unusually heavy increases in rates. The insurance carriers are organized. How can the foundries organize so as to have some common basis on which to protect their business interests against unusually heavy or unnecessarily high rates?

Another question I would like to ask of our two guest speakers tonight relates to the question of analysis of these cases. I have understood that the method of analysis was to take a sample of the rafter dust, make the dust count from the air floated dust, and to make their analysis for the silica content from the rafter dust. I have understood that there is a great deal of difference between the silica content of such rafter dust and the dust collected from air floated samples. Is there any basis or any agreement that the chemical analysis of the silica content should be taken of that same air floated dust from which the count is made?

DR. MCCONNELL: The chief reason for using the rafter dust for analysis is because of the difficulty of collecting a sample in the impinger apparatus. One of the Westinghouse engineers has developed a method, I think of electrical precipitation, which is capable of collecting a sample sufficiently large for a silica determination. On the other hand, while we have been considering using this method, I still believe that we should have, at least in addition an analysis of the rafter dust, for the reason that the dust on the rafters has been accumulating for over a period of years and you get a fairly representative sample of dust that has been arising from the various processes over a long period of time.

In collecting a sample at any one time, it is quite possible that the silica content may be extremely low during that particular process or that particular location, whereas on another day, under similar conditions, the dust may contain a much higher percentage of free silica. Therefore, I feel that we still should determine the amount of silica in the rafter sample.

At this time, I wish to mention some of the general protective measures that foundries are using, enumerating them only in a general way. Some foundrymen are substituting less harmful substances for harmful substances. A good example of that is in parting compound. I was told that foundry workers are very temperamental and at first it was said that it would be impossible to get them to use a non-silica parting compound. I have had some foundrymen tell me that they had to disguise the non-silica parting compound to get the men to use it and, when they did not know that it was different, they found it very effective.

Another method is the isolation of processes where it is possible to do so. One example cited here this evening was that of removing the cleaning room to one end of the foundry and separating it by partitions and exhausting the room. Where the dust concentration is high, it is always possible to protect the men working in that particular location, but you also protect a large number of men in the general foundry.

Another method is that of hydraulic cleaning. We have taken a number of dust counts during this hydraulic cleaning process and have found the counts to be extremely low. Wherever it is possible to clean castings with water, I believe it is an excellent method of control.

Another method is, of course, that of local exhaust ventilation. Where it is possible and practicable, all processes should be exhausted.

Some foundries are using a combination of air and water for cleaning the foundry. I think the apparatus is called a glony and it is very effective.

In some foundries, it is found practicable to do the shakeout operations at night. I think wherever it is possible and practicable to mount your castings on a moving platform to one section of the foundry that may be isolated and protect the men doing that particular operation, it is an excellent method; but where that is impracticable, I believe the shakeout operation can in many instances be done at night or at least at the end of the shift, thereby exposing many less men.

It is also possible under certain conditions to substitute steel shot for sand. Here again, however, a number of foundrymen believe it is impracticable. On the other hand, we must remember that there are different types of sand. Some sands fracture more easily than others and those sands are much more of a hazard than those which do not fracture easily. So that, with your isolation, your substitution, your local exhaust,—and we must not forget general ventilation, but we must also be careful that the general ventilation does not interfere with the local exhaust systems, your combination of water and air for cleaning purposes, and the removal of unnecessary equipment, or, in other words, good order in your foundries, you have all these very valuable methods in reducing and controlling your dust hazard.

V. HYMAN*: I believe we have instituted at the Falk Corporation some things that will prove interesting for they have proved effective in removing or at least minimizing the dust hazard.

The spray which was referred to a while ago is a home-made gadget. We use a welding tip for the tip of the spray. Water is fed to this device by means of a little manifold body to which the welding tip is attached. It is discharged through the small holes around the periphery of the tip, and air from the air line through the center hole. This atomizes the water. Quite a spray can be shot up into the air to help bring down dust. Also it can be used for spraying castings that are in the process of chipping without getting them too wet. In those cases where the chilling effect of water on the casting would be detrimental, one can still dampen them without chilling them seriously.

Our silica wash problem, I feel, has been quite well met in that we have gotten away from the old idea of mixing the dry silica flour with molasses and water in order to produce our silica wash. We buy a prepared compound which is rather pasty in substance, put it into a mechanically operated agitator, add enough water to it to give it the proper consistency, and the men can draw it out of a tap at the bottom of the agitator as they need it.

Perhaps the most outstanding thing that we have done is putting dust arresters and exhausting equipment on our sand mixers. We have tried two different types of housing on our sand mixers, and both have been quite efficient and effective. One of them goes up vertically from the top edge of the sand mill and terminates in a very flat conical top which has an air exhaust fitted to it. The other goes up in about a 45 to 50 degree cone from the rim of the mixer and also is connected with an exhaust fan. The dry ingredients are fed to the mixer through batching hoppers which have double compartments, or, rather double traps to them. The first trap opens from the bins to a compartment which contains or can contain just so much of the ingredient and then a trap opens from that compartment into the mixer. The housings are equipped with sliding doors that can be closed once the batching has been completed and mixing proceeds. But we have found, in testing them that even with the doors open, there is a sufficient draft to keep all dust from getting out into the foundry.

We have gone through the usual cleaning up and painting up process. We have used a lot of white paint and aluminum paint, largely with the idea that dust will show up more readily on light colors, and in that way we know just where to concentrate our efforts in order to keep down the hazard. Our big problem is still shakeout control.

MR. CUMMINGS: I would like once more to re-emphasize the import-

* Falk Corp., Milwaukee, Wis.

00485

ance of physical examinations in preventing the occurrence of occupational diseases. A young man who enters a dusty industry, with a small lesion of tuberculosis may develop a larger lesion in a relatively short time. He may develop disability or may die and in all probability it will be necessary to assume that the course of his disease has been unfavorably influenced by his occupation. On the other hand, one may find many men past fifty years of age who have worked in high concentration of dust in foundries or other industries throughout their lifetime and who are still capable workmen in spite of the large amounts of dust which they have inhaled, because they were properly qualified for their tasks from the onset of exposure to dust.

The significant thing for you to consider is the fact that you must select your employees in order not to offer them an unusual risk. No matter how safe your foundry appears, it may still have enough dust in it to injure the man whose chest has already been damaged by an infection. If you will carry that one thought away with you tonight, you will have carried more valuable information than all of the engineering suggestions that could possibly be offered for the control of occupational disease.

H. S. WASHBURN*: On this question of examination before employment, which, of course, I believe we all think is necessary, how frequent re-examinations should be made of employees in order to be effective? Mr. Cummings speaks of having a later examination.

MR. CUMMINGS: That is a difficult question to answer. Tuberculosis is a disease which may be contracted at any time. A man may be examined today and contract tuberculosis tomorrow and he may work in your employment during the time he is contracting it. There is an opinion that tuberculosis is usually contracted in the early age groups. I do not wish to imply that the disease manifests itself at early ages only. One may become ill with tuberculosis at 50 or 60 or any other age period, but present information indicates that if one does become ill at 50 or 60, the disease was probably present at 20 or 25. I believe that young men are more likely to contract tuberculosis than others and, for that reason, they should be examined rather frequently.

Men in your employ who have tuberculosis which may be arrested or which may not be active enough to justify their being removed from the industry should also be examined rather frequently.

The general conclusion is that where men of all age groups are employed and are working full time, they should be examined at least annually, and that specific cases may need examination more frequently. In any event, men should be examined at least once every two years to screen against those possible cases of tuberculosis which may have developed since the last examination. The physical examination is intended to discover tuberculosis rather than silicosis and experience in each plant or industry will soon dictate how frequently examinations must be made. If examinations are made annually and no new cases of tuberculosis are found, a decision may be reached to examine every other

* Plainville Casting Co., Plainville, Conn.

year, but in the end, examinations should be made often enough to pick up cases that may be developing particularly among the younger men who enter your employment.

MEMBER: In examination of these employees on our first examination we find three or four cases of silicosis. What do we do with them?

MR. CUMMINGS: Dr. McConnell can probably answer that question better than I can, but we have both had experience with examining thousands of men. At the present time we are conducting a general survey of a rather large industry employing somewhere between five and six thousand men, all of whom have been examined, many of whom are silicotic, some of whom are tubercular. We try to do what I outlined in my paper. We separate these men into three main classes, those who have normal chests, those who have evidence of occupational illness, and those men who have some evidence of tuberculosis. The men who are young and who have normal chests, we try to initiate into the industry by placing them in the less dusty positions where we still have them somewhat under observation. The men who have silicosis, obviously have it already, they are good workmen, and we do not discriminate against those men in any way. We let them continue at their work. We do everything we can to improve the conditions under which they are working, obviously.

Men who have tuberculosis are dealt with as individuals through the medical division in the industry. Each of those men is judged on his merits. If he has active tuberculosis, we would simply suggest that he must be immediately removed, and there is generally no question about that, because it is realized that he is endangering his own health and that of his fellow workmen.

A man who has inactive tuberculosis, which may be a small lesion or it may be rather an extensive one, is dealt with on the basis of his physical condition. If he is rather badly affected, we suggest a job such as a night watchman or some such thing as that. If his lesion is small and not regarded as active, he is given a place of selected employment.

There is not enough tuberculosis in any dusty industry that I have encountered to make it impossible to place a number of men that are found in that industry at selected jobs. It is rather surprising to find that with slight improvement in the conditions under which these men work, their subsequent examination inevitably, or almost inevitably, reveals improvement in their condition rather than retrogression.

