Journal of Industrial Hygiene
vol. 16, July, 1934

HEALTH HAZARDS IN THE FOUNDRY INDUSTRY*

W. J. McConnell, M.D.
Assistant Medical Director, Director, Industrial Health Section
AND
J. Wm. Fehnel, B.Sc.
Chemist in Charge, Industrial Hygiene Laboratory
Metropolitan Life Insurance Company, New York

Introduction

In April, 1931, the Wisconsin Manufacturers Association, through Mr. Harold S. Falk, Chairman of the Association's committee on dust, fumes, vapors and gases, requested the Metropolitan Life Insurance Company to extend a health survey, undertaken for a group of its own policyholders, to include representative foundries in the State of Wisconsin for the purpose of determining the extent and nature of the health hazards in the industry, with the object of recommending measures for better and more sanitary working conditions.

The proposed study was discussed with Mr. F. M. Wilcox, Chairman of the Industrial Commission for the State of Wisconsin, who endorsed the Association's request that the Metropolitan Life Insurance Company undertake the survey. This request met with the approval of Mr. F. H. Ecker, President of the Metroplitan Life Insurance Company, who directed the Industrial Health Section to conduct the study.

Acknowledgment is gratefully made for the counsel and technical assistance of the following individuals in making this survey:

- Dr. F. V. Meriwether, Surgeon, U. S. Public Health Service.
- Dr. A. J. Lanza, Assistant Medical Director, Metropolitan Life Insurance Company.
- Mr. P. A. Petrick, Laboratory Assistant, Metropolitan Life Insurance Company.

Scope and Technic of the Survey

Although a total of 41 foundries has been surveyed by the Industrial Health Section to date, twenty-one foundries were selected for this study as representative of the industry. The various types of foundries were classified in four general groups, namely:

A. Grey iron foundries;
B. Steel foundries;
C. Malleable iron foundries;
D. Non-ferrous metal foundries.

The first group (A) is represented by plants A to L inclusive. Plant J of this group manufactures both iron and steel castings, and Plant K manufactures grey iron and malleable iron castings. The former, therefore, may be classified in groups A and B, and the latter in groups A and C.

The second group (B) is represented

* Received for publication, June 1, 1934.

VF-T&S McConnell, 6/7

by plants M to P inclusive; the third group (C) by plants Q to T inclusive; and the fourth group by plant U. Plant Q manufactures steel and malleable iron castings and may be classified in groups B and C.

The survey includes plants of all sizes and those considered good, average and poor. Therefore, the selection is representative of the industry, as far as size and plant conditions are concerned. Although physical examinations were not made, except where these were the routine of the plant, 215 X-ray examinations of the chests of workers exposed to foundry dusts were made. These workers were selected from locations where the dust concentrations were highest. Dust samples were taken at various places of employment and in the line of travel in each department. To secure a picture of working conditions and, if possible, sources of health hazards, process analyses were made, and sanitary conditions and personal service facilities were noted.

Measuring Instruments and Methods of Collecting Samples

The measuring instruments used in the survey were the foot candle meter for determining the illumination at the working levels; the sling psychrometer for measuring the dry and wet bulb temperatures; flasks for collecting gas samples which were analyzed for carbon monoxide; and the impinger and electrical precipitator for collecting dust samples.

Air samples were collected around the cupolas and in the vicinity of freshly poured molds. These were analyzed for carbon monoxide by the pyrotannic acid method, but the results of these analyses were negative.

Air sampling for dust was made with the impinger (1) method which collects the dust by aspirating the air and impinging it onto a flat surface covered by a liquid in a container; and with the electric precipitator (2), an instrument designed upon the principle of a Cottrell precipitator. Both are standard methods used in America for determining dust concentrations and particle size.

The impinger was placed in close proximity to the largest groups of workmen and at a height corresponding to the breathing level of these workers. The liquid used in the container of the impinger consisted of distilled water. The impingers were actuated by suction supplied by steam ejectors operated by compressed air. The rate of air flow, during sampling, was measured by means of a small vacuum gauge inserted into the suction line. The entire set-up, in turn, had previously been standardized against a standard wet meter. Wherever masks or respirators were worn by the workmen, a connection was made either into or under the helmet by means of rubber tubing which was connected to the impinger. Each sample collected by the impinger method represented a sample of dust from a volume of air amounting to from 50 to 100 cubic feet.

