FILE NAME: Engineering (ENG)

DATE: 1935 Apr

DOC#: ENG004

DOCUMENT DESCRIPTION: Trade Journal Article - Prevention of Occupational Diseases: Other Than Those That Are Caused by Toxic Dust

©CIB 256529

MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 57 NUMBER 4

Contents for April, 1935

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Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage to Canada, 75 cents additional, to foreign countries, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B2, Par. 3). . . . Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921. . . .

Prevention of

OCCUPATIONAL DISEASES

Other Than Those That Are Caused by Toxic Dust

By R. R. SAYERS and J. M. DALLAVALLE

UNITED STATES PUBLIC HEALTH SERVICE

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.

Contributed by the Safety Committee and presented at the Annual Meeting, New York, N. Y., December 3 to 7, 1934, of The American Society of Mechanical Engineers.

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-platingroom	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	3/4	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
Phosphine	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		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	No data	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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