We do not discriminate against silicotics—I would like to make that point clear,—unless they are disabled, and we find in the most instances that such men have what we regard as some complicating condition.

MEMBER: Should an x-ray examination be made?

MR. CUMMINGS: We make the most careful x-ray examination that we are permitted to do. We use the best equipment. We think that is essential. We ask for competent interpretations. The diagnosis of silicosis or tuberculosis is in the realm of the medical expert and I think it will have to remain there for some time. The ordinary practitioner, capable as he may be, is generally unfamiliar enough with this particular field to qualify, originally at least, for that work.

MEMBER: Are there any authentic published negative reproductions that would guide, not the amateur in x-ray but a physician who has pursued it beyond the experimental stage, in differentiating between silicosis and tuberculosis?

MR. CUMMINGS: Yes, I think there are. The question of differential diagnosis of silicosis is one that is difficult and though one might get reproductions of cases which were typical for any given industry, it would be quite possible to bring forth films which simulated the appearance of the films that were used for demonstration which might consist of quite another pathological process, and hence I would still suggest that this particular field be left in the realm of experts, much as Ontario has delegated its authority to people who have made a special study of it.

Dust Collection in the Foundry

By S. D. MOXLEY,* BIRMINGHAM, ALA.

Abstract

Due to the need for preventing health hazards in foundries and to the increasing inclusion of references to dust elimination in state labor and occupational disease acts, greater attention must be paid to dust collection in foundries. A most economical way to meet this problem is to do a good job of house cleaning and by the installation of proper equipment for eliminating dust. The dust collection problems consist of three phases, apprehension, collection and disposal. Each of these three phases are discussed. Types of equipment are shown and compared. Dust characteristics are described. Under collection seven types of equipment are listed and discussed. In conclusion, it is stated that it is for the engineer and foundryman to properly analyze the problem at hand and to ascertain the degree of fineness of dust it is expected to collect before choosing the collector.

1. In recent years there has been an increasing interest shown in the prevention of dust in the foundry. Many of the northern and eastern states have references to dust elimination in their labor laws and quite a number have included occupational diseases caused by excessive dust inhalation in their workmen's compensation laws. This legislative action is rapidly spreading to other states and will in time no doubt include all of the states in the Union. Industry is vitally interested in this problem from the standpoint of health, dust nuisance in plant and surrounding community, and depreciation in equipment.

2. Undoubtedly the most economical way to meet this problem is to do a good job of house cleaning first and then install the proper equipment for eliminating the dust. There are so many kinds of equipment and methods used in the various phases of dust collection and air conditioning that the engineer and foundryman faced with dust problems sometimes become confused while at-

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NOTE: This paper was presented at a session on Dust Control and Safety Codes at the 1935 Convention of A.F.A. in Toronto, Canada.

tempting their solution. There is a methodical approach to the problem in every case, and there are a few basic principles involved which, while familiar to most engineers, are not always practiced in the foundry. It is the aim of this paper to clarify some of the points that most commonly cause confusion and result in inefficient and inadequate systems.

3. Quite often a system is designed for sand conditioning as well as elimination of dust nuisance. The same equipment can perform both of these operations satisfactorily, as usually they are inter related. It is not often in the foundry that the recovered material has any economic value, therefore the separation of sizes of particles collected is not important. The problem then naturally breaks down into the following three distinct phases: Apprehension, collection and disposal.

APPREHENSION

4. In most cases the apprehension of the dust is the simplest but least understood of the problems. Almost without exception the best place to catch the dust is at the point of creation, as once it is liberated into the atmosphere it is very difficult, if not impossible, to recover.

Use of Hoods.

5. It is common practice to provide hoods over dusty areas which are fitted with suction pipes leading to the collector. This is illustrated in a general way by A of Fig. 1. In this type of installation the hood should be as small as possible and the openings in the hood reduced to a minimum. It has been found by the writer that with most foundry dust it is necessary to maintain a velocity in all hood openings of from 250 to 300 ft. per min. to prevent dust escaping from the hood. Fig. 1 B illustrates roughly the use of a small hood attached to a flexible exhaust pipe, which has been used quite successfully in connection with snagging wheels for grinding castings. There are many other variations of this principle used in connection with grinding operations.

6. Fig 1 C illustrates a close fitting hood applied where dry sand is fed on a belt. The hood openings are kept as small as possible.

7. When conditioning sand by removal of fines, it is most effective to pass all of the shake-out sand through a current of air. A successful method of removing the desired size of particles is

shown in Fig 1 D. A constant velocity and volume is maintained in the duct at all times. The end of the duct is provided with a hinged hood having an opening near the sand stream, approximately 50 per cent larger than the duct itself. This hood can be adjusted to varying distances from the sand stream, which regulates the effective velocity through the sand stream and hence the particle size removed from the sand. As the air velocity in the

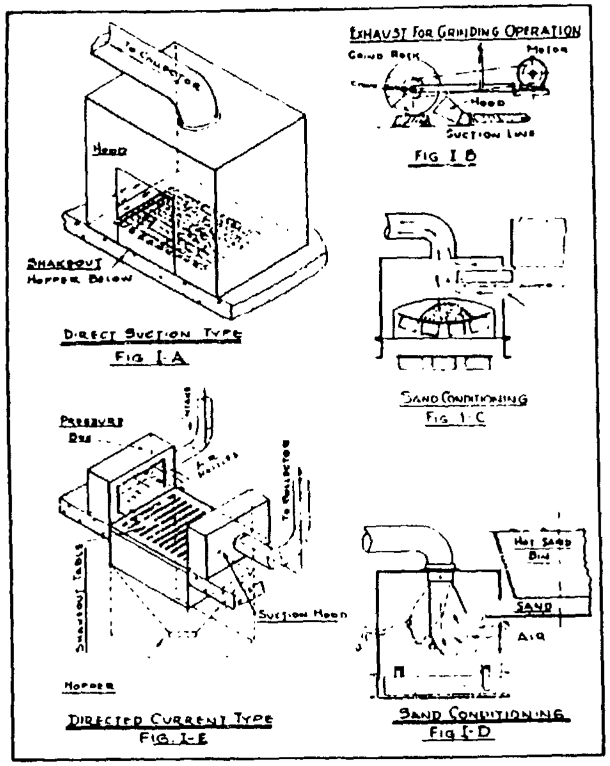


FIG. 1 TYPICAL DEVICES FOR TRAPPING DUST.

duct is always greater than at the opening of the hood, any particle which is picked up at the hood opening will surely be carried in suspension to the dust collector with no clogging of the air duct.

8. A method of controlling dust known as the air curtain dust control system has recently been developed and patented which has proved quite successful Fig. 1 E illustrates its application to a shake-out station. A pressure box is provided with thin slots on the top and sides which keeps a thin layer of air moving at a high velocity over and around the shake-out operation. This prevents the dust generated in the shake-out operation from passing through the air curtain and into the atmosphere. At the other end of the station is a suction hood which receives the projected air curtain and exhausts it along with the dust laden air arising from the shake out. The air is passed through equipment which removes the dust before it is re-circulated.

9. In sand conditioning machinery, where the sand is handled in many types of machines and conveyors, there are of necessity large amounts of dust created. It is usually possible, although sometimes inconvenient, to provide practically all such equipment with hoods which are exhausted to a dust collector. The removal of fines for sand conditioning purposes should be done at the shakeout while the sand is hot, as this is usually the first point of origin of dust in the plant. If separation is made at this point there would naturally be less dust to escape in the remaining operations. Oftentimes it is almost impossible to provide suitable hoods for shake-out and cleaning stations. In such cases these departments can be enclosed or moved to a distance from the other operations to prevent atmospheric contamination in the rest of the plant. The men in these departments may be provided with suitable respirators.

Correct Design of Hood Pipes.

10. Correct design of the pipes connecting the hoods to the dust collectors is essential to an efficient system. Branch lines should enter the main at the smallest possible angle and the main should be increased in size proportionately at each connection to prevent variation in the velocity of the air. These branch lines should enter the sides of the main. Dust pipes which incline downward in the direction of flow usually give trouble by clogging.

11. A system should contain as few elbows as possible and they should be of the longest radius permissible and never less than 1½ times the diameter as measured on the center line of the elbow. Ordinary foundry dust can be handled with little clogging of the pipes by an air velocity of between 2500 and 3000 ft per min

COLLECTION

Types of Collectors.

12. In dust collecting equipment for sand conditioning and dust nuisance prevention in the foundry, the following types of equipment usually are considered:

Centrifugal
Centrifugal, (Fan Type).
Cloth Screen.
Cloth Bag.
Electrical Precipitation
Washer.
Froth-Flotation.

13. Each of these types has distinct advantages in certain fields and the writer believes there is no particular type that can be economically and satisfactorily applied to all problems. It should be remembered that every dust prevention job is more or less peculiar in itself, and the equipment selection should be the one best adapted to all phases of the problem.

Dust Characteristics.

14. Fig. 2A shows certain characteristics of dust, and the general range of the various types of dust collecting apparatus with reference to recovery. This chart reproduced from the original supplied by the American Air Filter Co., Inc. has been modified slightly by the writer with reference to range of recovery of grain sizes by some of the equipment suggested for recovery. This has been done to make it more applicable to foundry dusts.