The electric precipitator was placed in a position similar to that of the impinger. The air is drawn through this instrument by means of a small rotary fan, run by a motor, the quantity being measured by a flow meter. Each sample collected by the electric precipitator represented a volume of air of from 10 to 50 cubic feet. These samples were used for determination of particle size.

Particle size measurements were made by taking microphotographs at a known magnification of the dried preparation of dust, as described by Green (3), and then enlarging the negative further by projecting the images upon a screen by means of a stereopticon. The longest diameters of the images of the dust particles were then measured upon the screen. From the results of a sufficient number of these measurements a curve was plotted of the size frequency relations on Hazens' logarithmic probability paper, the logarithms of the function measured in microns plotted as ordinates, and the probability of occurrence as abscissae (3, 4). It is a simple procedure to interpolate from these plots, which develop into straight lines, the frequency of occurrence of any sized dust particle less than 10 microns present in the particular dust under investigation.

It has been demonstrated repeatedly that no silica particles exceeding 10 microns (5) in greatest diameter enter the lung tissue, and for this reason it has been the general practice to count only dust particles under 10 microns. Figure 1 indicates that 96 per cent. of the dust particles were less than 10 microns and 55 per cent. were less than 3 microns in greatest diameter.

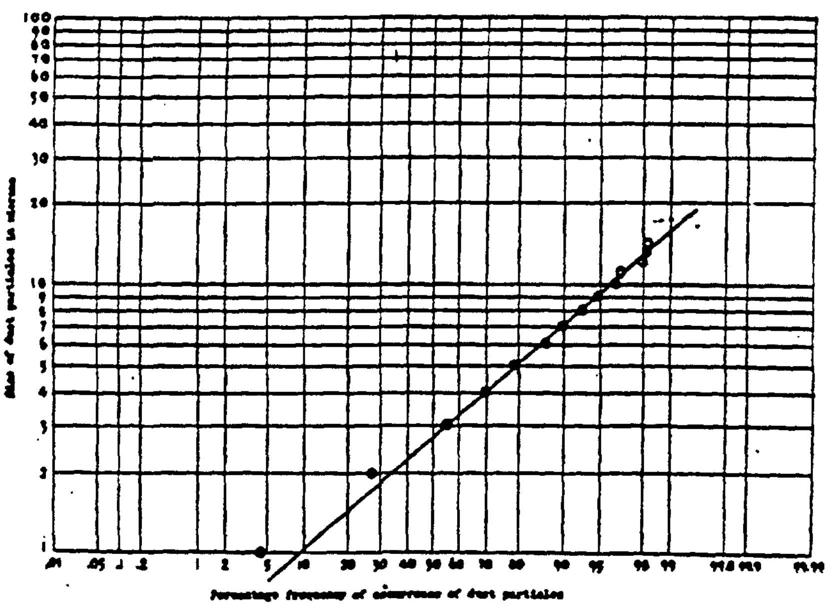


FIG. 1.—Composite Graph of General Air Samples from 12 Foundries of Which 3 are Steel, 5 Grey Iron and 4 Malleable Iron Foundries

Dust Counts

The reader is referred to the March

18, 1932 number of Public Health Reports (6) for a detailed description of methods for standardizing and cleaning equipment and necessary precautions for accurate work. Accurate technic is acquired only by observation and diligent work under the guidance of a qualified technician. The method of dust counting used by the United States Public Health Service is an empirical or rule-of-thumb technic devised to measure the extent of air dustiness. This method was demonstrated to be effective in the Service study of the granite industry at Barre, Vt. (7).