15. The dust to be recovered should be analyzed for the following:

(a) The nature of the dust from the standpoint of grain size and percentages of the various sizes of particles.

(b) Specific gravity.

(c) Amount of clay or other sticky substances contained.

(d) Moisture.

00489

(e) Temperature.

(f) The degree of fineness it is necessary to collect (this factor is usually determined by the shop conditions and the proximity to the surrounding communities).

Hood Openings.

16. Next, the hoods at the various points of collection should be designed and the areas of hood openings determined. With known velocities the volumes of air can be determined and correct design of air ducts made. These calculations will also show the volume of air to be handled by the dust collector and the pressure under which the system is to operate.

17. If possible, the probable dust concentration per cubic foot of air which will be delivered to the dust collector should next be determined. Usually, all of this information can be determined by the local engineer in cooperation with testing laboratories or engineers representing manufacturers of dust collecting equip-

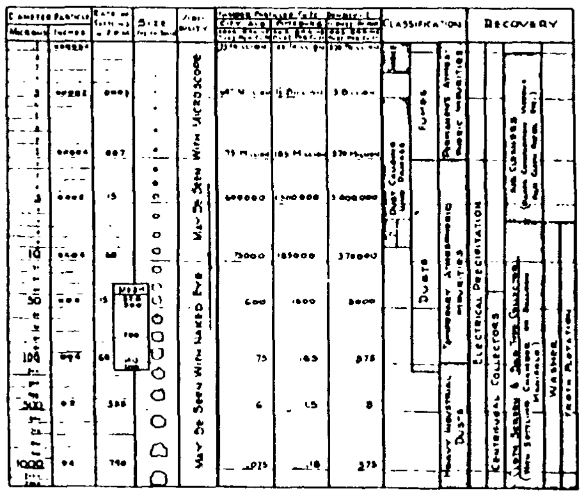


FIG. 2A. SIZE AND CHARACTERISTICS OF AIR BORNE SOLIDS (REPRODUCED BY PERMISSION OF THE AMERICAN AIR FILTER CO. SLIGHTLY MODIFIED BY R. D. MOXLEY WITH REFERENCE TO RANGE OF GRAIN SIZE AND THE EQUIPMENT SUGGESTED FOR RECOVERY.)

Table I
DUST COLLECTOR CHARACTERISTICS

Type	Style*	Vol. Air Per Sq. Ft. Cloth	Min. Grain Size Microns	Temperature Limits	Moisture Limits	Maximum Dust Concentration Inlet Grs. Cu. Ft.	Concentration Outlet 5 Gr. Inlet	Efficiency 5 Grs. Conc.	Relative Cost 13,000 Cu. Ft. Unit
	A		70–75	800° F	Dewpoint	Any	.75	85%	$ 750
	B		70–75	800° F	Dewpoint	Any	.75	85%	1,000
	C		50–60	850° F	Dewpoint	Any	.50	90%	2,000
Centrifugal Collectors	D		35–40	800° F	Dewpoint	Any	.25 to .10	95% to 98%	2,500
	E		35–40	1800° F	Dewpoint	Any	.25 to .10	95% to 98%	3,000
Centrifugal Fan Type	F		25–30	750° F	Dewpoint	150	.50	90%	2,000
Cloth Screen	G	2 Cu. Ft. 10 Gr. 3 Cu. Ft. 5 Gr.	5–10	200° F	20° Above Dewpoint	10	.05 to .025	99% to 99.5%	4,000
Cloth Bag	H	4 Cu. Ft. 10 Gr. 6–8 Cu. Ft. at 5 Gr.	5–10	Cotton 300° Wool 250° Fahr.	20° Above Dewpoint	20	.05 to .025	99% to 99.5%	6,000
Electrical Precipitation	I		Any Suspended Particle	None	None	Any			10,000
Washer	J		5–10	Boiling Point of Liquid	None				4,000
Oil Flotation	K		5–10	Boiling Point of Liquid	None	25	.017 and up	99.7%	4,500

*For detail sketches or illustrations of apparatus of these styles, see Figs. 1, 3, 4, 5, 6, 7 and 8.

00490

ment. When these facts are obtained, the chart of Table 1 will assist in the selection of the proper equipment.

Dust Collector Characteristics

18. Table 1 shows general characteristics of the various collectors when collecting dust, which the writer believes is fairly typical of that found in the foundry. The results shown are based on tests run on dusts arising from shakeouts and sand conditioning machineries in continuous molding operations and in jobbing foundry practice. All tests were run using a concentration of the collector inlet of approximately 5 grains per cubic foot. Figure 2B shows particle size distribution of new washed sharp sand, molding sand with clay added for a binder, and the dust removed from the molding sand for sand conditioning and dust nuisance prevention. Figure 2C shows a particle size distribution of the dust removed from the system to a larger scale and represents the average dust characteristics upon which the values in Table 1 are based. Figure 2D shows particle size distribution of average dust by numbers of particles instead of by weight as is shown in Figure 2C. This curve represents average characteristics of several tests where the sample was obtained by the impinger method and the particles were counted on light and dark fields under a magnification of 500. Particles under one micron in diameter were ignored. It will be noted that the atmospheric distribution curve bears a striking similarity to the curve representing the air exhausted from the bag-type dust collector. The values shown for volumes of air per square foot of cloth, minimum grain sizes, temperature and moisture limits and maximum dust concentrations represent what the writer believes to be within safe practice for satisfactory operation. Each will collect small portions much finer but will also allow certain quantities of much coarser material to escape. The temperature limits indicated assume that no form of heat exchanger is used in the system.

19. Outlet dust concentrations of collectors shown as styles A, B, E, F, G and H have been determined by the writer using the impinger method. The efficiencies were then calculated based on the above conditions. The values given in Table 1 for the remaining collectors were obtained from reported tests made elsewhere and from such information as was available. Installation costs are based on average conditions. Due to the wide variations in foundry

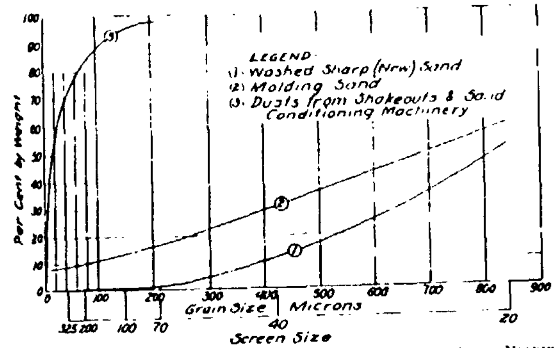


FIG. 2B—PARTICLE SIZE DISTRIBUTION OF NEW WASHED SHARP SAND, MOLDING SAND WITH CLAY ADDED AS A BINDER, AND DUST REMOVED FROM MOLDING SAND FOR SAND CONDITIONING AND DUST PREVENTION. PARTICLE SIZE DISTRIBUTION OBTAINED BY U. S. BUREAU OF STANDARDS PIPETTE METHOD.

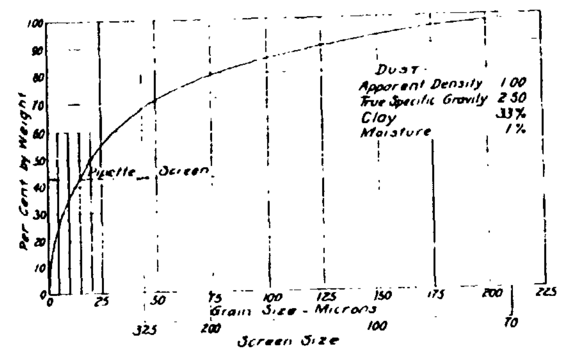


FIG. 2C—PARTICLE SIZE DISTRIBUTION OF THE DUST REMOVED FROM THE SYSTEM AT LARGER SCALE

conditions all of these values should be used only for comparative purposes

20. Examination of the characteristics of centrifugal collectors A and B of Table 1 will readily show that these styles are only suited to coarse material, and are not able to collect, with any high degree of efficiency, fine foundry dust. Their usual ap-

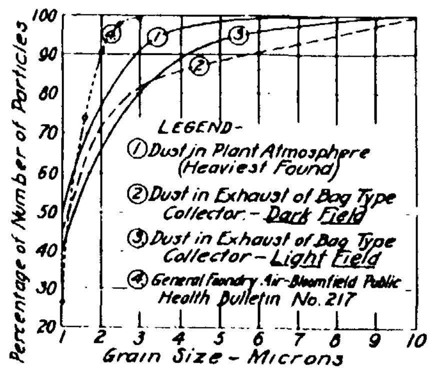


FIG. 2D. PARTICLE SIZE DISTRIBUTION OF AVERAGE DUST BY NUMBER OF PARTICLES INSTEAD OF WEIGHT AS SHOWN IN FIG. 2C. SAMPLE TAKEN BY IMPINGER METHOD AND COUNT MADE USING MAGNIFICATION OF 500

plication is in sand conditioning, exhausting tumbling barrels, etc., rather than preventing pollution of the atmosphere. These general types are familiar to foundrymen. (Fig. 3, A and B.)

21. Style C, Table 1, indicates reported characteristics of a centrifugal cone collector which consists of a number of small centrifugal cones connected as a unit. (Fig. 3 C.)

22. Styles D and E, Table I (Fig. 3, D and E), show the more efficient styles of centrifugal collectors. The double scroll type, shown as style E, is one of the most efficient of the centrifugal collectors from the standpoint of collection of the finer particles. The skimmer type collector is shown as style D (Fig. 3 D), which has a relatively high efficiency in collecting fine particles.

23. The characteristics of the fan type centrifugal collector are given as style F, Table 1. It is a combination fan and centrifugal collector driven by an electric motor. (Fig. 3 F.)

24. If the dust concentration is high, and the percentage of fine particles is high, with a relatively low specific gravity dust, these types of collectors can not be depended upon to solve a dust nuisance. When 50 per cent or more of a dust passes through a 325 mesh screen these types of collectors are apt to release into the atmosphere objectionable amounts of dust. This is particularly true when a large proportion of these fine particles is clay or other binding materials of impalpable character. However, on dusts

having high specific gravity such as pure silica sand, this type of machine can be efficient in the collection of extremely fine particles.

25. The cloth screen filter which has found wide application in the collection of foundry dust has characteristics shown under Style G, Table 1 (Fig. 4). Where it is necessary to collect the extreme fines, and where the dust concentration per cu ft of air is not high, this type of equipment has proved most efficient. The limitations of this apparatus are usually found in the amount of moisture in the air, the temperature, the nature of the dust, and the dust concentration of the air stream.

26. Where high concentrations are combined with relatively high percentage of very fine particles, and where the particles

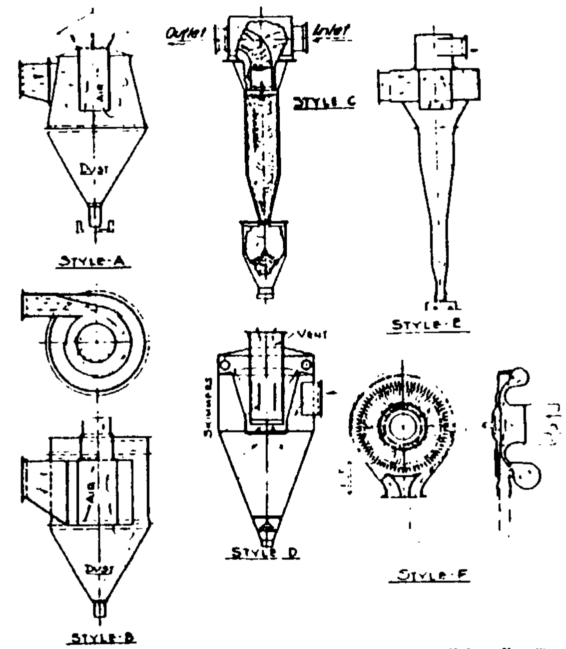


FIG. 3—SIX STYLES OF CENTRIFUGAL DUST COLLECTORS. STYLE F IS A FAN TYPE CENTRIFUGAL COLLECTOR

00492

themselves are composed of clay or other sticky substance with moisture included, the shaking mechanism is usually found inadequate to clean the cloth screen. This shaking is usually done by mechanically operated rappers, and the air must be cut off during the rapping operation. Practically any size material can be collected efficiently by this type of apparatus if it is provided with an expansion chamber or balloon type manifold which will first settle out of the air stream the larger particles.

Cloth Bag Collectors

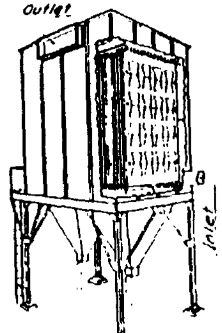
27. For the higher concentrations of dust and the greater percentages of impalpable fines the bag type cloth filter of Style H, Table 1 and Fig. 5, has been found more satisfactory. It is also more effective on relatively high moisture conditions. The reason for this is that the bag type collector has a much more effective shaking mechanism. The collecting unit is divided into compartments, each containing from 15 to 18 bags suspended on a rack which is shaken by pneumatic equipment. During the shaking period the compartment is disconnected from the fan and the direction of the air is reversed. The compartment is then automatically cut into service while another compartment is disconnected for shaking. By this arrangement only a small part of the capacity of the collector is removed from service during the shaking operation. Large amounts of moisture can be handled by the bag type collector with little difficulty if the temperature of the air is kept some 20 degrees Fahr. above the dew point.

Electrical Precipitation

28. Another type of dust collecting equipment which may require consideration in the collection of foundry dust is the electrical precipitator. Characteristics of this equipment are given in Table 1. The principle of operation is to pass the dust laden air through a strong electrostatic field where the dust particles are ionized. In this condition they will be attracted by the electrodes of opposite polarity.

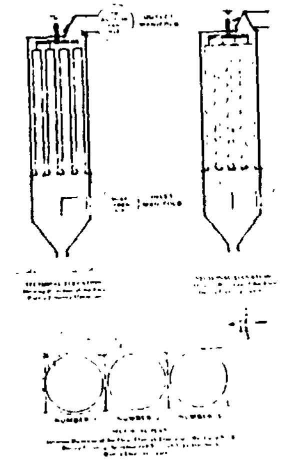
29. A simple form of the apparatus is shown as Fig. 6, where a fine wire is suspended in and insulated from a vertically mounted pipe. By electric connection the pipe acts as the positive electrode and the wire as the negative electrode. Dust laden air passing through the pipes becomes a part of the electric circuit, and is ionized, caused the suspended particles to be precipitated on the

interior of the pipe. Another form of this apparatus is also indicated (Fig. 6) where vertically supported concrete slabs form the positive electrodes, while vertically suspended wires between these slabs form the negative electrodes. In this case the ionized dust particles are attracted to the sides of the concrete slabs. They are



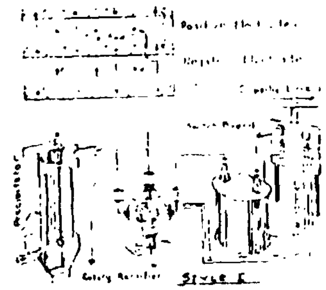
STYLE-G

FIG. 4. CLOTH SCREEN FILTER



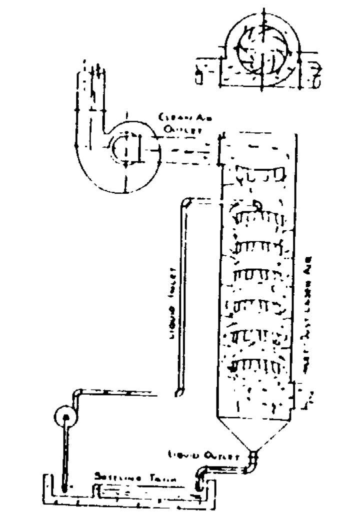
STYLE-H

FIG. 5—BAG TYPE CLOTH FILTER.



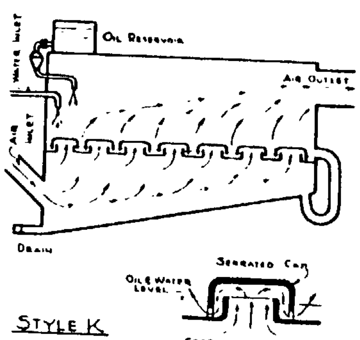
STYLE-E

FIG. 6—TWO ELECTRICAL PRECIPITATION TYPE COLLECTORS.



STYLE J

Fig 7 – Wet Dust Style Collector



STYLE K

Fig 8 – Froth Flotation Style Collector.

discharged by gravity into hoppers below. Sometimes mechanical scraping or cleaning devices are used to remove the precipitated dust.

30 The efficiency of this type apparatus on fine particles can be very high if the equipment is designed properly. The writer does not know of an installation of this kind being used for the collection of foundry dust The reason it has not been used in this field, probably, is the high initial cost of the equipment. With the rapid improvements now being made, this disadvantage may shortly be overcome.

31. Style J (Fig 7) shows an adaptation of the wet dust collector principle which has recently been applied to the collection of foundry dust. The dust laden air is introduced at the bottom of the tower tangentially. Water or other absorbing liquid enters the top of the tower and falls in a spray through succeeding plates, making contact with the upward moving dust laden air. Vanes are mounted on the bottom of the center plates which cause the air to travel upward in a spiral course. There are two washes per plate and usually six plates or twelve washes are used

32. The collected material is absorbed in the liquid and flows by gravity from the bottom of the tower into settling tanks. The water from these tanks is recirculated in the tower and the sediment is disposed of by the most convenient means.

33. In Table 1 there are given reported characteristics of a collector of this type (Style J) The claims made for this equipment are beyond the performance of the usual type of scrubbers or air washers which have been tried in the dust collection field. The author has indicated such characteristics as were available without having them verified.

34. An equipment using oil flotation which utilizes the bubble tower principle is shown as Style K (Fig 8). This newly developed apparatus was announced and displayed about a year ago Dust laden air is drawn through ducts to a distributing chamber The air passes upward through thimbles and is deflected downward by means of hooded bells passing first through water and then through a froth filter carpet. The filter carpet is obtained by frothing oil on the surface of the water. The dust trapped in the wetting agent is floated over an adjustable weir to a settling chamber. The cleaned air passes to the exhaust manifold and into the atmosphere

35 The characteristics shown for Style K in Table 1 are

based on tests made in the laboratory of a well known technical school. These tests were made using dusts similar to that encountered in the foundry. Additional time and practice will be required to determine the full scope of application of this equipment in the foundry dust collecting field

OTHER TYPES

36. Attempts have been made to adapt many other types of collecting equipment to foundry dust, such as the dry air filter using a paper composition filter medium, the viscous film filter, and the usual types of air washers Little success has been met with these types of equipment in the foundry dust collecting field as they are either not suited to the type of dust, or the dust concentration is far beyond the range of the equipment. For these reasons, they have been purposely omitted from this paper. The dry air filter is effective in cleaning air for ventilating and positive pressure respiratory systems, as the viscous type filter is suitable for cleaning air to compressors Such services are not within the scope of this paper.