In 1928, one of us, J. W. F. (8), while conducting a study of the hazards of rock drilling on building and subway construction work in New York City, experienced difficulty in checking with this standard procedure of counting and after consultation with other technicians it was learned that certain modifications were introduced, such as tilting or shading the microscope mirror, thereby modifying the light. With the increase of the free silica content of the dust the difficulties in counting by the standard procedure increased. It was definitely demonstrated by experimentation that as the dust approached the pure form of free silica, the refraction approached that of the lens system of the microscope, making it difficult to focus the image clearly. Therefore, a modification of the illumination was tried by using a Plankton or fixed stop condenser, which resulted in marked improvement. A series of counts was conducted by both standard and the modified illumination, and it was found that the counts checked more consistently, but they also ran higher by the modified method than by the standard light field procedure. It was found later that this procedure of modified dark field counting is identical with the method used on the Witwatersrand in South Africa since July, 1923. The advantages of the modified dark field over the standard light field illumination are illustrated in the photographs here reproduced of identical fields using 3 micron silica, the only difference being the type of illumination (Figs. 2 and 3).

It has been demonstrated that the employment of the dark field method enables one to count readily particles of 0.5 micron in size, while with the standard light field method particles under 1.5 microns are frequently missed. Both methods were used in this study and it was found that the modified dark field method gave results consistently twice as great as the standard light field procedure. The results obtained by the standard light field method are here reported.

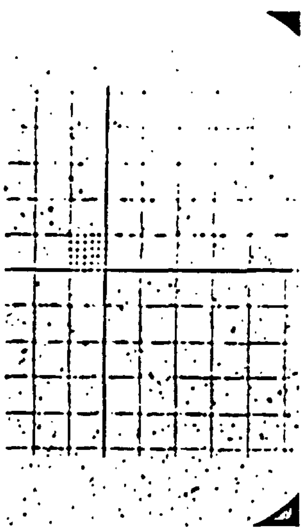
Foundry Buildings and Plant Processes

The general condition and appearance of foundries have been improved and they have, therefore, become more desirable places in which to work. The foundry buildings for the most part are large and high, with a great amount of window space available. Brick, stone, corrugated iron and steel are the usual materials used in construction, although a few foundries of frame construction were found.

Foundry work requires the use of ponderous machinery. Industrial railways, cranes, hoisting accessories and certain types of foundry machinf interest from the viewpoint its, but need not be discussed port which is confined to the ition of health hazards.

PLANT HYGIENE

ation.—While most of the studied have a large window .s permitting the use of lumination in the vicinity of ows, the majority require



2.—Standard Light Field

tem of artificial lighting. ognized that an adequate natural light is desirable ld be more generally used by a systematic method of f windows. It was noticed some instances, where the were not cleaned for a long e glass had become rust- d almost opaque, resulting smission of very little light. l light is not always used

advantageously. The use of bare lamps is to be discouraged from the standpoint of operating economy and on account of the glare, which is annoying to workers. Steel reflectors having a porcelain enamelled reflecting surface are well adapted to foundry work. Special treatment of foundry illumination is almost a necessity, owing to the darkness of the materials used, which absorb a great deal of

FIG. 3.—Modified Dark Field

light, and on account of the smoke, steam and dust in the air, through which the light must penetrate. A large volume of light is required and can be secured by large lamps or clusters of smaller units, hung low enough and equipped with reflectors and diffusing globes which direct the light downward in order to distribute properly the light on the work. Where bench work or machine molding is done, the general illumination should be reinforced with local illumination. The cleaning of these units at frequent intervals is important. The painting of the interiors of foundries with light colored paints will facilitate light distribution.

Ventilation.—The usual ventilation of foundries is by means of windows. A system of forced draft, either for general ventilation or for the ventilation of individual rooms, is used in some instances. The general ventilation is supplemented, as a rule, by ventilating hoods at specific points. The ventilation of foundries, so far as supplying pure air for breathing is concerned, is quite difficult on account of the smoke, fumes, and dust incident to foundry work. Where these can be collected and exhausted at the point of origin, the problem of their control is simplified, but unfortunately this cannot always be effectively accomplished.

Air dustiness.—The introduction of new methods, new apparatus, and new protective measures has greatly ameliorated the atmosphere in foundries. The mechanical cleaning of castings in conjunction with suitable exhausts, the use of tumbling operations and dust-tight sand blast rooms, the hydraulic washing of castings, and the provision of positive air pressure helmets for workers engaged in sand blasting are all measures designed to control the health hazards resulting from the inhalation of dust. Certain types of foundry work must be done by the older methods, particularly large castings where the production is so infrequent as not to warrant the expense of sand blast equipment, or where the size or character of their cores will not admit the use of sand blast equipment. It is a fact, however, that most of the dust incident to foundry work results from defective equipment and lack of proper maintenance.