DISPOSAL

37. The disposal of the collected dust often presents a real problem, as once the dust is collected it must not be liberated into the air. There are many types of equipment such as screw conveyor loaders, etc., which can be adapted to most installations. Often the dust is so fine that it cannot be transported in open wagons or cars and if air tight wagons or cars are used, the vibration in transit settles the dust so that the whole mass becomes hard and cannot easily be discharged. A method of overcoming this difficulty, which has been used quite successfully, is to discharge the dust into an agitated water tank some 2 ft. below the surface of the water, thus mixing a sludge composed of water and dust. This sludge can be readily pumped to the disposal point by suitable sludge pumps. After each pumping the sludge line should be thoroughly purged with clean water to prevent settlement in the line.

POWER AND MAINTENANCE

38. The power requirements of the various dust collecting equipments will depend altogether on the particular installation. In centrifugal collectors of the low efficiency type it may be as low as 1 H.P. per 1000 cu. ft. of air per min. and as high as 3 H.P. in

the high efficiency unit, where it is necessary to greatly increase the air velocity in the collector in order to collect a greater proportion of the extreme fine particles. In general, it can be said that the maintenance on these types of machines is relatively low, as the only upkeep involved is caused by abrasion on the collector and fan. The fan is usually protected by being placed at the outlet end of the collector, thus handling the finer and less abrasive particles. To overcome this wear, the centrifugal fan type collector has a rubber lined rotator and casing when installed for abrasive dust.

39 The power required in cloth collectors will vary from 1 to 2 H.P. per 1000 cu ft of air per min. depending upon the relative size of the equipment and the concentration and nature of the dust Maintenance is relatively high because of screen and bag replacement. Also, the equipment is more elaborate as there are more moving parts to keep in repair and adjustment

40. In the washer type collector the air velocity is relatively low with a corresponding low power requirement of 1.5 H.P. per 1000 cu ft. or less The water recirculated will contain relatively large amounts of dust unless large and hence expensive settling tanks are provided Due to the small amount of water recirculated, the total cost of pump maintenance would not be high.

41. The power requirement for the oil flotation collector is approximately 1.5 H P. per 1000 cu ft The water and settling tank requirements approximate those of the washer type. Only a small amount of low cost oil is required.

CONCLUSIONS

42 In solving a foundry dust problem there are many factors to be considered. In northern climates the shop buildings are necessarily completely enclosed and the operations compact. Many of them are in densely settled communities Such conditions demand highly efficient dust collecting equipment which in some cases might approach air-conditioning practice. In the south we find open type buildings with maximum natural ventilation in thinly populated areas. Under such conditions a much higher dust concentration can be discharged from the operations without undue pollution of the surrounding atmosphere.

43 Weight efficiencies of dust collectors are of little value unless considered along with a complete analysis of the dust to be

caught and the operating conditions. The percentage of silica has a direct bearing on the problem.

44. Some workers in the field have recommended the maximum number of particles per cu ft based on certain free silica content for safe atmospheric working conditions.

45. Rather than efficiency, a more satisfactory way of expressing effectiveness would be the concentration and dust count of the air exhausted from the collector. Such information can be readily obtained by various apparatus such as the impinger dust sampling apparatus as used by the United States Public Health Service. These values could then be compared with those thought to represent safe atmospheric working conditions. These data would indicate the advisability of discharging a collector into an enclosed building.

46. *It is for the engineer and the foundryman to properly analyze the problem at hand, and to ascertain the degree of fineness of dust it is expected to collect before attempting to choose the collector.* Since any type of collector will collect a certain amount of real fine particles, in general, it is better to have an inefficient collector than no collector at all. If the dust is collected immediately at the point of its creation, the chances are good that the dust found *in* the *general* atmosphere of the shop will be within reasonable safe limits.

(Discussion of this paper begins on page 222)

Methods of Dust Control

By J. D. Leitch,* Toronto, Canada

Abstract

Dust must arise from a source and, according to the author of this paper, the point to begin elimination of the dust hazard is at that source. In his paper, the author discusses methods used for controlling the dust hazards which originate at different types of sources. He discusses the general methods used in dust suppression problems and the estimation of the hazard, contending that the efficiency of a dust collection system is best determined by dust counts. He explains methods used for testing ventilating equipment and discusses the selection of fans. The latter section of the paper deals with the dust collection equipment itself. Dust collectors of various types and respirators such as helmets, filter type respirators and positive pressure masks are discussed. The paper closes with the admonition that maintenance of equipment is necessary to the successful operation of such equipment and to the efficiency of any installation.

1. The engineering aspects of the dust problem must deal entirely with prevention and must be concerned with manufacturing processes, production requirements, and other economic considerations. It is necessary to obtain the greatest reduction in dust concentration with the minimum capital expenditure and maintenance costs. It can readily be shown by considering a number of particular cases, that money spent to improve health conditions often has resulted in unexpected economies in the processes which more than paid for the original outlay in a very short time.

Difficulty of Laying Down General Regulations Governing the Control of Dust in Industry

2. From a public health point of view, it is desirable to lay down minimum rules covering the suppression of dust for all op-

* Ontario Department of Health.

Note: This paper was presented at a session on Dust Control and Safety Codes at the 1935 Convention of A.F.A. in Toronto, Canada.

00496

erations in industry Because of the wide variation in the dust producing processes in industry, it immediately becomes apparent that some attempt must be made to subdivide these processes. The first natural division would appear to be a division of the industries themselves into groups foundries, granite cutting, mining, etc This is hardly a satisfactory division *from the point of view* of the engineer whose job it is to consider all the industries.

3 When the foundry division alone is considered, a wide variety of processes is encountered, such as tumbling, grinding, sandblasting, coreblowing, shaking out, molding and brushing, but on examination of, say the granite industry, some overlapping occurs, for in that industry we find operations involving sawing, surfacing, polishing, sandblasting and chiseling. If a foundry were visited and then a *granite shop, it would be seen that al*though some of the operations are similar, the most efficient methods of removing the dust are quite different in detail Observations in a number of foundries show variations in type of equipment installed An example of this may be noted in the different methods of sandblasting castings, *i. e.*, barrels, sandblast rooms, cabinets and special equipment, among which may be listed numerous homemade devices. However, in spite of these variations, a number of general cases may be considered, into which *most of the common* processes will fit.

Consider Dust Source

4. First, let us consider the source of dust as a variable condition. In other words, we should always go to the source of the dust hazard and try to suppress it there before contamination of the shop air occurs.

Point Source.

5. When the source of dust is at a fixed point, it is natural to think of using a fairly high velocity through a relatively small pipe attached as closely as possible to the point. This method is desirable from the point of view of handling the minimum amount of air but care must be taken that the hood be attached very close to the point source, because it is well known how rapidly the velocity falls off as we move away from the hood face. Should the *point source move* in a random way, the problem of maintaining the hood close to the point becomes difficult in some cases, *e. g.*, it is very difficult in the case of the hand pneumatic tool in the granite

industry and not so difficult in the surface machine in the same industry.

Wide Source

6. If the origin of the dust is over a wide area one naturally thinks of two methods

a Enclosing the source as much as possible and then removing sufficient air to maintain the enclosure at a pressure somewhat lower than atmospheric, or,

b. Providing ventilation over a wide area This necessarily involves a high volume of air and a relatively low velocity.

7 *The former method would appear to be more feasible in* cases where such enclosure does not interfere with the process.

Moving Dust Clouds

8. If the process produces a cloud of dust having a definite direction of motion, advantage should always be taken of that fact by arranging to draw off the dust in the same direction A simple example of this is the grinding wheel and the standard method of ventilating it There are a number of cases, however, where this is not so easy on account of interference with the process, and ingenuity is required of the engineer who tackles such a problem.

Intermittent Source.

9. It often happens in industrial processes that a dust cloud is produced in the form of puffs at regular intervals These clouds of dust may be so high in concentration as to render it impossible to collect all of them by means of a low volume of air at a high velocity. In such a case, it would be better to use a hood having a large area giving a lower velocity of air, so that the dust would be caught before it left the range of influence of the exhaust system.

10. From the point of view of economy, first, in the conservation of heat, it is desirable to remove a minimum quantity of air from the shop; second, from the point of view of power consumption, it is desirable to use the minimum velocity at the source of dust yet obtain conditions within the safe dust concentrations as laid down by the health authorities Therefore, it is apparent that for every dust suppression problem, there is a best choice of air

volume and velocity according to the design of hood required by the process. What these conditions are for any particular operation, can be determined only by experiment and experience. Every foundry operator and every engineer who is concerned with the dust problem, will be required to do some experimental work which will lead to solutions of these problems for each dust-producing operation in industry. It is obvious that those men who are daily in contact with these operations, who understand the production requirements, who fully appreciate the nature of their problems, will be the most likely persons to solve them.