The dusts encountered in foundries have a high free silica content, averaging between 50 per cent. and 90 per cent. free silica, which makes control of these dusts a necessity.

Dusty processes.—The health hazard from the inhalation of foundry dust results chiefly from three foundry operations:

1. *Sand conditioning and conveying.*—The conditioning of the sand which is accomplished by the addition of binders, such as flour, molasses and water in proper proportions, together with sieving, mixing and the preparation of the mold facing sand, is usually done in the central area of the foundry. The sand is carried back and forth by means of mechanical conveyors. Although by centralizing these operations, the raw materials and conditioned sand are conveyed a minimum distance, the dusts that are created are distributed throughout the entire foundry. Marked improvement, from the viewpoint of dustiness, would be noticeable were these operations to be carried out in a separate department completely isolated from the foundry proper, and a considerable amount of dust could be confined by enclosing the sand conveyors.

2. *Shake-out operations.*—These operations are usually located near the sand conditioner, but may be carried on in any convenient space in the foundry. When a sand cutter is used for sand conditioning, it is customary to shake out castings wherever poured.

Because of the hot dry sand and the mechanical means of handling castings subjected to the shaking out operations, clouds of fine silica dust are set up which penetrate the entire foundry atmosphere, thus exposing practically every worker to the dust. In foundries where heavy castings are shaken out by means of suspending the mold with a crane and applying a vibrator hammer, fewer workmen would be exposed to the dust if the operations were carried out in a separate room or, preferably, outside the foundry proper. In the case of small castings, the shaking out operation can be done over a grate attached to an exhaust or in a separate room. Where the molding is done on the foundry floor and a sand cutter is used for sand conditioning, the shaking out operation should be begun preferably at the end of the working period, thus exposing the least number of foundry workers to the resulting dust. Sufficient time would elapse for the dust to settle before the beginning of the next working day.

Cores are now effectively removed rom castings by washing with high ressure streams of water inside a abinet or outdoors. This operation liminates the dust hazard due to and removing and cleaning.

3. *Cleaning operations.*—Casting leaning by means of chipping, grind-g, and sand blasting is sometimes rried on in a separate department, it it is common practice to conduct ese operations in the foundry proper almost any convenient location it has the advantage of the least ount of handling. Proper hoods d exhausts for entrapping dust sing from grinding wheels, and mechanical maintenance of a good type of sand blast cabinet, together with the use of an efficient type of respirator by operators, will greatly aid in safeguarding the workers.

Harmfulness of Silica Dust

The hazard of silica dust with special reference to the lungs has long been appreciated. It has been firmly established that the inhalation of this dust results in a fibrosis of the lungs, which disease is known as "silicosis," and its presence, for some reason yet ill-defined, results in extraordinary predisposition to pulmonary tuberculosis. It should be borne in mind that silicosis develops very slowly, taking from five to fifteen and even twenty to twenty-five years to become established. This rate of progress is influenced mainly by the dosage of silica which the lungs receive and this dosage, in turn, depends upon three variables: the amount of silica in the dust, the quantity and particle size of dust in the air, and the extent of exposure. Individual idiosyncrasy might be included as a fourth variable. However, little is known of the variations in susceptibility in those exposed to dust.