General Methods

11. In looking at a dust suppression problem, it is often advisable to consider a variety of methods, that is, not necessarily assume that all dust suppression problems will be most effectively solved by means of ventilation. Consideration must be given to methods involving water or other liquids as a means of settling dust. The advisability of entirely enclosing the operation or isolating it from the general shop atmosphere also must be weighed. Making certain parts of the operation automatic might be considered, thereby eliminating the necessity for workmen to stand in a dusty atmosphere; or the whole process might be changed and carried out in such a way that no dust hazards exist. A good example of this is the use of water blast in cleaning large castings. Then again consideration might be given to the materials that are used. A suitable product might be obtained by the use of a substance that produces dust which has a relatively low health hazard. This has been done in a number of cases, *i. e.*, non-silica parting, artificial grind wheels, and steel grit in blast cleaning operations.

12. These general methods are mentioned, not because they will necessarily lead to a solution of any particular problem, but to widen the approach. In other words, it should never be assumed that the only and best method has been found.

13. One of the first things that should be done in an attempt to introduce a dust control program in a particular industry, is a thorough shop cleaning, including rafters, window sills, windows, floors, walk-ways, etc. This will be a very large job, and more than likely expensive the first time, but once done, it will be found that periodic cleanings will be much less costly. As a matter of fact, a program of regular periodic shop-cleaning would serve as

an excellent indicator as to the effectiveness of any steps taken to control dust at its various sources throughout the shop. Of course, the shop-cleaning process is a very dusty one and the use of water sprays and suction devices is preferable to blowing with compressed air.

Estimation of the Hazard

14. It is extremely difficult to estimate the maximum permissible concentration of a particular dust in industry in keeping with the good health of the worker. It has been suggested as a tentative goal that the maximum concentration of dust containing 35 per cent silica should be not greater than 10,000,000 particles per cu ft below 10 microns in size. Of course, if the dust is quartz, which is 100 per cent silica, the maximum permissible concentration will be proportionately less.

15. In estimating the dustiness of an atmosphere, the present method is that of the United States Public Health Service which uses a bright field in the microscope and a magnification of 100, the sample being collected by the Greenburg Smith impinger method. Apart from any differences in dust counting methods, and there are differences, any one of the recommended methods is quite useful in arriving at a measure of the effectiveness of a ventilating system should dust counts be made before and after its installation. A number of reports claim very high efficiency for various types of dust collectors, but the method of arriving at this efficiency is based, in almost every case, on weighing the dust entering the system and that caught by the collector. It is apparent that this method is not at all in keeping with efficiencies based on dust counts because a particle 100 microns in diameter will weigh a million times as much as a particle 1 micron in diameter, so that the efficiency of a dust collector would appear very much higher if there were any large particles in the dust fed into the collector. It is felt that the particles between 1 and 5 microns (1/25000 to 1/5000th of an inch) in diameter are biologically significant and for that reason, it becomes necessary to make dust counts rather than measure efficiencies by weights. Of course, such measurements of the efficiency of a dust collector or arrester are only of significance in a case where the cleaned air is returned to the shop atmosphere, a procedure which should not be carried out unless some type of collector

00498

is developed which meets the requirements laid down by the methods of dust counting.

16. At the present stage of the dust problem, it would seem that the most *practical* means of diagnosing the dust hazard is the naked eye, with all due respect to dust counts. If a shop is very dark so that no dust is visible, it would be advisable to use a powerful flashlight or clean some of the windows so that the sun's rays might show up the dust. It may be that in the near future a more rapid method of estimating a dust hazard will come into general use. Let us hope that this is so, for it is quite out of the question for any but the larger firms to consider purchasing of present equipment and employing of trained personnel for regular routine tests.

17. The first problem in the removal of dust is to get rid of all visible dust for in so doing a very great amount of the invisible particles will also be removed.

Testing Ventilating Equipment

18. If a survey is made of the various State laws relating to dust control in the United States, a very wide variation in the requirements is found. Some statements are made demanding that the static pressure measured behind the hood should give 2 in. of water difference in level in a manometer. In another State, for the identical operation, 5 in. of water is required as a minimum (this refers to grinding wheels). There is a great difference between 2 and 5 in. of water static pressure. Assuming the hood designs to be identical in both cases this would mean a difference in the air velocities of approximately 6 to 1. There cannot be very much scientific basis for regulations which vary by a factor of 6 to 1. However, this is not the worst indictment of these regulations. The worst is that static pressure readings taken behind the hood measures the sum of two factors and does not give a measure of the velocity of air being handled by the system. The two factors are—(1) loss of head due to resistance at opening, and (2) loss of head necessary to set the air in motion.

19. If static pressure is to be a measure of the effectiveness of a dust collecting system, it is necessary immediately to specify exactly the shape and size of the hood in every particular application; a procedure which is of course out of the question. It would be far better to say that the velocity in the duct must be not less than say 4000 ft. per min., the duct must not be smaller than say 4 in. in diameter and that the air velocity at the source must be no less than 400 ft. per min. In other words, it is necessary to define the minimum volume and velocity of air for any particular application. It is because of the ease with which static pressure readings can be taken that it has been used so much in the past, but their only value lies in observing the constancy of an exhaust system from time to time, thereby assisting in the detection of excessive fan wheel wear, belt slipping or dust arrester leaks. Care must be taken that the complete system, as far as duct inlets are concerned, is operated in identical manner at every test.

20. This immediately brings up the problem of testing and inspecting dust-removing equipment. In order to determine the most important factors, *i. e.*, volume and velocity of air handled, the use of the pitot tube in conjunction with a manometer is most suitable for the duct system, and for the measurement of air velocities below 500 ft. per min., the Kata thermometer has proven its value in many cases.

21. The American Society of Heating and Ventilating Engineers has formulated standard methods of testing fans, and these methods involve the use of a pitot tube in a definite manner. Such a procedure as recommended is too elaborate for factory inspection purposes or for the average individual in industry, but, if we neglect the refinements in measurement, the pitot tube will prove a most useful instrument in the hands of anyone who is willing to investigate his ventilating system.

Selection of a Fan

22. The selection of a fan for a particular dust problem is of primary importance and, to the end that the fan manufacturer may give the advantage of his experience, a precise statement of the problem on hand is essential so that he may intelligently recommend the proper fan, of sufficient size driven at an adequate speed. The author has seen a number of foolish applications of fans and does not blame the fan manufacturer for these, as very often he is not consulted, the fan merely being purchased through a purchasing agent according to a requisition with inadequate specifications supplied by some mechanic. The ordinary propellor

fan should never be used in forcing air through a duct system which offers any appreciable resistance.

23 The choice of fan depends not only on the operation but on the type and shape of the material to be handled. Therefore, it is necessary, in asking the fan manufacturer for a quotation, that all the details be submitted with the request. The author recalls recently seeing a letter written by a manufacturer to a fan company in which he outlined the piping on a very rough sketch and he received a quotation on a particular fan by return mail. It was apparent, on looking at the sketch, that the system of ventilation would require two separate installations, as the purposes for which the fan was to be installed were of two radically different natures.

PIPING

24. If a uniform distribution of suction is to be maintained, it is very necessary that the piping be properly proportioned. The author once went into a foundry in which a 15 in. diameter pipe ran directly over a number of tumbling barrels. From this 15 in. pipe, a 3 or 4 in. pipe ran down to each barrel. A number of manholes had been cut in the pipe and, on inquiry, it was found that every two or three weeks, the big pipe had to be opened and emptied. The cost of this work probably would have paid in a short time for the proper proportioning of the piping, apart from any gain in efficiency of the ventilating system.

25. The use of dampers at the various inlets of a ventilating system may seem very feasible from the point of view of controlling the air movement and is undoubtedly of value in adjusting improperly designed piping installations; but if an installation is properly designed, the use of dampers will be entirely superfluous and will serve only to upset the system.

DUST COLLECTORS

26 Four or five main types of dust collectors are in common use today. First, and perhaps the most common, is the ordinary cyclone. This type of dust collector is far from efficient in the removal of fine particles and under no condition should the exhaust from it be returned to the workshop nor should its exhaust be located near an open door or window. The second most common type in use is perhaps the cloth screen or cloth bag type. For a number of years, this type has held the foremost position as a

collector of fine dust, but the author knows of no tests that have been made regarding its efficiency on a dust counting basis and it is advisable that such tests be carried out. Often the claims made by the manufacturer would indicate that such a dust arrester would permit of the air being returned to the room. It may be quite true that when an arrester of this type is new its efficiency is high but there is certainly no assurance that it will continue to function in that manner.

27. Another type of arrester that apparently is gaining ground is the centrifugal type in which the fan is so designed and driven at such a high speed that the dust is thrown out at the periphery and collected by centrifugal force. Any test information which the author has seen on this type of collector, has always been taken on a weight basis, which is anything but adequate from a health point of view.

28 Considerable work has been done in the past few years on the problem of smoke abatement and in this work some new designs of gas washers have been developed. There is a similarity between these gas washers and some new designs on dust collectors of the water type. In one machine, the dust laden air impinges on a series of wet baffle plates as it passes upwards through the collector. The author often has considered the principle of the Greenburg Smith impinger type of dust sampling apparatus to possess a principle worth investigating with a view to its adoption in dust collector design. One of the great difficulties in gas washers developed for the smoke abatement problem has been the high consumption of water. It has also proved expensive to recirculate the acidified water. This should be a much easier task in collecting silica dust.

29. Many applications in industry do not provide any dust collection whatever as the amount of dust does not warrant such expense nor does the location require that the exhaust air be absolutely clean. In the author's opinion, it would be far better to use no dust arrester and exhaust the air containing the dust high into the atmosphere than to install a dust arrester of low efficiency and re-circulate the air back into the shop.

30. The choice of a dust arrester, although important, is not the most important problem. The main problem is catching the dust at its source and carrying it through a duct system to a point where its disposal can be safely effected.

31. It is well known that the use of dust arresters often pays for itself over and over again if the product being collected is at all valuable. *In a recent case the amount of material collected in three months more than paid for the complete installation* since the material collected was worth about 10 cents per lb.

32. In choosing a cloth type of dust arrester, the most important factor (assuming a good grade of cloth) *is the ratio of* cu. ft. of air handled to the sq. ft. of cloth through which the air must pass. It is recommended that this ratio be not more than 3 or 4 to 1 in the collection of silica dust in foundry practice. This ratio may be increased slightly as dust concentrations drop but *it is important that* it be kept as low as economically possible. The author once was called out to investigate the reason why no air was being delivered by a unit heater. The unit heater had a capacity of 3000 cu. ft. per min. and was equipped with a propeller fan. On investigation, it was found that *the 24 in.* square duct had a sheet of cheesecloth, mounted on a wooden frame, inside it so that the ratio was 750 to 1. The owners were amazed when told that they could not get air through cloth like that.

RESPIRATORS

33. The subject of respirators is one of considerable importance in dust control. It is not meant that the use of a respirator is a desirable solution, for it is well known that most workmen would *rather "take a chance"* than suffer the inconvenience of wearing a respirator. Many dust producing processes in industry do not lend themselves readily to effective ventilation by means that are at all economical, and it becomes necessary to rely upon some type of protective device worn *by the workman*. Perhaps the outstanding process of this type is sand blasting, but here the problem is further complicated by the danger of injury from the bounding abrasive, which makes it necessary not only to provide safe guarding of health, but protection from cuts.

34. *Respirators*, in a broad sense, may be divided into three classes:—

a. Helmets.

b. Filter Type Respirators.

c. Positive Pressure Masks.

Some of the fundamental considerations in the choice of a suitable respirator may be summed up as follows:

Helmets

35. Where dust is at all hazardous to health it is essential that all helmets be supplied with air at a positive pressure, preferably from a source of fresh air, rather than from the compressed air lines. The amount of air required by a helmet depends on the design of the helmet itself, and how it is to be worn by the operator. A loosely fitting helmet will require considerably more air per minute than one which fits rather tightly over the face or neck of the workmen. In general the amount of air should be sufficient to maintain the positive pressure within the helmet throughout *the entire breathing cycle of the workman*, so that at no time will air be drawn in through any crevices. A sufficient pressure inside the helmet should be 2 or 3 ounces above atmospheric and an adequate volume of air should be about 6 cu. ft. per min. Of course, it is not meant that this air volume will develop sufficient pressure inside a helmet in every case, especially if the helmet is a loosely fitting one.

36. A helmet should preferably be designed in such a way that its weight rests on the shoulders thereby permitting a free movement of the man's head. *The air line attached to the helmet* should be firmly fastened to the man's body, so that he will experience no inconvenience in moving it about inside, say, a sand-blast room.

Filter Type Respirators

37. The main requirement of any filter type respirator is that the rate of flow of air through the filter medium be as low as possible, for if the workman must exert himself in breathing, considerable dust will be pulled through the filter. This would mean that the filtering medium should present as large an area as possible, and the main problem becomes one of convenience in wearing an apparatus which must present so large an area.

38. *A filter mask, which is efficient, will naturally plug up* sooner than one which is inefficient, and it is essential, both from the point of view of economy, and efficient health protection, that the filtering medium may be readily replaced or cleaned.

Positive Pressure Masks

39. It is undoubtedly true that a positive pressure mask is far superior to any filter type, but it requires a supply of air. Many

00501

companies who use such masks attach them to their compressed air lines through an adjustable reducing valve, and the objection is raised by the workman that the air smells of burnt oil and contains considerable amount of water vapour. Both of these objections can be overcome by the use of a small blower which will provide an adequate supply of air at a sufficiently high pressure from a source that is free from contamination. There is considerable room for development of a cheap and effective blower designed for use with fresh air masks. The use of air filters and after-coolers in the compressed air lines presents another approach to this problem.

THE IMPORTANCE OF MAINTENANCE

40. Machines, like everything else in this world, wear out; and the essential parts must be replaced by new ones from time to time. This is particularly true of fans, especially when there is abrasive dust in the air which they handle. The author has found fan wheels in such installations completely worn out, the ventilation system practically useless and the driving of the fan merely a waste of money. Regarding dust arresters, especially of the cloth type, great care must be taken to maintain them or they will plug up and develop such a high resistance that the air cannot get through them, with the result that eventually the cloth tears away from its support and large quantities of dust come out of the clean air side. Dust arresters should be cleaned at regular intervals, better often for short intervals than for long intervals at less frequent times. One naturally should consider how to reduce the maintenance costs and it is proposed that every man who has installed a fan and dust arrester should look and see whether the dust arrester or the fan comes first in the ventilating system. If the fan, he should change it and save the wear on his fan wheel. This may seem like a very obvious remark, but in many instances this point has been neglected with the result that the fan wheel was completely worn out in a relatively short time.

GENERAL CONCLUSIONS.

41. It might be well to sum up with a few general conclusions:

1. No source of dust is too insignificant for attention.

2. Any efforts made to control dust will probably result in other economies being effected.

3. A dust problem requires not only cooperation of employers, but of *employees as well, in a conscientious effort* to control the dust hazard.

4. There is always a best way of handling a given dust problem, and this can usually be determined only by experiment in the application of fundamental principles.

5. Apart from all dust counts as a means of indicating the relative hazards in industry, the ultimate test of the effectiveness of the dust control can be determined only by medical examination. Therefore, it is a necessary part of any dust control program that periodical examination be made of all workmen engaged in dusty atmospheres.

(Discussion of this paper begins on page 2??)

DUST CONTROL — DISCUSSION

P. J. POTTER[1]: In Mr. Moxley's paper, paragraph 11, it is stated that the proper air velocity to handle ordinary foundry dust would be between 2500 and 3000 ft. per min. I would like to ask Mr. Moxley if they had long horizontal pipe runs, because it has been our experience and, I believe, common practice, to keep the pipe velocity about 3500 ft. per min.

MR. MOXLEY: We have found, with the amount of dust in our plant (and we are talking about the dust as indicated by the curves on the slides I have just shown) that between 2500 and 3000 ft. per min. will prevent clogging of the dust line. It is most important to reduce the duct at each intake and correctly design the duct as it goes along through the shop. We have one duct 48 in. in diameter and gradually reduce it to 12 in. in diameter. Its horizontal length is about 200 ft., and we do not have clogging. Our velocity is kept maybe closer to 3000 than 2500 ft. per min. but it plays between those figures.

MEMBER: Would moisture in the air affect the 2500 to 3000 ft. per min. velocity of which Mr. Moxley speaks?

MR. MOXLEY: We have made a complete analysis of our dust and it shows approximately one per cent moisture. Of course, as the moisture increases, it may go beyond the range of a cloth collector. As moisture increases, it is more and more difficult to handle the dust without clogging the pipes and the velocity should be increased.

MEMBER: It has been intimated in one of the papers that manufacturers of dust collectors have recommended a return of the air into the shop after it has passed through the exhaust system. I would like to correct that impression. I believe I am correct in saying that manufacturers of dust collectors with whom I am acquainted have not for some years past recommended the return of any of that air to the shop.

DR. J. T. MACKENZIE[2]: I would like to ask Mr. Allan whether he has any data on the washer type collector to indicate the retention of the fine particles. After listening to the discussion at the health hazards session this week and that today, it is quite apparent that the harmful size of the dust particles lies somewhere between half a micron and ten microns. You could have collection which is 99.0 per cent efficient by weight of the dust collected without taking out very much of the fine material. If the dust which is being put into the collector is 99.5 per cent above ten microns, you could have that efficiency without doing a bit of good, if you do not take out the fine particles.

J. R. ALLAN[3]: In answer to Dr. MacKenzie, we have not made any test on the efficiency of such collectors that we have installed. Where we have them on the foundry shakeouts and the tumbling mills, the set-up is so we are unable to get a reasonable sample and we have made no attempt to make the tests referred to by the first speaker. We have some cloth collectors on carburizing materials and these showed consider-

[1] Pangborn Corp., Hagerstown, Md.
[2] American Cast Iron Pipe Co., Birmingham, Ala.
[3] International Harvester Co., Chicago, Ill.

able evidence of dust in the discharge stack. The wet collectors on the same type of work indicated no visible trace in the discharge stack.

MR. LATTCH: I wish to correct an impression that I may have given. I said that as a *practical* measure in the immediate future in our attack on the silicosis problem the use of the naked eye in determining atmospheric dustiness would seem the most practical thing to do. From the point of view of measuring the efficiency of dust collectors, I would be much more in favor of dust count by standard methods in terms of microns.

DR. MACKENZIE: As I understand it, the dust you see does not hurt you. Is that right?

MR. LATTCH: That may be true and is true, of course, of the larger particles. I am sure that if you have a large cloud of fine particles you can see them, though not individually, especially if contrast in light exists in the shop.

DR. MACKENZIE: The point I am making is that the dust collector will render air, which though perfectly invisible, may be very dangerous, especially if you return the air to the shop. The type of collector that takes out only the visible dust returns all the harmful dust to the shop.