In an investigation of granite cutting plants (7), conducted by the United States Public Health Service, most of the workers were found to be exposed to an average of about 60,000,000 particles of dust of less than 10 microns in greatest diameter, per cubic foot of air. The dust contained about 70 per cent. silica, of which about 35 per cent. was in the form of quartz or free silica. Under such conditions, there was an almost universal occurrence of silicosis among

1. Sand blasting cabinets		22.7										
a. From under helmet	70.7	437.5§		23.5	1,036.3	39.8			[illegible].7	141.7	74.3	3.9
b. Operator outside cabinet				52.8	98.2							6.0
2. Rotary sand blasting	57.5						126.2					
3. Tumbler barrels	7.8											2.5
4. Blasting cabinets using steel shot												
5. Rotary blasts using steel shot			1.5									
6. Tumbler barrels using steel shot												
6. Sand reconditioning:												
a. Mechanical	37.4	23.0		263.6	22.2						23.4	
b. Sand cutters												
7. Conditioning of core sand												
8. General air sample in foundry	12.47	5.0			3.2	2.7	12.5	8.0	8.3	17.9	3.5	8.9
9. General air sample in cleaning room			7.0	76.8		3.1	23.6	10.7		15.8	10.8	
10. General air sample in core room					49.4		19.7					7.0
11. Facing mills					2,608.1	32.4		445.7	34.6			

* Plant J has both a grey iron and steel foundry; see table for steel foundries.
† Plant K has both a grey iron and malleable foundry; see table for malleable foundries.
‡ Millions of particles less than 10 microns per cubic foot of air.
§ Home-made helmet.
In some instances the counts given in the tables are averages of several samples taken at the same station within a short period of time.

TABLE I—*Continued*

Steel foundries

PROCESSES	PLANT E*	PLANT M	PLANT N	PLANT O	PLANT P	PLANT Q1
	million particles	million particles	million particles	million particles	million particles	million particles
1. Coremaking:						
a. Hand	12.2	14.7	8.5	4.7	5.1	1.0
b. Machine						
2. Corerubbing						
3. Molding:						
a. Hand bench	19.5	18.2			10.0	
b. Hand floor	100.2	1.3	7.3	12.8	6.5	
c. Machine and hand bench:						
1. Sandslingers						2.0
2. Jar and squeeze		9.0	33.9			
3. Bumper		9.1	13.0		11.4	
d. Roll-over				21.7		
4. Shake-out:						
a. Floor	4.3		2.1			
b. Casting suspended on crane cleaned by hand and air hammer		83.9	23.0	12.0	19.1	2.0
c. On continuous line casting machines						
d. Traveling crane used in combination with continous line casting machines						
e. Floor shaker		25.9		9.5		
5. Cleaning:						
a. Chipping				22.6		
b. Flexible shaft grinder						
c. Stand grinder		1.3	5.7	10.9		30.8
d. Swing grinder		16.9	15.0	36.2	6.8	25.6
1. Sand blasting cabinets under helmets	1,235.5	638.7	148.0	110.7	300.7	217.7
a. Operator outside cabinet						

TABLE 1—*Concluded*

Malleable foundries. Non-ferrous metal foundries—*Concluded*

PROCEDURE	PLANT K*	PLANT Q†	PLANT R	PLANT S	PLANT T	PLANT U
	million particles	million particles	million particles	million particles	million particles	million particles
4. Shake-out:						
a. Floor	75.4				87.0	20.8
b. Casting suspended on crane, cleaned by hand and air hammer		13.0	2.1	6.7		
c. On continuous line casting machine						
d. Traveling crane used in combination with continous line casting machines						
5. Cleaning:						
a. Chipping						
b. Flexible shaft grinder						
c. Stand grinder	13.4	10.0	1.5	8.9		5.9
d. Swing grinder		12.5				
1. Sandblasting cabinets from under helmet						
a. Operator outside cabinet						7.1
2. Rotary sandblasting	209.0		4.4	3.7		
3. Tumbler barrels	6.0	22.0			13.9	11.8
4. Blasting cabinets using steel shot						
5. Rotary blasts using steel shot						
6. Tumbler barrels using steel shot			0.8			
6. Sand reconditioning:						
a. Mechanical						
b. Sandcutters		52.5			80.4	
7. Conditioning of core sand						
8. General air sample in foundry	16.5	7.0	2.3	3.6	?	5.9
9. General air sample in cleaning room						17.1
10. General air sample in core room	4.3					6.7
11. Facing mills		67.5				

* Plant K has both a grey iron foundry and malleable foundry; see table for grey iron foundries.

† Plant Q has both a steel and malleable foundry; see table for steel foundries.

in the foundrymen's work which operates to produce a high incidence of respiratory affections among them. What few statistics there are on the incidence of disabling sicknesses and of the incidence of physical impairments among these workers, support the findings of the mortality investigations.