MR. LATTCH: At no time did I recommend having the air returned to the shop.

MR. MOXLEY: I would like to say a word regarding the checking of a dust hazard by the naked eye. It is quite generally recognized that you can barely see a particle of over ten microns in diameter. A micron is 1/1000th of a millimeter.

Most of the workers in the medical field claim that the upper limit really is about eight microns. I have heard of one case where the worst dust hazard in the plant was in the core room where there was no visible dust at all.

That is the reason I put a great deal of dependence upon weight efficiencies and dust counts in analyzing the effectiveness of a dust collector. I still believe the weight efficiency method is a fairly good measure but only when considered along with all of the other characteristics that are available.

H. L. MCKINNON[4]: On the question of the dust count in our plant, we have made upward of two hundred tests in the past four months, involving the actual dust count from a wet collector. We have, at the present time, three large machines in operation, two of which have been tested for dust count. The question of what the final dust count will be, we find, bears very close relation to the fineness of the dust when at the source because you will get a percentage of the fines on any of these collectors.

We found, for instance, in getting dust which was swept off the beam of a foundry and tested, that we got a very high rate of efficiency and a comparatively low dust count with that material.

Then we tried some silica flour which had been ground under 325

[4] C. O. Bartlett & Snow Co., Cleveland, O.

mesh, 92 per cent of which was less than five microns, and we found that the dust count went up materially with the same loading.

We found an analysis of some of the dust swept off the rafters indicated that the dangerous dust was not more than 20 per cent of the total dust, about 80 per cent being above the ten micron size.

We have not gone far enough along yet to give anyone any final conclusion on this. We do know that we can get within the range of reasonable cleanliness with the wet collector and we do know that the dust count will vary definitely with the nature of the dust that is fed into the system.

I want to make one remark in regard to Mr. Moxley's paper, namely, in the tabulation of the wet collector, he made the statement that the maximum loading be 25 grains per cu. ft. That we feel is not strictly so; we have used much higher loadings than that in certain instances. I am satisfied we can take any loading. It depends entirely upon the fineness of the product and I would not want to take 25 grains per cu. ft. of 325 mesh material into a machine. I would not want to guarantee the condition on the output of that machine. The fact is, it is going to be possible and is possible now to get a reasonable dust count with the wet process.

W. G. FRANK[4]: Working in both the dust collecting and the air filter field, I must say I have enjoyed the various papers very much. There have been many interesting details given which should furnish an incentive for further thought and development in dust collecting practices for the best interests of everyone concerned, especially the workman who is handicapped in some instances by difficult conditions.

It is quite definitely true, if a manufacturer takes steps to introduce dust collecting equipment in his plant he will not only have the satisfaction of improving sanitary conditions but he will also reap a definite benefit in improving his production and in reducing his costs.

F. A. EBELING[5]: It has been inferred that dust collectors might be sold just for the sake of making sales without taking actual conditions in the foundry or any other manufacturing plant into consideration.

I do not believe that is so with established manufacturers of dust collecting apparatus. None of them, including ourselves, would make any kind of a recommendation unless we were pretty sure as to what was to be accomplished.

In other words, when we are making a recommendation for equipment, whether by invitation or otherwise, we would not make any recommendation for size of collector, or size, speed or power of fan, unless we knew in considerable detail what the dust collector should do.

We must know what a collector should do. Neither we, nor any other manufacturer, can back up an installation recommended unless we are sure that the pipe system, the hood system, etc., are designed properly. Many times we have no control over the installation of hoods and pipes, yet we feel it our duty to ascertain beforehand that hood and pipe conditions and construction are correct. I believe that people who have dust

[4] American Air Filter Co., Louisville, Ky.
[5] W. W. Sly Mfg. Co., Cleveland, O.

problems may go to any established manufacturer with confidence that the recommendations made by the manufacturers will be in accordance with the problems presented.

CHAIRMAN E. W. BEACH[6]: I do not think that there is any question as to the soundness of the ethics of the manufacturers involved which led to Mr. Ebeling's rebuttal. I think, rather, the statement mentioned was meant to convey that very often a plant manager or his mechanical superintendent simply requests the purchasing department to order some fan, without the purchasing agent or anyone else knowing for what purpose the fan is to be used.

I believe there is no doubt, if the master mechanic had told the purchasing agent that he wanted a fan for a special use as applied to a certain problem of removing dust, and his requirements passed on to the manufacturer, he would have been given full information and probably many questions would have been asked before apparatus was shipped.

E. H. BALLARD[7]: I think a little more consideration might be given to some of the facts brought out by Mr. Leitch.

This is absolutely a cooperative proposition. We as foundrymen, have a distinct responsibility. I recall that in the early days of dust collecting we, ourselves, had been sold equipment that through lack of knowledge was guaranteed to do certain things without specific measurements. I think the time has come when any equipment manufacturer selling equipment to perform a certain job should not undertake a sale until he knows all the facts. Unless he does, the equipment so installed is absolutely useless to accomplish the purpose for which it was installed.

Salesmen differ. Some want sales and some want to put equipment in to perform a certain function they agree that it will do. So, I say again, I believe that the equipment men have to work closer to the foundrymen to know what the problem is. In my opinion when a piece of equipment is installed, it should be subjected to the same type of test as we are going to be subjected to by the health authorities in coming into the foundry and analyzing our dust and our conditions. Equipment so purchased should meet specifications agreed upon based on and subjected to tests and methods used by state and insurance inspectors in determining dust counts.

Incidentally I believe the manufacturers are going to have to perform a service which they so far have given to us only when requested, and then, probably, in only a superficial way. I think they will have to have a service and come in and check us up to see that the equipment is just where it belongs, the same checking we receive from our state inspectors. In other words, we have to be a little ahead. That is going to cost money, but it will be of untold value to foundries where they do not have a mechanical organization with sufficient knowledge to keep the equipment up. We need help, some of the larger plants as well as the smaller, but particularly the smaller ones. Any improper operation of

[6] Engineering Executive, Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich.
[7] General Electric Co., West Lynn, Mass.

00504

the smaller foundries is a reflection on the larger ones and on the operations of the industry as a whole.

So, I say again, I think we as foundrymen are going to appeal to the manufacturer to work with us and I think they, in turn, should demand to know of us what our true conditions are. Then between the two, I am sure we are going to make tremendous strides in overcoming a hazard that without doubt exists.

MR. LEITCH: The problem of loss of heat is a very important one and one that costs a considerable amount of money. In the ventilating of the tumbling barrels, for instance, I believe the air enters at one end and goes out through a pipe at the other end. Why not pipe in the air ventilating the tumbling barrels the same as you pipe the dusty air out? I know installations where 10,000 cu. ft. of air per min. are being taken from the shop which would mean a considerable saving in heat if the air were not taken from the shop but brought in from the outside.

Regarding sand blast rooms which in many cases require ten or even twenty thousand cu. ft. of air per min. in their ventilation, I do not see why such equipment should or could not be ventilated in a similar manner, *i. e.*, by bringing the air in from outside. The only objection I can see is that the man might feel rather cold in the winter time, but I am sure he would enjoy it in the summer time. In the winter time it is not necessary for a man so well clothed as the man in the sand blast room, to have as high a temperature of air as the man in the shop. After all, the man in the sand blast room is a very busy man and therefore does not require such a high temperature on the very cold days when it is 20 or 30 degrees below zero. I think it would be quite feasible to install heating coils to take the chill off the air when necessary.

I place these points before you for your consideration. I have not yet seen an installation to which these considerations were given.

There is another point and I have often wondered why advantage of it has not been taken; that is, the sand blasting of castings in a more automatic way, with the man standing external to the apparatus. I refer to the granite industry where they sand blast and the man always stands outside. When you understand that dust conditions such as prevail inside sand blast rooms are of the order of 2,000 or more, million particles per cu. ft., it becomes of some importance that the operator preferably stay outside. I think we may all look for the development of sand blasting machinery in which the man does not enter the room.

DR. J. G. CUNNINGHAM*: I am very interested in this problem of the extent of the dust in the air. It does seem to me to be unfortunate that the impression was left that any of us would depend on eyesight entirely for estimating the dust hazard.

I am sure Mr. Leitch, in his discussion of the subject, was referring to gross exposure to dust. In a great many instances where dust is visible there is fine dust also. I do not think that anyone familiar with the subject would undertake to say that there was no health hazard because they could not see any dust, particularly if they knew that the

*Department of Health, Province of Ontario, Toronto, Can.

processes might emit fine dust into the air. It is quite possible to have a health hazard from silica and not be able to see the dust.

It is true that in indirect light one can see the evidence of dust where it would not be seen in ordinary light. I do think it is important, in discussing estimation of dust concentration to understand that we are referring only to gross exposures.

C. J. HEATH* (*Submitted in Written Form*): In testing the efficiency of various types of centrifugal dust collectors, it is essential that each dust collector be tested under identical conditions, preferably on the same problem. To state in one case that 50 per cent of the dust collected passes through a 325 mesh screen in one locality may mean something entirely different to say that 50 per cent passes a 325 mesh screen in another locality. In one case, the 50 per cent passing may mean on down through a 2500 mesh screen on which no type of centrifugal separator would be very effective, and in the other case, the 50 per cent passing 325 mesh may show that that passing would all be retained on a 400 mesh screen on which a high efficiency centrifugal collector would show very favorably.

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00505