Three recent mortality investigations, made by American life insurance companies, and a report of the Registrar General of England and Wales show clearly how unfavorable is the respiratory disease mortality of foundrymen. In the following paragraphs, we shall discuss the main findings of these investigations:

Combined group mortality experience.—1922–1930 (10).—Table V was compiled from the report entitled "Combined Group Mortality Experience 1922–1930" published by the Committee on Group Mortality Investigations, July 17, 1931. The Committee analyzed the mortality records of employees of industrial concerns insured under Group Life

TABLE II

AGE GROUPS

	Grey iron			Steel			Malleable iron			Non-ferrous metal		
	Positive	Doubtful	Negative	Positive	Doubtful	Negative	Positive	Doubtful	Negative	Positive	Doubtful	Negative
years												
50 and over	11	6	13	6	1	3	1	0	2	0	0	0
40–49	14	7	29	11	3	9	0	1	0	1	1	0
20–39	7	6	22	7	0	12	3	1	2	0	0	2
20–29	0	1	13	3	2	5	0	0	1	0	0	1
Under 20	0	0	1	0	0	0	0	0	0	0	0	0
Not given	0	0	0	0	0	0	3	0	4	0	0	0
Total examined...	32	20	78	27	6	29	7	2	9	1	1	3

TABLE III

YEARS OF EXPOSURE

	Grey iron			Steel			Malleable iron			Non-ferrous metal		
	Positive	Doubtful	Negative	Positive	Doubtful	Negative	Positive	Doubtful	Negative	Positive	Doubtful	Negative
years												
15 and over	19	9	18	12	2	8	1	2	1	1	1	2
10–15	5	3	13	5	1	7	2	0	1	0	0	1
5–10	5	7	29	8	1	7	3	0	2	0	0	0
Under 5	3	1	18	2	2	7	1	0	3	0	0	0
Not given	0	0	0	0	0	0	0	0	2	0	0	0
Total examined...	32	20	78	27	6	29	7	2	9	1	1	3

Insurance contracts written by six large American and Canadian insurance companies. All employees of a particular company, regardless of occupation, are classified under but one industry.

It is more than twice that for workers in any of the industries selected for comparison. More than one-third of all the deaths among foundry workers were caused by some respiratory disease, whereas but little more than

TABLE IV

By Occupation

	Grey Iron			Steel			Malleable Iron			Non-Ferrous Metal		
	Positive	Doubtful	Negative	Positive	Doubtful	Negative	Positive	Doubtful	Negative	Positive	Doubtful	Negative
Molding	7	3	5	5	2	5	0	1	2	1	1	1
Coremaking	2	3	5	4	0	2	0	1	1	0	0	1
Pouring metal	0	0	0	0	0	1	0	0	0	0	0	0
Chipping	0	0	2	5	1	5	0	0	1	0	0	0
Sand blasting	1	2	9	2	1	1	0	0	1	0	0	1
Tumbler operators	0	1	0	0	0	0	2	0	2	0	0	0
Sand conditioning	1	0	0	0	0	0	0	0	0	0	0	0
Sand cutter	1	0	0	0	0	0	1	0	0	0	0	0
Sand mixing	0	1	0	0	0	0	0	0	0	0	0	0
Annealing	0	0	0	0	0	0	1	0	1	0	0	0
Melter (electric furnace)	0	0	0	0	0	1	0	0	0	0	0	0
Poke out	0	0	0	0	0	1	0	0	0	0	0	0
Shake-out	1	2	7	2	0	4	0	0	0	0	0	0
Grinding (swing or stand)	3	0	5	2	0	3	1	0	0	0	0	0
Steel treating	0	0	0	1	0	0	0	0	0	0	0	0
Flame cutter	0	0	0	0	0	1	0	0	0	0	0	0
Machine repairer	0	0	0	0	1	0	0	0	0	0	0	0
Foundry laborer	0	0	1	0	0	0	1	0	0	0	0	0
Cleaning mill operator	0	0	0	0	0	0	1	0	0	0	0	0
Craneman	0	1	0	2	1	4	0	0	0	0	0	0
Chainman	0	0	0	1	0	1	0	0	0	0	0	0
Welding	0	0	0	3	0	0	0	0	0	0	0	0
Cleaning room laborer	1	1	1	0	0	0	0	0	0	0	0	0
Cupola tender	1	0	2	0	0	0	0	0	0	0	0	0
Enameller	0	0	2	0	0	0	0	0	0	0	0	0
Painter	0	0	1	0	0	0	0	0	0	0	0	0
Not given	14	6	38	0	0	0	0	0	1	0	0	0
Total examined	32	20	78	27	6	29	7	2	9	1	1	3

The death rate for respiratory diseases (including all forms of tuberculosis and influenza) for iron and steel foundry workers, is shown to be about two and one-third times that for workers in all industries combined.

one-fifth of the deaths of workers in other industries were due to these causes.

Table VI is also based upon the Combined Group Mortality Experience. It presents death rates by ages losis is lower only at central ages 18 and 23, while their rate for other diseases of the respiratory system is markedly in excess at all ages.

Comparing the crude death rates for all ages combined, it is found that the influenza death rate for foundrymen exceeds the average by about 80 per cent, while their rate for tuberculosis is 54 per cent in excess. Most outstanding is the high rate for other respiratory diseases (pneumonia, bronchitis, etc.) where the foundrymen's rate was nearly three times that for all workers combined. Unfortunately, deaths from pneumonia were not separately distinguished. Other studies have indicated that this disease is the leading cause of death among foundrymen. Undoubtedly this cause is largely responsible for the high rate reported in this investigation for other diseases of the respiratory system.

Evidence of the excessive mortality among foundrymen will be found in the graphic presentation of the data embodied in columns 2 and 3 of Table VI. This is crudely presented in the graph shown in Fig. 4.

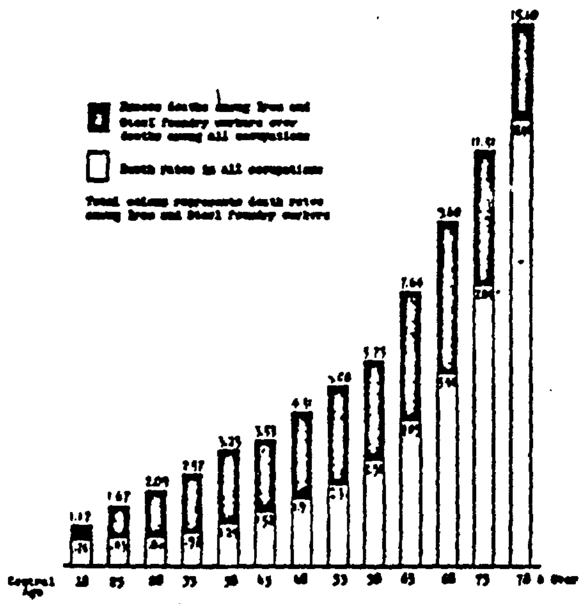


Fig. 4.—All Respiratory Diseases

Deaths per thousand life years exposed. Intercompany group mortality experience 1922–1930. Employees of steel and iron foundries 450,012 years. All occupations 20,333,309 years.

Joint occupation study—1928 (11).—This study covers persons insured in twelve large life insurance companies under Ordinary plans ($1,000 or more) during the years 1915–1926. As a measure of the effect of employment on the mortality rate, the ratio of actual to expected deaths was used. The number of deaths which would be expected to occur from respiratory diseases among the group of persons

Decennial Supplement, 1921: Part II. Occupational Mortality, Fertility, and Infant Mortality. H. M. Stationery Office, London, 1927.

14. U. S. Public Health Service, Public Health Bulletin No. 205: Lead Poisoning in a Storage Battery Plant. Government Printing Office, Washington, D. C., 1933, p. 45.

15. U. S. Public Health Service, Reprint No. 1370 from Public Health Reports, Vol. 45, No. 18, May 2, 1930, pp. 997-1009: Effect of Radiant Energy on the Skin Temperatures of a Group of Steel Workers. Government Printing Office, Washington, D. C.